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QUANTITATIVE MEASUREMENT AND THE DESIGN OF THE CHEMICAL BALANCE 1750 - c. 1900

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ABSTRACT

The techniques involved in manufacturing and using instruments for weighing small quantities of expensive commodities have been established for many centuries. Apothecaries, assayers, and merchants dealing in gold or precious stones had always had to work to a high degree of accuracy in the weighings they carried out and their instruments and skills became a traditional basis on which the design and use of 19th century balances could be based.

A further line in the development of the balance which became of particular importance from the 18th century onwards was an increased interest taken in the demonstration of basic physical concepts in mechanics and hydrostatics by the use of suitable apparatus.

A concern for the accuracy and uniformity of both the old and the new system of weights and measures in use around 1800 further encouraged the production and maintenance of instruments suitable for establishing accurate measurements.

The development of interest in the isolation of gaseous substances and early work on the establishment of new theories of composition and structure of materials emerged in the 19th century. This demanded quantitative investigation, and in this field were able to make use of traditional working techniques and skills for purposes of the analysis and synthesis without which the study of chemistry could not have proceeded.

This present survey is based on examination of a substantial number of instruments of many types, found in national and private collections. From these it has been possible to build up a general picture of the approach to design in different periods, and the problems involved in adapting the traditional designs to changing customs and new analytical techniques. Where possible primary source material has been incorporated especially to give some picture of instruments no longer extant.

From this information some general conclusions have been derived regarding the factors governing the success and limitations in design of the chemical balance.

To the Precision Engineers,

most of whose names are unrecorded,

who produced with patent care

the tools on which this survey is based.

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WEIGHTS

It may be found useful to have some indication of the various systems of weights in use in the period covered by this survey namely Troy, Apothecary and Avoirdupois.

Regarding the spelling of 'drachm', I have followed the practice indicated by Crellin op.cit. p.51. n.1.

> "As a modern convention, 'drachm' is commonly reserved for the apothecaries weight (1/8 of an ounce of 480 grains) and 'dram' for 1/16 of the avoirdupois ounce of 437.5 grains; yet during the period under consideration (1700-1900) "dram" seems to have been most frequently used for the apothecaries weight . The spelling 'drachm' has been used to indicate 60 grains throughout this study ...".

Troy

3.1683168 or 3 1/6 grains = 1 carat

151.707c or 151½ carats = 1 oz Troy

24 gr = 1 pennyweight (dwt)

5 dwt = 2 drachm

20 dwt or 480 gr = 1 oz Troy

12 oz or 240 dwt or 5760 gr = 1 lb Troy

1 lb Troy = 372 grammes (approx)

Apothecary

10 gr. = ½ scruple

20 gr. = 1 scruple = 1/24 oz Troy

60 gr. or 3 scruples ± 1 drachm or 1/8 oz.T.

8 drachm or 480 gr = 1 oz Troy

12 oz or 5760 gr = 1 lb Troy

Avoirdupois

1 lb Avoir = 453 grammes (approx)

437.5 grains = 1 oz (Avoir)

16 oz or 7000 gr = 1 lb (Avoir)

Metric

1 grain = .0647989 grammes or .065 g. approx.

1 gramme = 15.4324 grains

It must be stressed that these tables are included to give some indication of the order of magnitude involved in various weighings, and are in no way fixed absolute quantities; this is because:-

a) The basic unit, the grain, varied from time to time, country to country and even from town to town within that country,

b) also, these systems were not designed to be interconvertible, although conversion tables existed for the benefit of shopkeepers. It further follows therefore that any simple correlation with modern metric systems is purely accidental.

PRE-METRICATION FRENCH WEIGHTS & MEASURES

All conversion units to Imperial or Metric measures are approximate.

1 Livre poid de marc	=	2 marcs or 7555 grains English or 17 oz.
or Paris Pound		or 9216 grains (French) or 490g.

1 marc	=	8 oz
1 oz	=	8 gros
1 gros	=	3 dwt. or 72 grains
1 dwt	=	24 grains
1 grain (F)	=	.8 gr.(E)
1 pied	=	12.7 inches or 32.5 cm
1 pounce	=	1.06 inches or 27 mm.

Local variations were numerous.

The pound at Toulon	=	406.5 g.
at Avignon	=	408.7 g.
at Nancy	=	455.7 g.
at Rouen	=	509.1 g.

ILLUSTRATIONS

1. Oertling balance: Oertling & Co., Ltd., St. Mary Cray — p. 12

2. Field assay balance: Science Museum, London No. 1925/40 — p. 51

3. Oertling assay balance: Assay Office, London — p. 79

4. Fidler double cone balance: Science Museum, London. No. 1900/158 — p. 109

5. Troughton/Hassler solid beam balance: Illustration in "Report", ed. Cochran. — p. 136

6. Robinson balance: Whipple Museum No. 1413 — p. 156

7. Oertling long beam balance: Trading Standards Dept., Bromley — p. 173

8. Bunge short beam balance. Illustration in "Reporatorium ..." 1867 — p. 175

CHAPTER 1

Small scale weighing and its influence on the design of the nineteenth century balance.

Summary.

a) a general interest in design was shown by those who saw the scale as a useful tool to illustrate the study of mechanics.

b) a particular interest was shown by certain groups, e.g. apothecaries, jewellers, assayers.

i. The dispensing scale, its 18th century characteristics, manufacture, maintenance, and weights. The "Beale" balance.

ii. The assay balance, assaying and its importance, coinage, traditional designs and movement towards change in the late 18th century. Biringuccio, Agricola, Ercker, Leupold, Magellan.

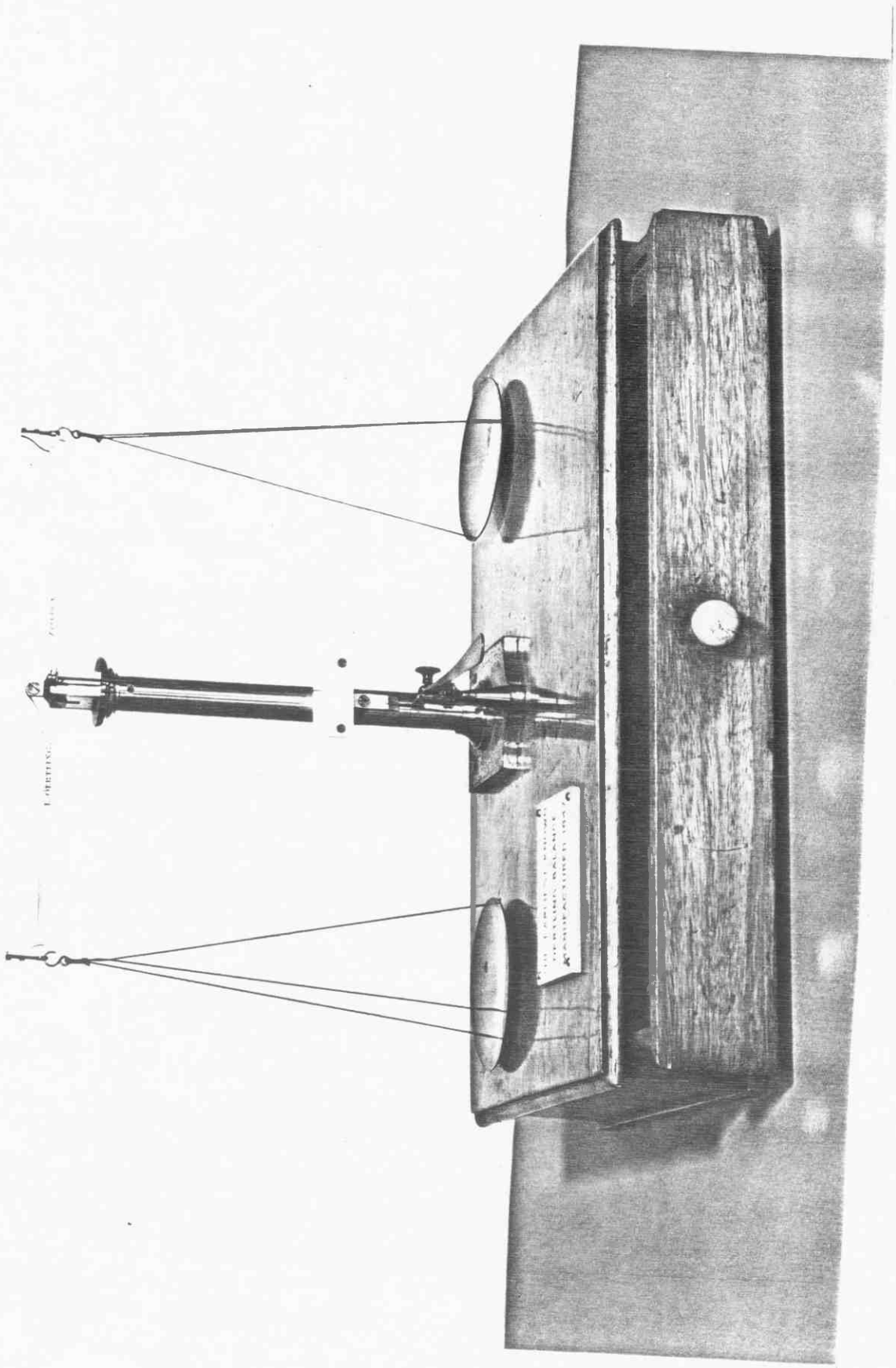


Fig. 1 "Beale"

CHAPTER ONE

SMALL SCALE WEIGHING AND ITS INFLUENCE ON THE DESIGN OF THE NINETEENTH CENTURY BALANCE.

"Their ballaunce and weights are so delicate, and their grains so small, as they cannot take them up with the hand, but with a small pair of pincers: and this triall they make by candle light, so that no ayre moove the ballaunce. For of this little the price of the whole barre dependeth." 1590 (1)

The art of assaying consists in determining the proportion of a specified metal present in a sample. It required accurate weighing both of the sample and of the metal extracted from it and before the advent of volumetric and spectroscopic analysis was the only reliable method available (2). The technique had been developed over many centuries, and could be adapted both to determine the likely yield of metal from ore samples obtained from a new mine, as well as to establish the proportion of base to precious metal in a sample of alloy. It was this latter and better known use of the art of assaying that was important to governments anxious to avoid the evils caused by debased or forged currency. A recognisable system of stamps or marks that could be placed by reputable agents on bullion metal or articles made from it had obvious advantages in promoting confidence. It also became an efficient form of quality control established by experimental methods, even during the Middle Ages at a time when most "experiments" were designed to demonstrate an accepted hypothesis (3). The continued need for and use of assaying techniques required the use of weighing devices and added another small group of people to those others, such as jewellers, money changers and druggists, to whom the correct establishment of small units of weight was very important. These groups built up skills in the manufacture and use of balances by careful manipulation: on these traditions new groups of people interested in exact weights of interacting chemicals could draw. For this reason the balances used by those earlier groups have an important bearing on later

developments in balance design during the nineteenth century. During that century both types of balances, whether chemical or assay developed along broadly parallel lines, often interreacting with each other in design innovation. Before the 19th century, the relatively small market for such items had encouraged few sweeping innovations, although styles had developed sufficient for the needs of those who used them. Only when the traditional specifications were no longer adequate did large scale changes occur in design; while the traditional tool could do the job there was no incentive to alter it.

The design of balances used by those concerned with the buying and selling of precious metals, stones and drugs reflected their owner's interest in accuracy rather than speed, and in numerous small transactions rather than one large one. Very much larger beam balances existed than those habitually used by assayers. These large scales were used for wool, bread and other agricultural produce. Scales with such large beams however, were known to create problems of inertia at the fulcrum and so wide spread were the deliberate abuses to which all simple beam balances could be put that Francis Hawksbee considered illustrations of these deceits worth including in the course of lectures prepared by himself and William Whiston in the early 18th century (4). For example a beam could be made to appear level by judiciously shortening the length of the beam arm on one side and decreasing the weight in the pan at the other side. As was pointed out in the printed text which accompanied the illustrations to the "mechanicks" section of the course,

"... this Cheat is easily discover'd by changing the Position of the Weights, and putting each of them into the other Scale" (5).

One suspects that any one who, having attended such a course (with demonstration experiments) actually put this sound idea into practice, might have difficulty in purchasing from that merchant again. Despite their limited practical help the popularity of these lectures and their illustrations is shown by the various borrowings from them

that appear in print as well as examples of similar apparatus, illustrations of which occur in the books of s'Gravesande (6), and others. Some of the apparatus Hawksbee suggested was given to Harvard in 1728 by Thomas Hollis, and similar items were purchased by Van Marum for Tyler's Museum and by Leiden by the end of the century (7). The undoubted popularity of such courses in this country and abroad must have depended on the examples chosen by the lecturer being immediately identified by those who watched, with familiar events and objects. These were the pegs on which 'Science' could then be hung. The success of the lecture in reducing fraudulent weighing is hard to assess, but they are a useful illustration of the problems faced by designers and users of fine small balances, for the livelihood of he who sells small items depends on the skill with which he buys, which will probably be in equally small batches.

The basic consideration in the design of any balance is the size of the load it is ultimately designed to carry. In the case of those working with small but costly items, a small capacity scale would be sufficient. This in turn does not require that there be any great strength in the beam which is to take the load, nor muscle in the arm of the user. Such balances can be and often were hand held. However, the accuracy demanded by the buyer would require several checks to be carried out during the sale. Was the item exactly, or a little more (or less) than the intended weight? Some simple provision for independent suspension of the balance must have been made for the convenience of all, if only with a loop of string over a convenient nail, very early in the development of the instrument, and although hand held balances continued to be made and used in very large numbers indeed, particularly during the nineteenth century, these were largely confined to the weighing of gold coins. Here the only important consideration was whether or not the coin was up to the official weight and acceptable, or under weight and probably forged. If so it was not worth its weight in gold and would be refused. The exact weight of the coin was of no consequence. The other considerable market

for hand balances was for the weighing out of drugs both by apothecaries and in the formulation of home remedies. These tiny hand scales would fit easily into the drawer of a home medicine kit but were frowned on by pharmacists for their obvious dangers in lack of accuracy.

"The same old system of using a pair of hand scales which are roughly taken out of a box and roughly thrown back again each time they are used, which prevailed a century or two ago in the days when Mithridate and Venice treacle were looked upon as potent medicines, still prevails and is apparently considered equal to the requirements of modern pharmacy." 1881 (8)

Free standing scales were undoubtedly in use in pharmacies during the nineteenth century in addition to hand scales, especially where large quantities were likely to be dispensed and the weight of business warranted it. It seems unlikely that the situation was any different during the previous century. Scales of both types could be purchased and instructions for do-it-yourself models existed. This situation might have continued well into the 20th century had not the Weights and Measures Act of 1878 brought changes. It is noticeable that this Act, like other earlier attempts at reform such as the institution of 'Inspectors' (1834-5) or the appointment of Commissioners (1870) or of "persons to examine weights and balances ... once every month at least" (1795) was as much concerned with the accuracy of the weights used as with the quality of the scales, if not more so.

Weights had been stamped to demonstrate proof of accuracy by the Plumbers' Company since the early 17th century and this practice had passed to the Founders' Company with the increasing popularity of brass in place of lead weights. Such weights gradually dispersed round the country, further authenticated by the marks of the City of London, and also after 1750, the City of Westminster. In the face of declining standards of coinage due to forgery and clipping, however, and despite the objections of the Founders' Company, a new post was created at the Mint in 1774 of an Officer to Stamp Money Weights. (9). The importance of accurate and reliable money weights in an increasingly monied economy during the nineteenth century, was apparent. The effect of this office

on the quality of weights used in pharmacies was more limited. It was necessary for the dispenser like everyone else to be able to check the quality of the gold coins he was offered in payment, but these were weighed in grains. It was soon customary for two basic coin "Weights" to be supplied, one to counterbalance a guinea, or after 1818 a sovereign, and the other for half that weight. Drugs however were basically dispensed in drachms and scruples, and these weights, not being units for coinage, were not stamped.(10).

It was not until the 1878 Act that this situation was altered to include apothecaries weights, and despite the depressing comments mentioned earlier regarding old hand scales still in use, their replacement by free standing scales would steadily follow the new legislation. Assuming the proprietor had purchased a set of stamped dispensing weights, the visiting Inspector might still require proof of the reliability of the scales. This could be demonstrated by placing weights of known and equal mass in each pan. The sensitivity of the scale might well make this checking a slow process, not helped by the owner's tiring arm muscles, and a tremor-free support would be an obvious purchase. This change of course applied only to commercial premises. In the home, where many preparations were made up, the hand scale could continue to be handled as well or ill as its owner pleased, and with as much accuracy as its manufacturer allowed. (11).

The making of scales and balances, like the verification of weights, had never been the exclusive province of one particular guild or group. The growth of the art like the demand was spasmodic, and was governed by economic factors rather than being the result of continuous development. The number of apothecaries, jewellers or assayers that any town could support or require was strictly limited, and scales like all other tools of trade could be handed down through many generations. The increasing interest, particularly in the eighteenth century, in Natural Philosophy had encouraged more instrument makers to set up in business, and for some the profits were considerable. The provision of scales was only a very small part of their output however. The general division of labour can be judged from a guide to trades and professions written in the mid 18th century. This lists the Mathematical Instrument Maker as he who makes,

> "Globes, Orrerys, Scales, Quadrants, Sectors, Sundials of all sorts and Dimentions, Air Pumps, and the whole Apparatus belonging to Experimental Philosphy". (12)

How many of these instruments would in fact have been made on the premises,

and how many bought in from other specialist suppliers at this date is difficult to establish; many parts may have been subcontracted to such craftsmen as the ... "Beam and Scale Maker".

> "This is a Tradesman compounded of the Smith and the Brazier, the Smith makes the Beams which is the nicest Part of the Branch; and the Brazier the small Scales which are adjusted to the Beams; they sell and make Weights of all sorts, and the few that keep shop of them make a very good Appearance and give their Journeymen from Twelve to Twenty Shillings a week." (13).

The reported scarcity of these Makers and their relegation to an Appendix of this book is noticeable, and suggests a very limited demand for their work.

Until well into the nineteenth century the general description of scale beams given above holds good. Beams of all types of free standing balances are found made of iron, and the pans are usually of brass. In balances that can be identified as intended primarily for dispensing work, iron (or steel) beams can be found on instruments datable to as late as the last quarter of the nineteenth century: it seems reasonable to assume that the traditional solid iron beam continued to be made while at the same time in the nineteenth century a more modern brass beam model was also becoming available. This move from iron to brass occurred earlier in the century with the beams of assay balances than dispensing scales, but again this does not presuppose the total phasing out of all assay work on older style instruments. Brass pans were always popular on all scales, but the more fragile, although more easily cleaned glass pan for dispensing is also represented, as are silver pans on instruments probably intended for jewellers.

Traditionally the pans were attached to the beam by silk or cotton thread. No great weight would ever be placed on them and these materials had the advantage of making the whole instrument easily packed. Among the surviving dispensing scales in the Wellcome Collection, the provision of a glass case or cover is an unusual feature until the second half of the nineteenth century and even then it is not universal. The scale was designed to be completely portable, the entire instrument being dismounted and packed into a fitted drawer. The drawer itself slid into a mahogany cover and the resulting box was readily transportable. Such a valuable piece of equipment could not be left on inadequately guarded premises, nor should its corrodable metal parts be exposed to damp or corrosive smoke. The provision of a fitted drawer capable of taking all the component parts of the balance and all its weights was an obvious advantage and persists even in the field of assay balances for a very long time, despite the early and almost universal tendency to

provide a glass case for the beam of the assay balance to hang in when in use.

A fitted drawer, if it is to make the instrument portable as well as secure must not be too large, and the consideration of size exercised considerable influence on the content of the box. The beam of the balance could not be folded, nor subject to pressure that might distort the points at which the pans were secured. Six to eight inches (17.5 - 18.5 cms.) seems to have been the average length of those dispensing balances beams in the Wellcome Collection. Both smaller, and larger twelve inches (30 cms) instruments do exist, but these were not generally intended to pack away, but to be "Counter Scales" and are so described.

Although the beam had to be forged from one continuous piece of metal, the pillar from which it was suspended, (usually by a simple metal pin thrust through a gallows type projection from the pillar), could be made in two pieces and usually was. One piece screwed into the top of the drawer cover, which thus became a piece of smooth 'bench' for working on, and the other piece screwed or slotted in the top of it and held the beam. These brass pillars were sometimes decorated with simple turning. The pans on their silk hangers were attached to the ends of the beams. The beam ended either in a simple swan neck type curve with a loop for attachment, or increasing in popularity in the nineteenth century, in a 'boxed beam'. Where as the swan neck ends could be adjusted to relevel a beam by altering the relative length of the two halves of the beam, the length of the boxed beam was fixed from the time it was made. The two pieces of steel from which the two pans hung were driven through the beam, and sometimes through the top link of the pans holders as well, rendering the pans captive and a piece of metal plate placed on each side of the beam boxed in the steel knife. There was thus no danger of unlawful 'adjusting' of the beam length, but also no possibility of repair either. To derive too definite a pattern of detail from the dispensing balances in the Wellcome Collection may be open to error, as they are few in number compared with the large number of assay and chemical balances covered in this survey, and perhaps unrepresentative, but the dispensing balances of free-standing design do seem to have been in a very poor state of repair when finally disposed of, suggesting a long working life, little maintenance being possible or considered necessary and only final

collapse being the signal for disposal.

How much maintenance was commonly provided is unclear. A lot of the trade cards that survive advertising the wares of well know Scale makers in the eighteenth and nineteenth centuries specifically state that scales and balances can be regularly serviced by the makers. It is also noticeable, and is in very marked contrast to the other groups of balances to be considered, that the majority of the dispensing balances have no maker's signature. Those that are signed tend to be from firms who came into prominence in the second half of the century, rather than earlier, such as S. Maw and Son, Oertling's and Steven's. This suggests that increasing legislation in the latter part of the century encouraged the provision of maintenance for dispensing scales, which earlier in the century had tended to be reserved for scales designed partly or exclusively for the verification of coin weights. Those who manufactured dispensing scales did not expect ever to see their products again, and like the vast majority of goods and chattels, these scales remained unsigned.

It is not easy to establish the amount of servicing or maintenance of balances that was in fact carried out during the eighteenth and early nineteenth centuries. Certainly many firms, including de Graves, offered such services on their trade cards. On a label inside the lid of a box of coin scales is printed,

> "Mary de Graves, widow and successor to Chas. de Graves, of 59 St. Martin Le Grand, London, ... Scales and Weights adjusted by the year". (14).

and an invoice survives from this firm for the same period circa 1800 "for repairs, and for cleaning and adjusting beams and weights". (15).

This gives an impression of a highly organised service, but such service was probably far from common. One of the reasons given for adding the servicing of balances to the duties of the Weigher and Teller at the Royal Mint in 1821 was because the new holder, John Field, had, he said,

> "for some years applied myself to mechanics, as an amusement..."

because of this,

> "... the Master of the Mint considered it would be a greater public advantage that the scales and weights should be adjusted and cleaned by someone attached to the department, rather than by a scale-maker out of the Mint, who might not be always at home to render the immediate assistance often necessary and therefore requested me to undertake it ..." (16)

This does imply that maintenance was an unreliable service even in the heart of London. By the last quarter of the century very regular servicing of balances was undertaken by the balance makers, Oertlings.(17).

Commercial undertakings were visited weekly by this firm and even twice weekly on request, but it is noticeable that the processing and assaying of bullion metals was the primary occupation of those visited. The offer of regular servicing of balances was a natural expansion of an existing tradition, but one more employed by those undertakings where the weighing of gold was involved, than by other trades.

Conditions in the second half of the nineteenth century also facilitated more frequent servicing of instruments. No amount of willingness on the part of the manufacturer to repair an instrument helps a purchaser who has no safe means of conveyance for himself or his property to the premises of the manufacturer. The congested, but still relatively small City of the 1870's ensured good communications between business premises, and the rapid spread of public transport gradually brought large areas of the country within convenient distance of London.

Even a reasonably reliable transport system is of little help to the user of a balance which bears no maker's name, as is the case with about half the dispensing scales noted in this study. By the second half of the nineteenth century Oertling's certainly, as evidenced by their account books, were repairing and servicing a very large number of balances of all makes from all parts of the country. The same may well be true of other manufacturers, old established and well known in their area during the nineteenth century, whose records are now lost. Very often less reliable method of repair must have been employed, such as the services of the local smith and brazier who would repin a damaged joint. Any adjustment to the knife edges at the pivots would have been more difficult, as these are frequently inaccessible behind metal plates. Increasing wear and decreasing sensitivity would eventually cause the scale to be discarded and replaced by a new but similar model.

The similarity of design of all balances used for dispensing during the nineteenth century and probably later, is most marked. It is an example of a design developed, found totally satisfactory and left unchanged. Even the arrival of new manufacturers and the replacement of steel beams by brass, which occurred rapidly in other fields, only affected dispensing scales slowly and then in the area of design materials rather than in the design itself. The provision of glass cases was a rarity. This was obviously not considered a necessary extra as a pharmacy was not subject to the noxious vapours that were known to be so damaging to other types of balances used in chemical manufacture. The absence of the case left the beam subject to draughts and damp, but the relatively

large masses being dispensed would make this less of a problem than it would have been to an assayer. The absence of a case also makes weighing easier and more speedy. The pans, usually brass, but sometimes of glass, tend to be about two inches in diameter, not suitable for a very large load, but noticeably larger than those intended for assaying. The steel beams are on average six to eight inches (13-21 cms.) with either swan neck or boxed ends. The arrestment system was very simple and in common with many eighteenth century balances designed for any purpose, consisted of a piece of cord, weighted, by the means of which the beam could be raised about an inch at its pivot. This cord in no way lifted the knife at the centre or removed it from the steel loop in which it rested. It was not therefore, any kind of arrestment system. If it had been, it would have greatly reduced the wear on the knives caused by constant rubbing on the holder when not in use. All the lifting mechanism really achieved was the raising of the pans from the board on which they normally rested. This enabled them to swing freely and the state of balance to be assessed. The weight to which the string was tethered was sometimes an ornamental metal block, but later this block was replaced by a push lever. As the lever was pressed, it pulled down a cord which activated a see-saw mechanism fixed to the top of the pillar. Depressing the rear half of the see-saw raised the front section from which hung the beam and pans. All these sections could be dismantled and packed away into the fitted drawer, and space was often provided for the weights to be separately packed. The basic simplicity and longevity of their design does not imply that it was inefficient, but rather that design in other fields of balance use altered to fit circumstances which had changed, while the needs of dispensing altered relatively little.

This basic design found in dispensing scales in fact bears a very strong resemblance to a typical assay balance as described in the sixteenth century by Lazarus Ercker. With reasonable care this design could produce reliable results within limits considered acceptable; it is worth noting that despite the very hard use to which most of the dispensing balances seen in this collection had been subjected, sensitivities of better than $\frac{1}{2}$ scruple or 10 grains can still be obtained in nearly every case; it seems reasonable to assume that sensitivities of one grain or less could have been expected of a new or well maintained scale.

It is difficult to establish a picture of the conditions under which these dispensing balances were used. Most of the balances referred to here were entered anonymously in auction catalogues and although it can be presumed that the free standing dispensing scale spent its working life in a pharmacy, it is not often possible to identify the firm concerned.

Only occasionally is some indication given of the original source of a scale and this is usually when it forms part of a large collection of items purchased, as for example in the Wellcome Institute records of purchase. The growth of large commercial institutions complete with successive generations of record keepers came about in the nineteenth century more rapidly among organisations involved in assaying or chemical research than those in the pharmaceutical industry. It is sometimes possible to trace the often checkered history of a balance used by large research or teaching organisations over a considerable period. Given a reasonably large volume of original records from such organisations, the possibilities of the survival of a representative sample of record books becomes possible. Dispensing however, has always been a localised activity carried on in scattered family firms in numerous High Streets, not concentrated in industrial or commercial conurbations or, until the present century, sustained by undying organisations, and records are less commonly available. The records regarding one particular dispensing balance however, are unusual in their relative completeness and have survived due to a combination of factors quite unforeseen by the original purchaser. The balance itself is in no way unique. It is, in fact, entirely typical of its age and function, and because something of its history can be established it must serve to represent vast numbers of equally unremarkable instruments about which little will ever be uncovered. In the case of the dispensing balance bought by Mr. Beale in 1847, it is the purchaser and not the instrument that is remarkable and the same is undoubtedly true of other balances and of apparatus in general. Instruments of advanced design from any period are well represented in major museum collections, but they represent only one aspect of the picture of an industry and of a profession at a given time. The majority of instruments were unremarkable and unremarked. As such they have not survived, even though a large number of people once considered them entirely adequate for daily use. To omit such mundane items from a survey would give a one sided view of the apparatus in use at a given time and imply that such ordinary items and their anonymous users were of no importance, or never existed. This would not be true of Mr. Beale of Long Acre.

The Beale balance is a simple scale made and sold by Ludwig Oertling in 1847 and now preserved in the present premises of Oertling's Ltd. It is typical of those scales previously mentioned, consisting of a drawer into which fit the pillar, the 8" beam and the pans. Some details of the design, however, show the changes that were beginning to take place in dispensing scales and balances in the nineteenth century. It is noticeable

that although there is no glass case to keep draughts from affecting the beam, more attention has been paid to the arrestment system than in a number of surviving scales of otherwise similar dispensing type. The press lever provided here lifts the pans slightly above the working surface of the drawer cover, but does not merely operate a see-saw mechanism at the centre pivot. Instead it raises a pillar which is fitted inside the main pillar. The central pillar carries a flat steel plane which makes contact with the steel knife set in the beam when the lever is pressed. This removes much of the cause of excessive wear on the knife as the two surfaces are not in contact for the majority of the time. The beam itself is a plain piece of metal, but it is made of brass and not of steel as formerly; the ends of the beam have small steel loops attached to them from which the hooks holding the pans can be suspended. No provision is made to adjust the effective length of the beam and this end suspension is as permanent as a box ended beam would have been. A pointer is attached to the beam, but this, unlike those for the majority of dispensing scales, points downwards rather than up. Upwards pointers could not easily be provided with graduated scales over which to pass, but were quite adequate for determining whether the contents of the right hand pan did counterbalance the weights placed in the left hand pan. Only when it becomes necessary to calculate the exact weight of an unknown amount of substance on the right did a graduated scale really become necessary. In dispensing, the operator controls the volume of materials used, in assaying the material is an unknown and must be checked to see by how much it may depart from the expected answer. This improved arrestment and pointer detail and the provision of a third pan complete with small hook on its underside suitable for specific gravity work, suggests that either the manufacturer or the purchaser intended a more general use for this scale than the usual dispensing routine. The third pan is provided with fine platinum chains for its suspension, while the other two have traditional woven thread. It is not possible now to determine which represents the original and which the later alterations, or even if both are in their original state. Unfortunately the surviving catalogue description does not mention this detail.

The practice of printing lavishly illustrated catalogues of scientific apparatus obtainable from a specific supplier does not seem to become general until the latter part of the nineteenth century. Catalogues of scientific apparatus which do survive from earlier years contain only a few illustrations, or none at all. Until items could be easily sent by post or rail there would seem little point in illustrating catalogues as items would be inspected by callers and not bought sight unseen. Ludwig Oertling who made the Beale balance had set up business

in London in the 1840's and his earliest surviving catalogue datable to 1848-54 is little more than a printed sheet (18).

It does, however, list,

"Balance with eight inch beam, standing on mahogany box with drawer; to carry 500 grains in each pan and turn with 1/50 of a grain £3 3 0." (.0013g)

It is the only balance of that size listed and matches well with the receipt given to Mr. Beale on 8th June 1847 for

"Balance, 8 inch beam in box - £3
Paid L. Oertling." (19)

Oertling describes himself on the receipt as a "Manufacturer of Balances, Mathematical and Philosophical Instruments", and was,in 1847, living in Jewin Street just off Aldersgate Street in the City. The difference in price between the two items could be due to a price reduction by 1849, but more probably indicates a 5% discount for cash to an important customer. The popularity of this design of balance may be judged from the fact that it is still listed in the illustrated catalogue of circa 1880 and at the same price. The survival of a receipt in association with the balance is of particular interest as it provides evidence to suggest that this is the earliest Oertling balance still surviving which can be positively dated. For this reason both balance and receipt have been preserved with great care by the manufacturers to whom the balance was subsequently donated as an important item in their history. Oertling's built up quite a collection of balances manufactured by their firm, of which this is the earliest example. It is not certain exactly when the balance was presented to them, but it seems probable however, that it was at some date prior to 1910 and perhaps was given by L.S. Beale F.R.S. 1828-1906 son of L.J. Beale 1796-1871 (20)

An outline of the career of L.J. Beale will help to explain how he may have come to order such a relatively advanced balance. Lionel John Beale M.R.C.S. was born in Falmouth, became a member of the College of Surgeons in 1815 and was in practice in Covent Garden by the early 1820's. Ten years later with a growing family he moved to 108 Long Acre where he remained until his death. (21). The premises which he took over in Long Acre had formerly been occupied by another chemist Jos. Hume who had been there since at least 1794. It seems reasonable to assume that the family, including an assistant chemist and an apprentice as well as servants (22) lived over the dispensary which also included a surgery and consulting rooms. Several sources of income were thus available to him. This was fortunate as the area contained some substantial family properties, but in addition a vast

number of courts and alleys whose inhabitants would be unable to afford any medical care except the cheapest of drugs. Beale wrote books on health and on physical deformities and his interest in what would now be termed social medicine must have contributed to his becoming Medical Officer of Health for the area of St. Martin's in the Fields in 1856. (23)

The setting up of permanent officials to act as Medical Officers of Health, was one of many attempts during the nineteenth century to combat epidemics and promote health. (24) Various ad hoc attempts to launch such a scheme had been made earlier in the century, but by the 1850's increasing pressure of population in large cities and the greater ease of transport was enabling infection to spread faster and giving it an ideal medium to travel through. L. J. Beale's son, L. S. Beale, not surprisingly also made his career in medicine. He would have been nineteen years of age when the new balance was purchased from Ludwig Oertling and may have pressed for the purchase of a more "modern" instrument from a relatively new manufacturer. This tentative suggestion is supported by the fact that L. S. Beale F.R.C., F.R.S., spent much of his early career at King's College Hospital and became a very eminent microscopist, encouraging and promoting the use of instruments of his own design for medical work. (25) He may well have presented this historic, but by then outmoded balance to Oertling's at the end of the century.

When first purchased this small balance, in conjunction, no doubt with both a set of hand scales and a larger counter balance, could have been used for weighing out inorganic chemicals as well materia medica in the family dispensary. "Joseph Hume, Chemist" from whom L. J. Beale obtained his premises in the 1830's, had supplied chemicals to Michael Faraday (26) and also collaborated with James Stodart in 1805 on early methods of gilding iron and steel (27). As Stodart himself later worked with Faraday in 1818 Hume's reputation would have been spread quite widely. Certainly the good will and recognition that would have passed with such distinguished premises to their new proprietor can only have added to the number of Beale's customers and the range of their requirements. The sensitivity quoted by Oertling of $\frac{1}{50}$ grain for this balance was well in excess of anything that simple dispensing would have required, but serves to illustrate the very close connection that existed between those whose interests were in the dispensing of drugs and pharmaceuticals, and those who were to use the training thus provided to become eventually. chemists of

another sort. The simple dispensing balance has therefore a distinguished ancestry and by its very ubiquitousness has encouraged those with a taste for chemical research of any kind. The identification of 'Mr Beale' on a receipt of 1847 with the eminent medical family of that name was a fortunate chance assisted by their descendant. Most families' records are less accessible and most old balances were thrown away or sold for scrap. The survival of this one must represent the rest.

The Beale balance exhibits various features, such as high sensitivity and the presence of a specific gravity pan which would not immediately be considered essential to a dispensing instrument and only a knowledge of the occupation of the purchaser enables it to be clearly classified. Classification is not necessarily helped by having a signed instrument because it is not always possible to determine the exact use for which the manufacturer designed a specific balance. Often the description given by the catalogue, (where one exists), is very general:

"Balances for Chemical, Philosophical and Assaying purposes" (28) is the heading given for details of balances made by Robinson in 1831. Sometimes entries are even more vague and refer merely to scales "of the best quality" or to,

"Pair of box-end Laboratory Scales £3 13 6" (29)

Not only are manufacturers undogmatic about the classification and use of their products until relatively late in the nineteenth century, in addition the purchaser could and did use apparatus for purposes quite other than those for which it was intended. Darwin, investigating the relative weights of skeletons of pigeons, used a pair of postal scales.(30) In such cases, provided the instrument chosen was adequate in capacity and sensitivity for the purpose required, any design could be used. This all adds to the difficulty of classifying surviving balances, whose precise provenance is uncertain. It can be said that most dispensing scales exhibit many of the features found in the Beale balance, but it is probable that this balance was in fact designed and sold for general chemical use. Such general purpose balances could even be used for assaying: even those balances thought to be specifically designed for assay work, however, present problems of identification because the design of assay balances underwent considerable modification during the nineteenth century. The more traditional dispensing scale produced fewer variations in design, but no design change in a product ever leads to the overnight

cessation in production of older, well established designs. New and old patterns continue to co-exist in production at least for a while, and continue in practical use by older customers for a very considerable period. Often only an exact knowledge of the occupation of the purchaser (where he can be identified) enables one to state whether a balance was or was not used for dispensing or general analytical chemistry or for the highly specialised and old established analytical art of assaying.(31) Some of the problems inherent in the design of assay balances will be more clearly seen if the analytical process of which they form an essential part is first outlined.

Assaying has been described as an old established method of quality control.(32) It consists in determining the ratio by weight between the base metal and the noble metal in a sample of alloy. At the present time gold, silver and platinum are all 'assayed', but in practice only gold is estimated by direct weighing. Platinum, which has only been included in this practice since 1975, is tested by absorbtion spectrometry, while silver is tested by volumetric analysis. Once it has been established that the proportion of precious metal is in accordance with the standard claimed for it by the manufacturer of the item, the article is then hallmarked. This mark comprises the initials of the manufacturer, the year of marking, the precious metal content and the town in which the test was performed and it provides a very valuable guarantee to the owner, and is of great benefit in establishing the resale value of the piece or even its basic value as scrap metal. Such a mark cannot therefore be given lightly and the possibility of experimental error must always be guarded against by the assayer.

The testing of silver by fire assay which was the only method available before the nineteenth century, was always prone to error due to the nature of silver itself, and the development of graduated glassware and an understanding of volumetric analysis during the first half of the nineteenth century enabled a more reliable method of assay for silver to be introduced. The fire assaying of silver involved heating the alloy, previously wrapped in lead, on a bed of bone ash. The ash absorbed all the base metals and left a silver button. The need for an alternative method to fire assaying lay in the fact that molten silver can absorb twenty times its own volume of oxygen. As the metal cools this gas will escape. The metal must, however, be allowed to cool very gradually. Even the small buttons

of metal normally tested were known to require fifteen minutes more to cool. Rapid cooling would trap gas under the solidifying shell of silver causing violent eruptions and probable loss of small metal particles. Incomplete cooling would retain some gas and again cause errors in weighing. The violence of the eruptions caused by the gas and known as "spitting", leave the surface of the button resembling the surface of the moon.(33)(34) The new method of volumetric analysis had much to commend it and by the 1850's had replaced the older process.

"The results of the process of the assay by cupelation, even in experienced hands, may vary by as much as two parts in a thousand; this circumstance induced Gay-Lussac to contrive a different method, which is now adopted not only in the French Mint, but is employed in the mints of Great Britain and the United States..., it admits of an accurate estimate of the value of an alloy to within 0.5 in 1000." (35)

The problems associated with the assaying of silver by cupelation do not fortunately affect gold which continues to this day to be tested in the traditional manner. A weighed sample of gold from the item to be tested is wrapped in a piece of lead foil, together with a quantity of silver equal to about $2\frac{1}{2}$ times the estimated weight of the gold in the alloy. The exact quantities for both lead and silver vary with the assumed weight of gold. The lead, on melting, absorbs all the base metals present in the original sample and during firing in a muffle furnace these base metals are absorbed by the cupel (a block of magnesium carbonate) and the gold silver button remains. These buttons are hammered, annealed, rolled into cornets (small spirals) and boiled first in dilute and then in concentrated nitric acid. The silver is later recovered being added to the gold sample only to increase the silver content of the gold alloy. This not only makes the resulting alloy more malleable for hammering, it also ensures that there should be a wide spread distribution of gold particles through the sample when the hammered metal is added to nitric acid. As the silver disolves out, a sponge of gold is left, the holes encouraging the removal of as much silver as possible. The gold sponge is washed, reheated to form a cohesive spiral and re-weighed. A large number of samples can be processed simultaneously by ensuring that each separated sample remains in the same position relative to the other samples in the cupel and in the acid flask that it occupied on the original tray. The numbered identifying slips remain on the tray during the assay and to these the weighed samples finally return. In practice it is very difficult to ensure a

complete removal of all the silver from the original alloy and for this reason a tray of samples would be made up from items of similar composition, 9 carat, or 18 carat, etc., and one sample would be added of known standard composition which could be used as a test piece. Any deviation found in the final weight of this test sample from the expected result could be assumed to represent a standard error common to the entire batch and thus allowed for in final calculations. (36).

The balance on which the original sample or "drawing" and the final gold bead are both weighed does not require any great capacity. The metal object to be tested, if large and made of several separate components such as a lid or foot or handle, would be assayed as if these were isolated pieces and from each part a sample would be drawn. Accuracy and sensitivity are therefore of far greater importance to the user of an assay balance than rugged construction or large scale pans. The balance would always be treated with considerable care as befits the final judge of the fineness of a piece of plate or coin, and can be expected to have a long life. As with dispensing scales both hand held and free standing types of assay balances existed, but the very great need for accuracy led to the use of some free standing balances by assayers from a very early period. Because of the undoubted economic importance of those involved in the purification and testing of metals, written accounts of their work survive from ancient times describing the tools and techniques of this craft. It cannot be assumed that every metal worker aspired to the quality of workmanship extolled by some accounts or the quality as seen in surviving artifacts, but these accounts were not based on fanciful imaginings and such skills were used by at least some of those involved. Basic information on the purification of gold survives in such early writers as Pliny (37) and was transmitted along with the works of other Greek and Roman writers to European goldsmiths and alchemists of the Middle Ages. The interest of alchemists in this unchanging metal and the possibility of transmuting other substances into gold ensured their continued interest in gold with its unusual properties of high density and lack of oxidation and indirectly added to the number of those interested in working precious metals. The ease with which gold could be debased was well known, as was the separation of precious metals from base by fire assaying. The earliest written description of fire assaying in England comes from the twelth century. This account refers to a "trial" of silver coinage in the reign of Henry II circa 1180: there was no gold

coinage in common use until the reign of Edward III (38). It is reasonable to assume that the practice was already long established. The "trial" of coinage, the checking of a few representative coins issued during a reign to establish their fineness and by inference the quality of the entire money supply, eventually became part of the official role of the Worshipful Company of Goldsmiths. Trial plates of metal were made of known fineness and sections cut from these plates were kept by the Goldsmiths Company, the Exchequer and the Mint. These plates were used as standards against which sample coins kept in a box or Pyx could be checked. This test is still carried out annually. (39).

Illustrations of scales and balances in use in Mints for assaying of metal or checking of coins are a valuable indication of the types of instruments in use in a certain period. The importance of public confidence in the official coinage would tend to ensure that the best and most reliable apparatus available at that period would be used. The advent of printing in the late 15th century which encouraged the production of larger quantities of any written text also increased the likelihood of a copy of that text surviving and further, that the text would carry illustrations. Changes in attitudes towards pictorial representation generally in the later Middle Ages encouraged the painting of scenes other than those which were purely religious or ceremonial. Portraits of wealthy patrons set in domestic interiors were produced and in these among the domestic objects in the background, where appropriate, a pair of scales appeared. Because of these changes and innovations in art generally, illustrations of scales and balances do exist from the latter part of the 15th century onwards and show a variety of simple balance designs. Any of these designs could have been in use many centuries before they were finally recorded. What is noticeable is that the available illustrations of the early 16th century include people such as merchants and bankers, who are represented using scales or at least, with a pair of scales somewhere in the background of the picture. There is "Georg Gisze German Merchant in London" painted by Holbein in 1532, (40) and in a Flemish "Banker and his wife" both partners are shown concentrating on the verification by weight, of a pile of gold coins, and ignoring a devotional book open on the table. (41). A century later but in the same tradition is "A Woman Weighing Pearls" by Vermeer. In each case a small hand balance of the type that was to remain popular for many centuries, is shown in use. Often one or both of the pans of this type of scale was flat and triangular for ease of transferring coins.

In contrast, scales intended for weighing jewels had one or both pans deeply indented. These pictures indicate the increasing importance of merchants and bankers in the economic life of a country, and the importance to them of the money supply, both in quality and quantity. This change had come about gradually with increasing international trade in Europe and the move towards a more monied economy. The availability of illustrations and descriptions of metal working processes from this period must not be taken to suggest that no such concern had previously existed but been unrecorded in earlier centuries. In England, however, the spasmodic but definite trend towards higher prices for agricultural and manufactured goods from the early years of the 16th century onwards undoubtedly gave rise to much concern about money and its value among all classes. The causes of inflation in this period are still the subject of debate. As far as England was concerned supply of metal from the New World may have been of less overall importance than the increase in population; and the extent to which this increased population was engaged in manufacturing industries to the detriment of agriculture. The abrupt realisation of the assets in land and plate of the monasteries did not promote a more equable distribution of wealth, but did, at least temporarily, increase the available metal supply. The value of this supply was rapidly dissipated by prolonged European Wars and inflation problems which affected the whole of Europe. A shortfall in the supply of bullion metal was overcome for a while by debasing the coinage, but this provided no lasting solution. Contemporary accounts in England blamed the debasement of the coinage which took place after 1542 for many ills. Whether or not this was entirely justified certainly the change in the exchange rate between London and its vital market of Antwerp altered at a rate that would be considered alarming even today. The pound sterling which had been worth about £1. 6s. 8d. (133.3p.) in Antwerp before 1540 fell until it was worth only 13s. 4d.(66½p) in 1551 (42). For this reason considerable pressure was put on Elizabeth I's new government to issue a new coinage, which was done in 1561. Sir Thomas Gresham advised the Queen,

"When time and opportunity serveth, to bring your base money into fine .... to keep your credit, and especially with your own merchants, for it is they who must stand by you, at all events, in your necessity." (43)

Agricultural and industrial prices certainly increased at a far

more modest rate after 1560 than before it and inflation seems to have remained at levels considered, after the dramatic events of the 1540's, to be more acceptable. How much this was due to the new coinage and how much to that ephemeral thing "confidence", and the avoidance of European conflicts or to the run of good harvests which occurred after the lean years of the late 1550's and before the disasterous years of the 1590's, is very difficult to assess. All these events, however, must have had the effect of making increasing numbers of people aware of the importance of coinage in their lives and of the real value of bullion metals, even if they themselves were unlikely ever to possess much of either. Holingshead considered the subject of the new coinage of 1561 worthy of illustration in his Chronicle. It depicts the melting of metal, the hammering of metal into sheets and the clipping of these sheets into coin sized pieces. These blanks are shown being weighed on a free standing balance with one triangular pan on the left for the blanks. Because this was a repetitive operation requiring care over a long period, a hand balance would be unsuitable. The free standing balance also leaves the operator of the metal shears with both hands free to adjust the pieces of metal. In the background, by contrast, the completed stamped coins are being checked in bulk on a large hand scale. (44)

All these operations involving coins and jewels, or bullion weighing however, are able to assume within quite close limits the answer they will obtain to their weighing. The question becomes one of whether or not the item in question is of the required and predetermined weight. Those involved in the difficult task of extracting a metal from an alloy or still more from its ores could not afford to make any such assumptions. Because the term "to assay" is now considered so much a part of the quality control of precious metals, it can be overlooked that its wider and more general application to all metal ores was the one in use in sixteenth century writings, and it continued certainly until the nineteenth century to have this wider application. The extraction of all metals from their ores and the various stages of their purification were all included in the term assaying. Further, the quest for new sources of metals, the sampling of ores and the decision whether or not to mine in a specific area were all based on calculations of probable output, which were themselves based on the gravimetric results of fire assays. Whatever may have been the causes of inflation in Europe in the

sixteenth century, encouragement was given to anyone who could find and successfully exploit new sources of raw materials, especially metals and printed texts describing mining and assaying techniques were produced and circulated in this period.

The topics discussed in the texts concerned with metal exploitation published during the sixteenth century fall into two main groups, those concerned with mining in general, and those concerned with assaying and metallurgy. Sometimes both topics are covered in a single volume. Among the earliest of such works are the "Burgbuchlein" a "Little Book on Ores" circa 1505 and the "Probierbuchlein" a "Little Book on Assaying" circa 1518. Both went through many editions and describe techniques as used in German mining areas around Freiburg and Augsberg at that period. (45) The illustrations of these books are of particular interest. They show both a hand balance being used and also a free standing balance depicted in a case. The details of the picture vary slightly from one edition to another, but there is usually a small furnace in the background and weights and samples on the table at which the balance user sits. (46) No great amount of detail is possible in these woodcuts, but the upwards pointer of the balance is clearly visible as are the three strings holding each pan. The presence of an open fronted wooden box in which to hand the scale suggests that the adverse effect of draughts was appreciated. Unlike weighing designed to check a previously determined weight of coins, jewels or drugs, weighing of metals extracted from ores or alloys of unknown composition demanded a high degree of accuracy, for on this the livelihood of the operator depended. There is another representation of a balance in a case which probably slightly predates these mining books and that is to be found in Norton's Ordinall of Alchemy of circa 1500 (47). This long poem describes all the various processes involved in alchemical practice, the benefits likely to be derived and details of all the necessary furnaces, glassware, crucibles, earthenware pots which should be obtained. Unfortunately although a single balance in a case is depicted, it is only briefly mentioned and not described in the text. One possible reason for this is that the author considered the provision of scales so obvious a need and so readily available that comment was unnecessary. Furnaces on the other hand at a period when the provision of a domestic fireplace and chimney was unusual needed to be described. (48)

Detailed descriptions of all processes involved in metal working from the original prospecting to the final assay were given by Biringuccio in 1540 (49). He describes ores in general, other compounds not used in metal extraction, assaying, alloys, casting, processes other than metal working which are equally dependent on fire such as distillation and brickmaking, and finally fire-works. The illustration given of an assay furnace also contains a free standing balance in the background, although without a case. In the text, however, he makes reference to another obvious development in the technique of accurate weighing, the use of some device to lift the beam when in use. This device is shown clearly in the detailed illustrations to be found in another book of the period, Agricola's De re metallica (50). Book VII of this very detailed work is solely concerned with assaying practice, and describes techniques for sampling ores of lead and copper as well as precious metals. The illustrations are particularly fine and they show three balances, all provided with devices to lift the beam, i.e. a piece of string attached to the top of the beam holder at the point where a hand held balance would be held, passing over two pulley wheels and so down to the bench where the end is secured to a block of wood or metal. This simple device means that the threads holding the pans can be made long enough for the base of the pans to rest on the bench when not in use. Without this device they have to swing constantly an inch or so above it to make clearance for the beam to turn without fouling the work surface. In addition this device reduces wear on the simple metal loops to which the pans are shown as being secured, and far more importantly, takes the weight off the centre (and only) knife edge at the pivot of the beam. The top edge of this knife on which everything turns was subject to considerable wear by the constantly moving beam dipping to and fro, and the probability of greater stability and almost total reduction of pressure on the metal edge when the balance was not in use would considerably prolong its useful life. The three balances depicted are of different capacities and warnings are given of the dire consequences of overloading a beam especially that of the smallest balance (shown in a case) by placing unsuitable material in the pans. This would certainly abrade the knife and if persisted in, distort the beam also. Agricola, a physician in Chemnitz, admitted he had read Biringuccio's work and certainly owed much to him and earlier writers. Agricola's work,

however, was highly valued and translated from Latin into German in its year of publication, and into Italian in 1563. The Italian version is of interest in that the translator Michelangelo Florio chose to dedicate it to Queen Elizabeth.

By 1563 Elizabeth's interest in mining and metallurgy had become well known. It could be seen as part of her continuing concern to exploit every raw material to be found in the country and so avoid costly imports. At a time when the position of the pound in foreign exchanges was weak, the cloth trade no longer the massive money spinner it had been and large sums were owed abroad as interest on loans, considerable economy was essential. Despite Gresham's assurances that the recoinage, itself a very costly business, would reestablish confidence abroad and that he could, by his financial skill, obtain more favourable rates for repaying loans, any moves towards avoiding overseas commitments would be considered advisable. He also advised correctly that raising loans at home would be better than incurring debts overseas and this advice, also, the Queen heeded (51). Tentative moves towards bringing into the country foreign (i.e. German) workers with technical expertise in metallurgy had been made earlier in the century, but the undertaking of the recoinage reopened ideas, and plans often previously mooted were now followed through. The old Tudor currency contained 25% less silver than it should have done and was recalled. On the one hand proclamations (52) could be made in 1560 officially reducing the face value of a shilling to ninepence etc., on the other hand considerable technical skill would be required to remelt and re-assay the vast quantities of debased coinage handed in in order to produce good quality silver bullion in large amounts. For this work Daniel Ulstat from Germany and his partners were engaged. They were to be paid 6% of the value of the silver processed and given the right to keep the 25% copper contained in the metal(53). This profitable contract encouraged others to look towards England as a source of minerals suitable for exploitation and in 1564 was founded a company to explore the possibilities of profitable copper extraction in the Lake District, the Mines Royal. This operation was centred on Keswick in Cumberland and was run by Daniel Hochstetter (54). He was a member of a large firm of merchants in Augsberg and a master miner. The firm was already well known to Gresham for its banking and mining interests in Europe and it was considered that a contract profitable to both

parties could be operated. With the encouragement of William Humfrey, Master of the Mint, Christopher Shutz, manager of a zinc mining company in Saxony, came to England also, and obtained the right to mine for calamine and to make brass utensils and wire by water powered wire drawing machines and hammers (55) which would advance technical knowledge. The Mineral and Battery Works of 1565 which resulted from this, ran into considerable practical problems in the manufacture of good quality brass (56) and gradually profitable wire drawing side of the operation using iron wire took over from brass as the major output of the firm. Interest in mineral exploitation, once started however, persisted, in various parts of the country thereafter with spasmodic success. Large estates in areas of England not suited to intensive agriculture might be made to yield additional revenue in this way and with reliable practical handbooks on assaying available, prospecting became a worthwhile investment for large landowners.

The first of these practical books to have been translated into English in 1683 was Lazarus Ercker's detailed treatise on the art of assaying of 1574. This was incorporated by Sir John Pettus, Deputy Governor of the Mines Royal, into a volume containing also a dictionary of technical terms (57). By the mid 17th century the expertise of the German miners was being forgotten and not replaced by new arrivals (58). The Elizabethan industries of the previous century were languishing and metal was being imported again in large quantities. This translation perhaps represents an attempt to provide a text book in the vernacular which would revitalise the industry. Certainly the choice was a good one for those having to teach themselves the elements of metal analysis, as Ercker was described by Pettus as "Chief Prover (or Assay Master General of the Empire of Germany)".

Lazarus Ercker was Chief Superintendent of the Mines of the Holy Roman Empire (59) and his detailed book on assaying of 1574 is of particular value in the development of weighing instruments, because it contains drawings of an assayer's balance (60). The author has no opinion of those assayers who are unable to service their own instruments, or who cannot make a balance for themselves. He gives precise instructions for both these operations and even describes how to make a set of weights to go with the balance, and a case to hang it in. The balance itself is of simple construction with a

steel beam terminating in two swan necks from the ends of which the pans are hung. Most of the skill in making and maintaining a balance, as Ercker makes clear, lies not in the metal working involved, but in the care taken over setting it up when complete. This, as he points out, is enough to try any ones patience, but must be done properly. Most of the problems arise over a beam that will not level when the pans are empty and the whole instrument is free to swing. This could be due to the pans not being a matched pair, but is more likely to be due to the beam not being suspended from its exact centre, one arm then being longer than the other. This can be corrected by carefully bending the swan neck at one end and re-checking. If the beam dips and then sticks first on one side and then the other, probably the position of the central knife and the centre of gravity of the whole beam are so nearly synchronous that the beam will not necessarily rest in a level position but in any position chance may dictate. The distance between the knife and the edge of the beam must be altered so that the centre of gravity of the whole beam is slightly below the knife and it will come to rest horizontally. Finally, the hole in the fork in which the knife rests and in which it turns must be neither too large nor too small nor have too rough a surface. By following these detailed instructions a patient person could set up and maintain his own scale quite satisfactorily, although as Ercker admitted "It requires great pains to fit a Ballance thus".(60) A piece of weighted string passed over a simple pulley, as shown by Agricola, would complete the scale.

Simple but efficient scales of this type continued in use and and in print for more than two centuries after Ercker. In 1707 the Goldsmiths Company embellished an invitation card with an engraving depicting all the processes involved in making objects from gold and silver plate (61). Men are shown cutting, shaping and polishing items in a large workshop with a furnace at one end and another to the side. On a table stands a scale such as Ercker would have recognised. The same basic scale designs, with and without a balance case and both with and without any form of arrestment appear in Diderot and D'Alembert's Encyclopédie of circa 1750 (62). These represent the designs in popular demand in that period, as does the picture of the scale maker's shop in the same volume. J. A. Cramer summed up the situation in the mid 18th century in his work on assaying : (63)

"The Structure of the Assayer's Scales is hardly different from that of common Scales otherwise than by its Nicety and Smallness".

Cramer then goes on to give instructions for the assembly, testing and care of the assay balance which are similar to those previously mentioned. He stresses that,

"... the Assayer stands in greater Need of knowing how the faults of a Balance are corrected, than the Manner in which the Balance is made; because, by mending, he at last obtains the scrupulous Exactness requisite in docimastical Ponderations". (64)

He illustrates his article with drawings of the components of a typical draw string swan necked scale with an upwards pointer, and this also appears but without the draw string in Leopold's Theatrum Staticum of earlier in the century (65). As similar designs continued in production until the mid to late 19th century, it would seem to imply that no advance in design was even contemplated during the long period from the 16th century - 19th century. In one regard this was in fact true. As various of the practicing assayers mentioned above had pointed out, care in construction, maintenance and use of a simple scale was more important than any other consideration. Given this care, good results, sufficient to meet the demands of the metal worker, could be achieved. Without this care design alterations would not give any better return and the desirability of continuity of design for both manufacturer and user was obvious. Plotting design innovation is not an easy matter in this period given the limited surviving evidence. There obviously were new ideas put forward from time to time and some were no doubt incorporated in some instruments at unspecified dates. The difficulty in tracing these new patterns lies first in the chance governed nature of surviving instruments and secondly in dating accurately such objects as chance may have provided. It would be fair to say that surviving balances of a free standing design and which were probably intended by their manufacturers to be used for metal assays date, where they survive at all, from the mid 18th century or later. This is also the period for which written evidence, scant though it is, suggests that considerable thought was going into the problems of improving the basic design. Dissatisfaction with existing designs is usually the spur to innovation. A better mousetrap is always a good goal. The success of a new design which would be indicated by widespread use of a new idea, especially in so traditional an area as assaying, is more difficult to gauge. Ideas that seem good to some inventors do not necessarily prove useful in practice, as can be seen from the

vast numbers of unused and unusable patents taken out every year. On the other hand the lack of surviving instruments showing technical advances does not prove that for three centuries only Ercker's designs were used. Within these limitations it is possible to see the small beginnings of change in the design of assay balances and spread over a considerable period of time.

One of the earliest signs of change is to be seen in the work of Leupold already mentioned. The plate in question in fact contains two quite distinct scales; the first in Figures I-IV is completely traditional. The other appears to be the earliest representation of an arrestment system of a type that became very much more common as time went on and particularly in the early 19th century. The beam, as shown in Figure V, is a traditional swan necked beam. The practice of putting the beam in a case had already made available the space for a useful drawer to be tucked under the floor of the case. The drawer often protruded forward of the pans and the balance "front" by several inches thus forming a useful level platform on which to place weights, samples, pans, etc. Leupold shows part of this useful false floor being used to house the seesaw arrestment system. A plunger outside the closed "front" and protruding through the "floor" when pressed down will depress a long piece of springy metal. This bow shaped band holds up a piece of wood on which rests, through holes in the floor, the bases of the outer covering of the centre pillar and the rests for the pans. Pressing the lever allows the beam and pans to descend slightly, the pans swing free and the centre knife engages on the plane. Releasing the lever allows the metal to resume its bow shape and put the balance into arrest. This simple but effective device requires that the centre pillar be drilled or drawn sufficiently accurately that one tube shall slide without any serious friction inside another and do this repeatedly.

The design suggested by J. Hyacinthe Magellan in 1781 (66) has a similar idea but installed upside down. His lever seems designed to bear down on a support under the board on which the balance rests and thus raise the centre pillar, beam, both pans and baseboard simultaneously. Stability would seem to be a serious problem here and it must be admitted that there is no proof that this balance ever got beyond the design drawing stage. The need for a system of arrestment for pans as well as the centre knife was obviously considered important at this time, as was a system more smooth in operation than

a piece of string drawn over a pulley. Another important idea of Magellan's, from the point of view of later developments, was the replacement of the standard steel bar beam by a lattice beam "d'une forme rhomboïde". This pattern in brass was to appear increasingly in the 19th century, giving strength to the beam without weight, a very important consideration in a light balance in particular. This beam was designed at its centre to rest on two pieces of well - polished agate. This suggested use of agate in place of curved metal as a centre plane is also of considerable importance, but gives rise in his design to problems of stability. The centre "knife" consisting of two steel pins will all too easily slip on the well polished agate and there is no method of preventing this. Agate did come into use increasingly in the 19th century as a replacement for corrodable steel for the centre and end planes of beams, but in conjunction with a triangular knife rather than pins. To a lesser extent so did Magellan's other idea of putting the pointer to indicate the movement of the beam acress a graduated scale on the end of the beam rather than at the centre and at right angles to it. Summing up all his ideas Magellan makes the apparently quite justifiable observation:

"Je remarquerai seulement qu'il est bien extraordinaire qu'on ait suivi depuis si long tems [sic] constamment et aveuglément l'ancienne méthode dans la construction des balances destinées à des expériences délicates". p.46

The assay balance so carefully described by J. Hyacinthe Magellan in 1781 contains several design features which are important indications of the direction in which ideas for improving instruments were moving in that period. His drawing shows an attempt to provide a smooth arrestment system by allowing the support beneath the pans to drop away leaving the beam swinging. An end pointer moving over a finely divided scale was an improvement on the usual blunt needle at right angles to the beam designed to be lined up against an equally blunt sight suspended from above. The triangular beam and its pans are to turn, not with the scrape of metal edge on semicircular metal ring, but on two steel pins balanced on a flat agate slab. All these ideas were excellent in theory. In practice they also have disadvantages, and although variations on some of them do appear in the 19th century, it seems probable that this balance as drawn may have remained only a prototype requiring further development. The arrestment system does not appear to have included the centre pillar in its

adjustment. The pan supports move down as the lever is moved sideways, but there does not appear to be any tube within the pillar which might slide up and down and so relieve the wear on the centre "knife". One has to assume that the two steel pins that constitute this knife remain permanently in contact with the agate plane and the pan arrestment merely serves to stabilise the whole instrument between weighings. The probability of the pins slipping uncontrollably on the agate is considerable and no centring device has been provided. This is the more surprising as grooves to locate the pan hangers on their pins are provided. In the same way there is no possibility of adjusting the length of the two halves of the beam should one be inexact, nor of compensating for the weight of the pointer metal attached at one end. Provision for adjusting the centre of gravity of the triangular beam, however, is made. The beam is described as being made of the traditional material (steel), but the difficulties of filing an accurately balanced rhomboidical beam from such a piece of metal seem very considerable. The design seems, in fact, to be the idea of one who could see the problems posed by available designs, but who was not himself a skilled designer.

Magellan is described as one who spread news and ideas through his extensive circle of correspondents and as such performed a valuable role in conveying information between the Royal Society of which he was a member and the Académie Royale des Sciences, of which he was a Correspondent.(67) It is now very difficult to disentangle the ideas in his writings which were solely his, from those which he collected elsewhere and passed off as his own. In the same article as the description of the assay balance there is a detailed description of the advantages to be derived from the system of double weighing. Nonetheless, some years later, in 1793, Lavoisier attributed this useful idea to M de Borde.

"Elle consiste à mettre le corps que l'on veut peser en équilibre avec un poids arbitraire quelconque, à retirer le même corps et à y substituter dans le même bassin des poids connus. Il est clair que cette méthode doit donner le poids du corps qu'on veut peser indépendamment de la différence de longueur des bras de la balance". (68)

Certainly the idea of double weighing and its obvious benefits could have been in circulation for some time and cannot be attributed with absolute certainty to any one person. Another possible originator of this idea, William Lewis, had already pointed out the advantages of this system in 1763.

"... any unequal-armed balance may on this principle have a set of weights adjusted to it, which being used always in one scale, the instrument shall be of the same accuracy as if the arms were most exactly equal." (69)

Lewis had been engaged in determining the specific gravity of various alloys of platinum, a metal at that time only recently introduced into the country. The frontispiece to his book shows a vast assortment of apparatus including two very simple free standing balances, of the type already described and apparently without even the simple string arrestment shown by Ercker. These may well have been the type Lewis himself used. Like Ercker he advocated making ones own weights for small masses and describes the standard procedure.

"... silver thread kept equally stretched by a heavy body at one end, may be coiled close round a thicker piece of brass wire and all the coils cut through at once by a sharp instrument applied lengthwise. Silver wire is drawn to such fineness and of so uniform thickness that weights thus made by measuration are of greater nicety than it is possible for any balance to weigh." (70)

Magellan reproduces this idea towards the end of his own account implying that the method is originally his own. (71) One is left with the conclusion that although Magellan is undoutedly valuable in indicating the ideas and problems being aired at the time of writing, some of the points he makes may well have originated far earlier than he implies and although some ideas may well have been his own it is difficult to disentangle the two groups. An impression remains, nevertheless, that during the eighteenth century increasing attempts were made to improve the performance of assay balances. These attempts could involve advocating better care and maintenance, simple aids to smoother (or any) arrestment systems, or the provision of more reliable weights without which the best of balances was useless. Taken together they do indicate that even so traditional a group of analysts as the assayers, whose techniques had not altered for centuries, considered that analysis within a finer range of tolerances was both possible and desirable. The need for more geological surveys to locate and identify minerals may have encouraged this atmosphere. Certainly the demands made on traditional designs by an increasing number of people whose interests were not primarily in the analysis of metal ores but in gases and salts, 'earths' and spa waters encouraged the gradual introduction of new ideas in design. It is fortunate that from this point also, namely the late eighteenth century, can be dated the earliest surviving balances which from their design suggest

they were intended for small scale analytical work. Although the balances themselves are chance survivals from a vast number produced over centuries, they are at least more numerous and collectively more detailed than any written account can be. Few were the investigators who expressed in print their satisfaction or dissatisfaction with their apparatus. Perhaps they remarked on it in letter to a friend and perhaps, if the writers themselves were famous, the letter might survive and eventually be published, but very seldom in the pages of learned journals do balances get honourable mention. One suspects that the 'good' balance was handed down through generations until it was beyond repair and then it usually joined the path which had been taken by the unreliable balance many years before. Those that survive in collections are not, of course, entirely there by chance. They are by definition 'good' balances. They were not discarded within months of purchase, but used for many years before being retired. Many were donated to large museums from existing private collections themselves composed of superior instruments. Some were used by the great and famous who could obtain the services of the finest makers even for traditional designs. Certainly in the case of the assay balance they were designed for use rather than for ornament. Those features which they have in common often bear out the general comment made in written accounts of previous centuries. They also reveal, by their numbers, aspects of design which would not be apparent or significant in one instrument, but which, when continually repeated, become noticeable and require interpretation. Because they belong to a very highly specialised world of analysis, the assay balances both reflect and anticipate the changes taking place in the rapidly growing field of chemical analysis of the nineteenth century. It is often difficult to classify a balance with certainty into a specific area so similar are they in some respects. The new ideas when applied in one field reappear modified in the other. The actual range of designs in assay balances is narrower than among chemical balances in general and this is partly the result of long tradition establishing exactly what characteristics were required of the 'good' assay balance. Improvements were carefully planned; once a good design idea had been produced, therefore, its benefits could be taken up by the less circumscribed and also more uncertain world of chemistry. Some consideration of the principle design features of assay balances in general will help to clarify the more diffuse and ever changing world of 19th century chemical balances.

1. Father J de Acosta 'Natural and Moral History of the Indies' [reprinted] The Haklyt Society London 1880 Vol.I p.186 ff as quoted by M. E. Weeks Discovery of the Elements 1956 p.18

2. The use of the touchstone, a set of 'needles' made from alloys of predetermined mix, required accurate matching by eye with the colour of the unknown sample and was limited to the range of mixtures in the set of needles. A sample could be grouped roughly but not accurately analysed.

3. Greenaway, Dr. F. Historical continuity of the tradition of assaying. Proceedings of 10th International Congress Hist. of Sc. Ithaca 1962 Vols I & II p.819-23.

4. A Course of Mechanical, Optical Hydrostatic and Pneumatical Experiments. To be perform'd by Francis Hauksbee; and the explanatory lectures read by Wm. Whiston M.A., Spectator January 15th 1712.

5. Catalogue by I. Greenwood, Professor ofMathematics and Natural Philosophy 1727-1738, 1738 of apparatus then at Harvard illustrated with diagrams from the Hauksbee/Whiston course, p.134 ff. From I. B. Cohen "Some Early Tools of American Science", published Harvard U.P. 1950.

6. 'sGravesande Mathematical Elements of Physics, translator Dr. J. Keill 1720, Chapter 10 Book 1 p.40 specifically mentions "the deceitful Balance".

7. Crommelin, Dr. C. A. Descriptive Catalogue of the Physical Instruments of the 18th Century, (including the collections Gravesande-Musschanbroek) in the National Museum of the History of Science, Leyden 1951.

   Turner, G. L'E & T. H. Levere. Martinus Van Marum Life & Work, ed. E. Lefebvre & J. G. Bruijn.
   Vol.IV Van Marum's Scientific Instruments in Teyler's Museum, pub. Leyden 1973.

8. Redwood, T. Pharm. J. Trans. 1881-2, 12 (3),674. quoted by Crellin J.K. & Scott J.R. Pharmaceutical History and its Sources in the Wellcome Collections. II. Drug Weighing in Britain circa 1700-1900 Medical History Vol XIII No.1 Jan.1969 p.51-67.

   An illustration of a pair of hand scales in use for dispensing in this period occurs in Hatton J. "An Historic Pharmacy". Supplement to The Chemist & Druggist, January 28th 1893. One of the interior views of "Old Plough Court" the pharmacy founded by Wm. Allen shows an assistant dispensing and using hand scales.

9. Crellin op. cit. p.53-55.

10. Crellin p.59. Out of over 1,000 Drachm and Scruple weights in the Wellcome Collection, only 8 appear to have been stamped.

11. Scales were only inspected on a local basis and not required to be stamped until 1889. Crellin, op. cit. p.52 n.8.

12. Campbell R. The London Tradesman pub. 1747, Chapter LV Sect.1 p.253

13. Ibid Appendix Sec.24 p.327.

14. Item from the Pinto collection, quoted by Pinto, Edward H. Treen and other wooden bygones, pub. Bell & Sons 1968, p.287.

15. Crellin op. cit. p.64 n.68

16. Evidence given by John Field, Weigher and Teller at the Royal Mint to the Select Committee, 4th May 1837.

17. Oertling archives. Messrs. Oertling & Co. Ltd., St. Mary Cray, Bromley, Kent.

18. Oertling Archives

19. Oertling Archives

20. Private communication from Miss P. Beale.

21. Trade Directory for the area.

22. Census returns 1851

23. Medical News 1st July 1871 Obituary p.24

24. Frazer Brockington C. Public Health in the 19th Century pub. 1965.

25. D N B. p.118-119 L. S. Beale received a medal for his collection of microscopes at the 1861 Exhibition.

26. Like all good Chemists Hume labelled the bottles he supplied with printed labels bearing his name and address. See Faraday's Chemical Chest, Science Museum.

27. J. Stodart Journal of Natural Philosophy, Chemistry & the Arts 1805 11 215-216 quoted in W. A. Smeaton Early methods of cladding base metals with platinum... Platinum Metals Review Vol.22 No.2 April 1978, p.65.

28. Astronomiste Nachrichten 8, 48 (1831) quoted by J. T. Stock "Thomas Charles Robinson and his balances" Journal of Chemical Education Vol.45, No.4, April 1968, p.254.

29. Bill for items bought by Dana for Harvard College from Frederick Accum and Alexander Garden in 1815. Reproduced in I. B. Cohen "Some Early Tools of American Science" p.89 ff.s.

30. DARWIN Francis "The Life and Letters of Charles Darwin". London Murray, 1887 Vol.II p.47.

31. This problem is not improved by the changes in occupation and interests that often occurred during a user's career; it was very common for basic chemical knowledge and training to be acquired in one field, and that knowledge and perhaps the apparatus, made use of in a quite different area of study later in life.

32. Greenaway loc. cit. ref. 3.

33. Illustration Fig. 258 p.865 T. Martin Lowry Inorganic Chemistry 2nd ed. 1931.

34. The cause of this phenomena seems to have been first established in 1815 by Samuel Lucas whose letter to Dalton was subsequently published. He describes how he collected over water a quantity of the gas evolved from molten silver as it was poured and rapidly cooled by immersion. Dalton tested the gas sample and added a footnote "I found this gas to contain 86 or 87 per cent of oxygen".
"An Account of some remarkable facts observed in the deoxidation of metals particularly silver and copper". Memoirs of the Literary and Philosophical Society of Manchester 2nd series 1819.3. p.271-2.

35. Dr. Miller Elements of Chemistry quoted in "The English Cyclopaedia" conducted by Charles Knight Arts & Sciences Vol. I London 1859 p.618.

36. Information supply by Mr. Dalladay of the Assay Office, London.

37. Hunt, L.B. The Worshipful Company of Goldsmiths Gold Bulletin No. 3 Vol.II 1978 p.95.

38. Johnson London, 1950 36-38 quoted by L.B. Hunt, op cit. Richard son of Nigel "Dialogus de Scaccario," translated by C. Johnson, London.

39. The Guardian Friday February 14th 1976, describes the first Trial held in public at the Goldsmiths Hall. The results of the assay are published in the London Gazette.

40. Kaiser Friedrich Museum, Berlin. Holbein. Geor Gisze 1532.

41. Quentin Matsys The Baker's Wife 1512. Louvre, Paris.

42. R.B. Outhwaite "Inflation in Tudor & Early Stuart England" Studies in Economic History ed. M.W. Flinn, London 1969. The silver content of coins dropped by 25% during this period.

43. Quoted in L.B. Hunt, op.cit., P.97 see ref. 37.

44. Outhwaite op.cit., frontispiece.

45. Annan, Robert Historic books on mining and kindred subjects H.M.S.O. 1968 p.19.

46. Bergbucklein translated by A.G. Sisco pub. American Institute of Mining and Metalurgical Engineering. 1949 and Probierbucklein translated Sisco & C.S. Smith.

47. Norton Thomas Ordinal of Alchemy British Museum M.S. 10302 f.37.

48. Ordinal of Alchemy ed. John Reidy, pub. for Early Eng. Text Soc. O.U.P. 1975. The MS in ref. 47 lacks the last two chapters of text but does contain the illustration which has been dated to 1480-90 and contemporary with the text: see p.xiii. The balance is mentioned in l.2554 Capitulum 5 f. 50v supplied from the Sloan MS 1873. ..... cont'd over.

"In parties tweyne full equallye with subtile balance and not with Eye;" Although Sloane MS is considered to be a later copy from early 16th century, the line was no doubt unchanged from the original. The illustration with slight variations is reproduced in the 17th century in Elias Ashmole's first English translation in Theatrum Chemicum Britanicum 1652. Reprinted Sources of Science No.39, N.Y. 1967.

49. Biringuccio V. De la Pirotchnia pub. 1540, translated C. Stanley Smith & Martha Teach Gnuidi, N.Y. 1942.

50. Agricola Georgius De re metallica 1556 trans. H.C.Hoover & L.H.Hoover, pub. N.Y. 1950.

51. Gresham to Queen Elizabeth on the fall of the Exchanges 1558 Tudor Economic Documents ed. Tairney & Power Vol.II p.146, 1924 ed.

52. op. cit., p.195 "Proclamation .... 1560". rej 51

53. M. B. Donald, "Elizabethan Copper", London 1955. p.11.

54. Henry Hamilton "The English Brass and Copper Industries to 1800" Longman 1926

55. Hamilton p.14.

56. These problems were mainly due to impurities in the copper used. As the standard of copper smelting improved in the 17th century so did the brass and the basic technique described by Pettus in 1683 of heating copper with calamine remained unchanged to the (19).

57. Entitled "Fleta Minor" as the author was in the Fleet Prison at the time. Annam op. cit.,p.22. Hamilton Appendix I.

58. Donald op. cit., p.3.

58. Donald op. cit., p.3.

59. Annan op. cit., p.21.

60. Lazarus Ercker Description of the Principal Mineral Ores 1574 trans. Sisco A.G. & Smith C.S., Chicago 1951.

61. Invitation to dinner. Goldsmiths Company, Feb.6 1707. Reproduced in W. A. Benton [Averys] The Record Vol.13 p.7-9 Plate I Rec. No. 299.

62. Diderot et D'Alembert. Encyclopédie ou Dictionaire raisonné des Sciences des Arts et des Métiers. c 1751-57ff. Vol.II The extraordinary story of the background to the publication of this remarkable work in the face of intense political pressure is contained in Collison Robert "Encyclopaedies; their history throughout the ages.", pub. Hefner 1964. Chapter IV p.114-136.

63. Cramer J.A. Elements in the Art of Assaying Metals. 2nd ed. 1764, trans. Cromwell Mortimar Sec. R.S. Originally published in Leyden 1739 and translated into English 1741. p.100-107 and Plate V Figs. II-VIII.

64. ibid p.104.

65. J. Leupold Theatrum Staticum pub. 1725 ff. Chapter V p.34-5 Reproduced in Benton op. cit., Vol.18 plate 2 p.5. Rec. No.414

66. J. Hyacinthe Magellan "Lettre sur les balances d'essai." Observations sur la physique, sur l'histoire naturelle et les arts. Vol.XVII Part I, January 1781, p.43-49 and Plate 1.

67. J. Hyacinthe Magellan D.S.B. Vol.X p.5.

68. Lavoisier A. Traité Élémentaire de Chimie T VI p.684 quoted in M. Daumas Lavoisier théoricien et expérimentateur Chapter VI p.133, 1955

69. Lewis W. Commercium Philosophico Technicum: on the philosophical commerce of the arts, London 1763. Sect. VI p.544

70. ibid

71. Magellan op. cit., p.47.

CHAPTER 2

Developments in small scale weighing as exemplified by surviving instruments.

Summary.

The survival of instruments and the diversity of designs in use as shown by these instruments.

Developments in the design of assay balances.

i. the arrestment system

ii. the beam

iii. sensitivity

Changes in the requirements of druggists, diamond merchants and assayers during the 19th century.

Balances associated with the work of John Field, Mégnié, P.N. Johnson, G.H. Makins, L. Oertling.

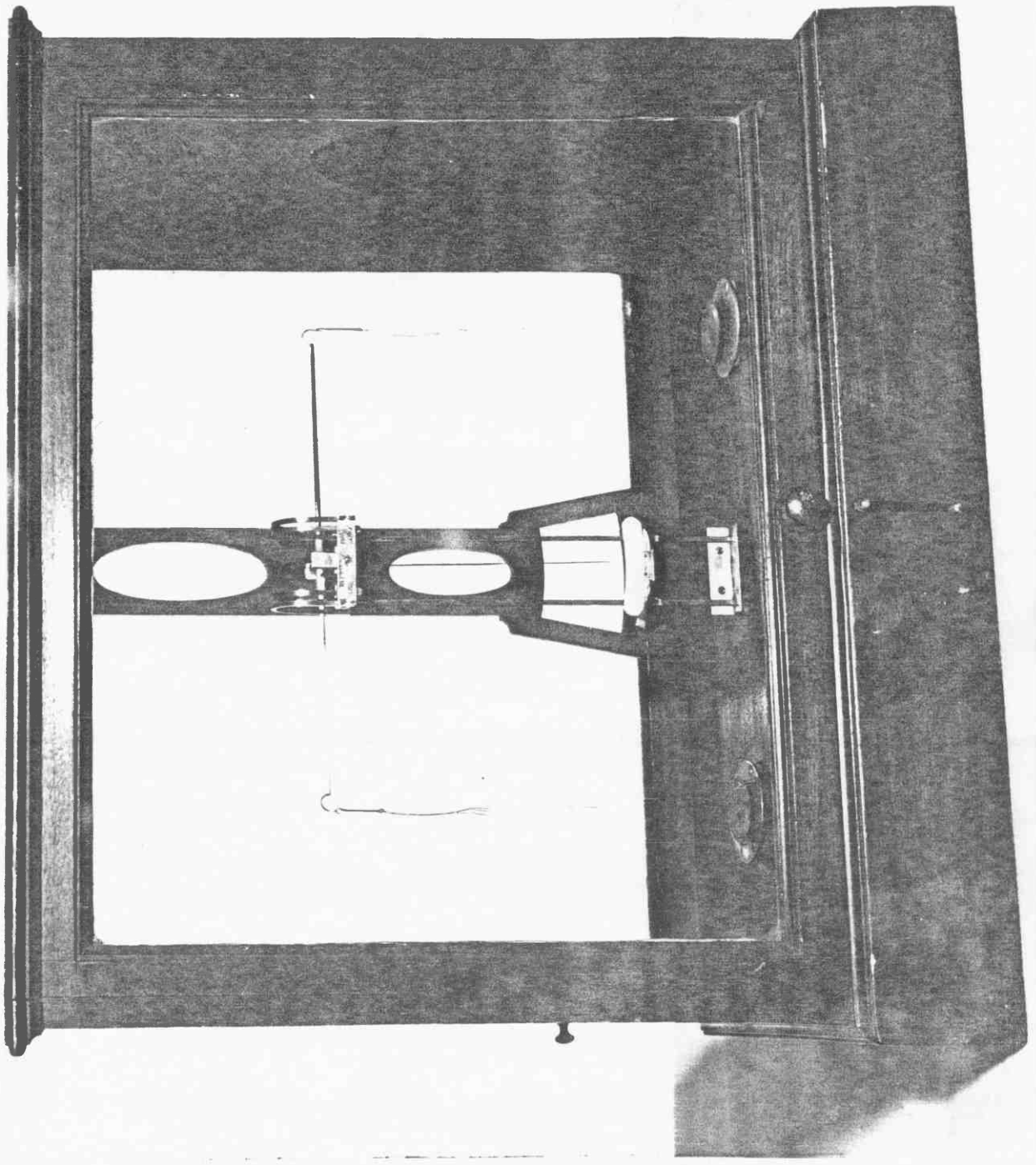


Fig. 2 Field

Developments in small scale weighing as exemplified by surviving instruments

Instruments used for small scale weighing survive in greater numbers for the latter half of the nineteenth century then for a comparable period in the eighteenth. This inevitably means that despite the existence of some documentary evidence for eighteenth century designs and those from earlier dates, there is a possibility that more will be deduced from later examples than from earlier rarer instruments. It would be very easy to extend this argument to imply that there were therefore few interesting developments before 1800; care must be taken not to equate lack of evidence with lack of occurrence.

One of the factors tending to produce more later assay balances than earlier ones apart from greater production, is the greater ease of identification of the instruments' intended use. Later objects often have more information regarding provenance and from this the former owner's utilisation of the object can be deduced. Also it had become increasingly obvious to those engaged in analysis during the nineteenth century that the analysis of metal alloys and ores was a separate branch of the science of chemistry to be separately conducted. This division was less marked at the start of the century when for example Wollaston was devoting a lot of time to determining both the basic chemistry of the platinum group metals and their reactions to reagents, as well as performing detailed assays of naturally occurring and artificial alloys of these same metals. Balances known to have been used by him really served both chemical and assay purposes and a clear classification is difficult. Later objects are also much easier to date than earlier ones. Not only will the former owner often be identifiable, but more information will be available about the manufacturer, who in turn is far more likely to have published surviving catalogues in which designs can be recognised. The tendency to underestimate the age of an object rather than overstate it may well cause a number of late eighteenth century items to be misplaced for lack of positive identification, and this will further diminish the

the apparent numbers of eighteen century survivals.

Even when all these conditions have been considered however, it still remains apparent that larger numbers of free standing assay balances were made as the nineteenth century progressed, and given a larger basic number more survivals can be expected. This increased production was facilitated both by improved machinery for the manufacture of precision made parts and also by an increasing need for the product. The move towards monied economy following the Industrial Revolution affected not only Britain, but progressively the rest of the trading world. New sources of precious metals were exploited, adding to the supply of bullion, and also increasing the demand for accurate assessment of mineral content. In addition, countries such as Canada which had formerly received all their coin supplies from London set up their own Mints in the latter part of the century, and these new premises had to be equipped to the highest standards. Such a growing market encouraged innovation and a reassessment of the basic problems underlying the technique of assaying. These changes are reflected in design as the century progresses, but they overlie rather than obscure the basic pattern of design which can be seen to carry through from previous centuries, and it is itself further adapted (in time) to the needs of more general analytical techniques.

A survey of surviving balances probably used for assay work reveals certain basic characteristics which are so uniform that they would appear to have evolved to fit certain definite needs. These common features can be reasonably assumed to have existed in previous instruments no longer in existence and help to complete or in some cases identify features unclear in illustrations. An important feature which illustrations are seldom able to show but which is very apparent from a survey of items is that the vast majority of assay balances are signed by the manufacturers. Of 49 assay type balances seen in the course of this study, 38 are engraved with a signature and a further 5 are confidently ascribed to a known manufacturer by the museum in whose collection they appear, either on the strength of surviving documentary

evidence or from known provenance and similarity to other items. This is markedly different from the situation with dispensing balances. Although it must be admitted that the few instruments whose makers cannot be identified would on the basis of design tend to be mostly eighteenth century rather than nineteenth century, it would still appear that assay instruments were signed as a matter of course rather than not. In this respect assay balances join those groups of specialised and sought after items whose owners were not averse to proclaiming the source of their supply, and whose manufacturers were anxious to encourage repeat orders. The same tendency to include signatures, and even some of the same names, occurs in other groups of instruments, including those used for the study and practice of surveying and navigation. It would seem that the same essential standard of quality is required of and supplied by assay balances as by sextants. Even allowing for the preference of collectors for collecting signed items, the same uniformity is not to be found in dispensing scales and its presence in assay and jewellers scales does suggest a deliberate attempt at establishing identification.

Another feature almost total in its uniformity is the provision of some kind of case in which to hang the beam. The tendency, seen in drawings from the sixteenth century onwards, had by the latter part of the eighteenth century and probably long before, became almost universal practice. Hand held balances were provided with a small box, usually fitted, into which they could be placed, but the overwhelming majority of assay balances were found with cases which were wholly or partly glazed. The close connections between the origins of the dispensing and the jewellers and also the assay balances in their free standing designs can be seen in certain particular examples. One is in the Wellcome Collection (1) and another at the Assay Office London (2). The former was made for use as a jewellers' scale by Frederick Sheldon of Birmingham, and is supplied with both sovereign weights and penny weights. There is a manufacturers card enclosed giving prices for both new and old gold and silver metal per dwt. Were it not for the clear indication given of the intended and no doubt actual use of this scale, it would not immediately have been correctly classified (as it could equally

well have been intended as a dispensing scale). The same is true of a scale at the Assay Office. It is of a type once in use there, as is also an extremely fine De Grave hand scale (3). Both are in the Assay Office collection, but as with the example from the Wellcome Institute those from the Assay Office are all basically dispensing scales in their design of the type previously described. The free standing ones can be dismantled and packed into a fitted drawer space, and consist of a brass pillar in two sections and a steel beam which can be assembled and mounted on the lid of the drawer to form a working surface. Despite their resemblance to dispensing scales, all these instruments can be correctly classified as assay or jewellers scales.

Any suggestion that these scales are accidental additions to collections and not typical of styles favoured by those whose business it was to buy and sell stones and bullion can be discounted. Current catalogues illustrating items offered by manufacturers to present day goldsmiths and diamond merchants for use in their work show exactly similar items available today, and such scales are much favoured by merchants for their ease of transportation and speed in use (4). Such items are of course used in addition to the extremely fine balances constantly checked and adjusted and in use throughout the Assay Offices and the Diamond Bourse, but they do show the difficulty encountered in trying to make too narrow or water tight classification limits based on design features. These two groups of balances, the one permanently in its case, of high quality and sensitivity, but until very recent design developments, very slow in use, the other group simple robust and of an accuracy acceptable between merchants in a small and closely knit organisation, were both needed by jewellers and goldsmiths at different stages in manufacturing and trading operations. Any large organisation would require balances of both types. Smaller traders would specialise in part of the process. The continued and continuing use of the simple pillar scale over a very considerable period makes it difficult now to decide whether the prototype was originally developed from a hand held scale by a dealer in precious stones or a dealer in precious ointment. The refinement of

this simple idea from at least the sixteenth century onwards and the provision of a moderately draught proof case was however most needed, and most likely to have been promoted by the assayer per se. The merchant buying or selling needed merely to be assured that the item selected was in its actual weight somewhere between the limits his experienced eye had taught him to expect. An experienced goldsmith can correctly determine the carat rate (proportion of base metal to gold) in a gold object of irregular shape merely by "weighing" it in his hand. He requires no scale, but uses it merely to confirm what he already knows (5). An assayer however, is in rather a different position. He requires to know to a high degree of accuracy the proportion of base metal to gold in a sample that may be of dubious or quite unknown quality. For his own convenience he will try to use samples of standard size but partly due to variations in quality of alloy between limits that may or may not be acceptable, and partly due to variations caused by chemical reactions in the process of fire assaying previously described, the result of the assay is always to some extent 'unknown'. For this reason two distinct lines of development in balances, both connected with the trade in fine metals can be detected. One line similar to that discussed for dispensing scales has altered in design but slowly, and continues to perform adequately the job for which it was originally intended. The other line resembles more in its development that of the evolving chemical balance and shows the ever increasing influence of changing analytical techniques. Free standing assay balances which originated as a broadly similar band of instruments gradually divided into more specialised groups as the nineteenth century progressed. Certain design characteristics persisted throughout and although no one criteria covers all such balances, taken as a group some features tend to recur and the presence of several of these features, such as the presence or absence of a glazed case, aid classification in a way that one design detail alone would not.

Although judging from surviving examples, the provision of a case was considered of great importance in assay balances, the provision of a drawer under the case was less vital. A quarter of those instruments seen appear never to have had what would at first sight seem to be a useful extra; several others had

lost either the drawer, or frequently the small knob, usually of ivory without which the drawer could not easily be opened. In a dispensing scale the drawer was a vital part of the instrument. In it everything including the scale itself could be conveniently packed, and space was often provided for weights, each with its own small socket. As dispensing and assay balances must both have originated as developments from an original basic weighing device, and since, as has already been shown, these remained in use during the nineteenth century, scales from both occupational groups are so similar that only certain provenance enables them to be distinguished and categorised correctly, some reason for this lack of emphasis in storage space in assay balances seems called for.

Motives of economy suggest themselves. A drawer is a skilled piece of joinery requiring care in manufacture and fitting. Its omission might therefore be expected on earlier items where every joint must have been hand made, rather than on late nineteenth century examples where some mechanised wood working equipment could be assumed to be present. In fact drawers are found with instruments of all dates, and equally are found to be lacking in items from both ends of the time scale under consideration. Manufacturers of highest reputation sometimes did not fit drawers to assay balances of good quality. Since no obvious common feature suggests itself which will include all the instruments that were provided with drawers and exclude the others, it seems probable that provision was made for two quite different sets of working conditions. Just as scales indistinguishable from dispensing scales were selected by jewellers and goldsmiths for use solely to check items against known standards, while even in the same establishment a more sensitive and expensive balance was provided for more rigorous analysis, so allowance was made by the manufacturer even within this latter group of balances to accommodate in his designs the varied conditions of work that the user might meet. That both the manufacturer and the user of a scale should be one and the same person became less and less likely during the period from the mid eighteenth century onwards, the period from which the surviving scales can be dated. By this time the skilled

instrument maker who signed and sold his own aparatus had come into existence in London (6). The need that Lazarus Ercher had hoped to meet by describing how the user might make and maintain his own instruments had largely passed away. There remained some independent designers however, and the records of one designer/manufacturer/user of assay balances, two of whose instruments survive, may give indications as to the connection between known working conditions and basic design.

John Field 1764-1843 was first employed by the Royal Mint as Weigher and Teller in 1815 (7). He himself had been trained as an instrument maker and had been apprenticed to the eminent optical instrument maker, Edward Nairne in 1779 (8). Later he had set up his own business in Cornhill which he sold together with the stock in trade in September 1795 (9). It is possible that his father who died the following year had already become ill and John Field's assistance was required to help run the various family concerns. The close connection suggested in this study between the origins of all scales used for small scale weighing, whether it was of gold or of pharmacutical "chemicals", and by extension the unity of interests among the users of such scales is further emphasised by the fact that John Field who eventually made fine balances for the Royal Mint had among his family an elder brother, a father, a grandfather who were all Apothecaries (10). The status of the family can be judged from the fact that the first two of these relatives, Henry, John's eldest brother and John, his father, held various offices in the Company including that of Master of the Society of Apothecaries (11)(12). John Field junior also held various offices in the Spectacle Makers Company (including that of Master),(13), but his known interest in the manufacture of instruments and the known integrity of the family (14) led to his appointment at the Mint.

In 1815 the Royal Mint had recently moved into large well equipped premises on Tower Hill supplied with the latest modern machinery for the production of coins, designed by Boulton and made by Maudsley. The traditional premises in the Tower had become overcrowded and cramped, despite their security, and the new building was much admired (15). Problems

however, arose very early on in the production of coinage, and these were really problems of vastly increased production and quality control. The coinage in use in the late eighteenth century had deteriorated due to excessive use and was in poor condition. Only gold of a very high degree of purity was used for bullion in order to maintain its face value, but this in turn gave a raw material for coin production of a metal alloy of 22 carat gold which was very soft and subject to wear. To increase the copper or silver content would have prolonged the life of the coins, but left the Mint open to charges of debasement. Because English Guineas were frequently found to be badly worn in the late eighteenth century, only new coins were acceptable as foreign exchange. This further depleted the Crown's internal supply of bullion, and progressively lowered the quality of coins remaining in England. Certain types of foreign coins, in particular Spanish and Mexican dollars, were of necessity accepted as legal tender in England. These had been struck with a design based on the head of the King of Spain and were then overprinted with that of George III (16). During the Napoleonic Wars the shortage of bullion grew so acute that payment in gold virtually ceased after 1797 and only notes were issued. At Wellington's insistence an exception was made for his army fighting on the Continent, which continued to be paid in gold rather than paper money which could not be readily exchanged. Silver coins by the late eighteenth century were often worn so smooth that counterfeiters were saved the trouble of engraving any design on their products (17). Copper coins were not issued by the Mint at all. It declared in 1751,

> "Copper coins with us are properly not money, but a kind of tokens ...." (18)

Large numbers of privately produced copper tokens were made at this period to remedy the deficiency in the supply of small change. Those produced by Boulton using his new steam powered machinery in Birmingham were particularly popular and of very uniform size and quality. Coins struck by hand had inevitably varied considerably in depth of engraving and length of useful life. Boulton obtained various Government commissions between 1797 - 1807 to produce pennys, halfpennys and farthings in vast

amounts and his success encouraged the installation of similar machinery in the new Mint, and the eventual production of "Mint" copper coins in the 1820's (19).

John Field's arrival in the Mint coincided with a period of modernisation and change. A total re-organisation of the coinage was obviously a dire necessity, and the dearth of coins of any quality made the demand for new coins overwhelming. A vast recoinage was ordered in 1816 and the decision was made to change from the Guinea to the lighter Sovereign. This had the useful effect of enabling more coins to be produced from a given weight of bullion. It also effectively demonetised any "old" coins still in existence making them speedily recognisable and encouraging their return to the Bank. A further consequence which had considerable influence on John Field's work was that the new "light" coins rendered obsolete all existing sets of weights sold in the eighteenth century to check the legality of coins in use. Field became "Stamper of Weights" in addition to his other duties, with the task of remedying this total lack of officially verified coin weights. It is against this complex background and urgent need that he set about producing new scales and also new standard weights.

The post which John Field took on in 1821 of Stamper of Weights had originally been instituted by an Act of 1774. This was an attempt to overcome the perennial problem of coins in circulation which were below the official minimum weight. This weight loss might be due to normal wear and tear, clipping or counterfeiting, and it was realised that only the existence of accurate weights which could be used to check individual coins was likely to make identification of such coins possible. These weights must of course themselves be authenticated and available in reasonable quantity. An office was therefore created of "Keeper of the Duplicate Weights", and the holder for a small fee was to check and stamp as correct any sets of duplication or copies of the Standard Weights "of a Guinea and of a shilling and of the parts and multiples thereof". (20) This useful scheme had the further result of encouraging the supply and use of small coin scales.

The first holder of the new post was John Whitehurst of Derby F.R.S. 1713-1788 who was a noted clock and watch maker. He was a man of wide interests, and a member of the Lunar Society. He had made a set of weights for Joseph Priestley, (21) and an assay balance in 1768 for Matthew Bolton (22,23). This balance may have been one of those borrowed by Roebuck ("of my friend Mr Boulton".), for some experiments on ignited bodies. One of the balances Roebuck used had a capacity of ½ ounce and would turn at 1/100 grain (= .0006g) (24). Further experiments described a balance made by John Whitehurst and "sensible to 1/2000 of a grain".(=.00003g)(25). This very high degree of sensitivity suggests that Whitehurst was an instrument maker of considerable skill and that the balances he made in connection with his work at the Mint would have been of similar quality. None of the actual instruments he made now survive at the Mint, but a description of them was given in 1788:-

> "Three scale beams in Glass Cases with apparatus compleat, made by the late Mr John Whitehurst for the use of the Office of Public Stamper of Weights". (26)

A balance signed by Whitehurst does survive in Leyden nowever;an illustration of it in Maurice Daumas' book on Scientific Instruments of the seventeenth and eighteenth centuries shows a massive and ornate case containing a balance with a simple suspended beam and a downwards pointer which passes over a graduated scale (27). It cannot be assumed that all Whitehurst's balances were of idential pattern, but it is interesting that a balance case with an almost identical carved front to that illustrated by Daumas remains at the Mint and shows signs of having been re-used at least once and probably twice. It now contains an early twentieth century Oertling assay balance.

Whitehurst's balances were transferred on his death to his successor Joseph Sage, but would have had little further use. Those who required authenticated coin weights would have obtained them during the fourteen years that Whitehurst was in office, and the general deterioration of the coinage and final suspension of minting and transfer to paper money in 1797

already mentioned, would have further reduced interest in coin weights. The decision to institute a complete recoinage after 1815 however, and the necessity for new sovereign weights to replace Whitehurst's guinea weights caused a revival of interest in the post of "Stamper of Weights". The position had in fact in the interim become a sinecure and the intention had been to abolish the post entirely on the death of Joseph Sage, but instead it was offered to and accepted by John Field, in addition to the position of Weigher and Teller which he already held. (28).

One of Field's first tasks was to prepare a new set of Standard Weights to the new official "least current weights" which had been authorised in 1821 at "Five penny weights two grains and a half" for the Sovereign" and "Two penny weights Thirteen grains and one eighth" for the ½ sovereign, (7.962g and 3.973g respectively). Field considered the apparatus he had inherited inadequate for the greatly increased amount of work now required. The old balances needed constant checking and maintenance and were slow in operation. As they were by this time nearly fifty years old replacements were obviously needed. Field's own account of how he came to be involved in the re-equipping of the Mint with new scales and weights fortunately survives in the evidence he gave to the Select Committee in 1837, (29) and has been briefly mentioned in the previous chapter. The practical results of his efforts greatly benefitted the work of the Mint, and he was highly regarded by his employers. This extract from his evidence will explain his position:-

> "In 1815 I received an allowance for the care of adjusting and examining the balances, &c., which arose from my having for some years applied myself to mechanics, as an amusement, and the Master of the Mint considered it would be a greater public advantage that the scales and weights should be adjusted and cleaned by some one attached to the department, rather than by a scale-maker out of the Mint, who might not be always home to render the immediate assistance often necessary, and therefore requested me to undertake it, which I did, at the reduced charge of 10s. each importation and delivery of bullion and coin, instead of 18s., the sum charged by the scale-maker;...."

"You have introduced several improvements in your department, will you have the goodness to state what they are?" - "The first was in the year 1818, a beam on a new principle, which, by actual experiment shows a saving of one-third of the time formerly required, and, by being more accurate, avoids disputes in the reweighings, as they always agree with the original weight, which was never the case with the old beams, they always varied considerably, from five pennyweights to ten penny weights in a draft."

"What has been the effect of this improved balance?" - "A saving of considerable time, at least one-third, both to the public and to the Mint officers, and an actual saving of precious metal, by its accuracy, compared with the Bank scales, making an average difference of from one pennyweight to 25 in the draft; which with the difference partly of the Bank not weighing so close formerly as they do now, a large sum has accrued to the public; I allude to the double weighing, which I proposed in order that this surplus weight be brought to the public account, and which in six years gained 1,CCO£. to the advantage of the public, and is still going on."

It is apparent from his account that Field had ample opportunity for observing the weak points in the design of Whitehurst's instruments. His own designs as seen in the two surviving examples are an interesting mixture of traditional ideas and some inovations. It is possible that several other scales may also have been made by Field which no longer survive, but the quality of the two remaining examples is undeniable, and is bourne out by the fact that not until the 1850's do any other new balances appear to have been brought into use at the Mint.(29b). The simpler of these two surviving balances is signed

"John Field fecit. His Majesties Mint" (30)

The more elaborate balance, of considerably greater capacity is inscribed

"Balance invented and made for His Majesties Mint by John Field Stamper of Weights 1826". (31)

As these two balances are examples of the work of a skilled instrument maker designing purely for his own use and convenience it is of interest to see that although the by now obligatory glass case is present, the large commodius drawer has vanished.

The former contains no drawers at all, and the latter two

shallow trays about ½" deep at the front of the case, and small sliding drawer at the back. These small drawers perform a totally different function from that associated with the drawer of the traditional pillar balance. In Field's balance they only are fitted only to hold accessories, in this case a surviving pair of spare 'J's' from which the pans could be hung, and no doubt originally other useful small items. The weights which are also extant and may be the originals, have their own separate fitted box and there is now no provision for placing each tiny weight in its own slot in a fixed drawer where it would be subject to corrosion and damage. In a separate box they were further protected from fumes, accidental spillage and loss. With the finer quality and more sensitive scale comes also a greater awareness of the need for obtaining and maintaining good quality weights. This was especially true of the work of John Field at the Mint. His job in fact depended on the accuracy of his weighing, which in turn depended on his tools; but the need for accuracy was equally applicable to the many other assayers, mineral analyists and chemists working both in the late eighteenth century and the nineteenth century weights took on an independent importance. It was realised too that the scale could no longer be both easily packed and highly accurate. As was pointed out with dispensing balances, the size of the case constricted the design of the contents considerably. In those establishments where sensitivity was paramount in a balance, convenience of transporation had to be foregone. Once a settled place of work became both desirable to the user and necessary to the balance the large fitted drawer was redundant. Its place was taken either by one or two very small drawers for accessories, spare pans, spare arrestment knob, etc., or it vanished completely. The customer decided which pattern was the more convenient, and chose accordingly.

Judging by surviving examples, the customer in the main chose the convenience of a small drawer or two as a catchall for odds and ends, spares, replacements and alternative fitments (such as a pan for hydrostatic work), but not for the weights. These in their own small fitted box could be, and no doubt frequently were, removed completely from the

workshop at night. If the drawer was now too small to take the weight box, as often happened, the weight box could always be slid into the case in which the beam hung. It was convenient, there was space, and for the security conscious, locks appeared on some balance cases. On a glass fronted object, these locks could hardly deter theft, but they could prevent unauthorised use by clumsy apprentices. The status of the balance and its user can be seen to be increasing with the accepted need for careful handling of this apparently simple mechanism. Further security was sometimes provided by hiding the keyhole behind a piece of the wooden case front which must first be found and then slid aside. The drawers too sometimes require a simple release mechanism to be operated before they can be opened, since the drawers themselves seldom lock. One balance (32) exists in which holes have at some stage been drilled through the floor of the case into the fabric of the drawers beneath. A large nail dropped into each hole effectively prevents the drawer from being opened until the lockable front is raised and the nail lifted out. It can be seen that the case for the beam which had once been only a desirable extra had, by the late eighteenth century, become more important to certain users than convenience of transportation. By the end of the century only those miniature scales designed for the geologist working on site under difficult conditions are provided with facilities for dismantling and packing the complete scale into a fitted box (33) and even here the 'box' is not the drawer, but the back wall of the case itself. The diminished importance of the fitted drawer was further encouraged by new beam arrestment designs which did not lend themselves to easy dismantling. It is not now possible to decide whether the new designs took advantage of a declining need, but certainly the two could not co-exist and the presence of one usually ensures the absence of the other.

The traditional method of raising and lowering the scale beam, where this was attempted at all, was by pulling a cord which was itself attached to a weighted object. Sometimes this object was a piece of metal shaped like a dog or a lion with one smooth under surface. More often the cord was attached to a weight shaped like an inverted small flower pot

which fitted snugly into the hand. Such a simple device could raise the entire scale and its pans a short distance from the working surface. This would enable the beam to dip, and any lack of balance to be clearly seen. If this simple device was lacking, it was necessary to cut short the strings that held these pans, so that even when the instrument was at rest they hung clear of the work surface. This in turn aggravated the degree of wear on the instrument particularly of the centre knife turning in its steel housing, and some form of arrestment was considered desirable. A device which avoided elaborate pulley systems was possibly a desirable alternative.

The success and popularity of the pulley and string arrestment system described by sixteenth century writers such as Agricola can be judged by the fact that systems of similar type were still being made and sold in the late nineteenth century. This was not because no other system had been devised. As will be shown, alternatives became increasingly available from the late eighteenth century onwards. The continued manufacture of an old system over so long a period can only suggest considerable popularity based on many generations of satisfactory usage. The system had much to commend it. It enabled a hand held scale to be converted into a more stable and sensitive object with a minimum of difficulty. The grip of the fingers of the operators' hand could be replaced by a pin driven through the same piece of metal attaching it to a metal bar over which the string could pass by a series of pulleys either down the back of the sectional pillar or via an attachment to the roof of the balance case to a weighed control knob. Most manufactured balances of this type used the pin as a convenient device to enable the owner to dismantle and pack his scale in the drawer or even to use it as a hand scale if required. The reverse of this sytem, the conversion of an existing hand scale into a free hanging beam can be assumed to have occurred many times over the centuries as the requirements of the owner altered. There does however, survive at the Assay Office in Edinburgh (34) an early assay balance which may be a surviving example of a duel purpose. The steel beam of the balance with its swan neck ends and upwards pointer is raised by a pulley towards the roof of the mahogany case. The

weight in this case is a brass model of a sleeping dog. The mechanism could well have been installed when the beam was already far from new, and there is no sign of any pillar ever having been set up in the case. The beam is attached to a square sectioned tube which slides up into another similar tube when the beam is raised. Beam and mechanism may in fact be contemporary and both may date from the eighteenth century. Even if the beam was given a new lease of life in this way during the nineteenth century it represents a deliberate attempt on the part of the Chief Assayer or his instrument maker to make the balance a more permanent fixture in its case. Like John Field in London, the unknown designer had tried to contrive ease of transporation and stability.

At the other end of the time scale during which assay balances of this type are found to exist, can be placed two assay balances made by De Graves, (35) in the second half of the nineteenth century. Both balances have a simple large drawer fitted to take the section of the balance, and the example in the Science Museum collection is also designed to slide fully assembled on its base board forward in the case, or even completely out and clear of it. This feature is also found in other examples (36) of assay balances, and perhaps was a method of providing closer control over the manipulation of the balance for the operator such as would have been usual with a hand balance. The design of the two De Grave balances however, is such that it is no longer possible to use them as hand held scales as the beam no longer turns in a ring of metal which could be hand held. Both balances still have an arrestment worked by a weighted cord, but no longer does the pull on the cord merely lift the entire scale slightly above ground level. In these two balances the beam which had been "resting" on two metal arms attached to the centre pillar, the arms ornamented with scrolls in one case, is lifted by a rising plane clear of the rests, the upwards pointer indicating the degree of balance. They can no longer be converted into hand held scales. An old device of a weighted cord has been retained, but an "arrestment" in the true sense of the term, where the beam actually "rests" between weighings clear of the centre plane, and irrespective of the length of the chain or thread holding

the pans, has been introduced.

The disadvantages of the simple string and pulley arrestment system have already been indicated in the previous chapter. These and other similar devices found in dispensing scales and operated by levers were at the base of the pillar, were difficult to operate with perfect smoothness, and the jarring of the mechanism would cause undue wear on the knife edge and an unreliable result. John Field's definition of an unreliable balance as indicated in his evidence was one that would not give the same reading twice when a load was double checked, and this was one of the irritations which prompted him to design a more reliable scale for his own use. His solution to the problem of uneven arrestment was to replace string and pulley by a push lever. Pushing down on this lever set in the lower front face of the case well away from the pillar and in the centre of the panel normally filled by a drawer, caused by a simple see-saw action twin pillars to be forced up in parallel inside the case, carrying with them the steel plane on which the beam, previously at 'rest' could sit. This device of sliding a pillar inside another pillar which had been used in France at the end of the eighteenth century (37) had advantages beyond the essential need of making a smooth collision between knife and plane. It also enabled the case to be entirely closed when the beam was in use. Any device operating above the base board of the balance whether by lever or string demands that some small opening be left for the mechanism to pass. By dispensing with the large drawer Field was able totally to close the case, an advantage he must have considered vitally necessary in his ground floor office which he stated was damp, draughty and bad for his rheumatism (38). He provided for side and back opening to the case. This replaced the loss of accessibility which had only been overdome in the designs previously mentioned by making it possible for the whole balance to slide forward in its case.

The distance which the balance was set back from the front edge of the case determined the length of the lever operating the plane. A longer lever would require less operating pressure for the same degree of movement than a short one and the whole device could be operated more delicately and

carefully. The fact that only the plane on its supporting pillar (or pillars) would need to be raised and not the entire weight of the balance beam and pans would further encourage a smooth movement, and the weight of the small load could be taken up with minimum jarring on the whole apparatus. One balance made by Field has no beam rest arms as such. In fact the beam is so light that two pieces of V-shaped steel at the centre are sufficient for it to rest in once the plane drops away (30). In Field's other balance (31) however, a slight variation occurs. This balance is altogether a more massive and elaborate structure. The difference in scale and intended load, can be judged from the fact that the smaller and probably earlier design has a beam 29 cm long, while the latter is 40 cm. In this latter balance arm rests were obviously necessary and they are attached to the centre pillar and designed to move downwards when the arrestment mechanism is operated. These lower the beam onto the plane, the reverse of the previous balance. John Field's designs were undoubtedly highly regarded by his employers who supported his unsuccessful request for an increase in superannuation by citing the benefits which he had brought to the Mint, where

> "great improvements have been made in the construction of Balances and Machinery" (39)

After the death of John Field however, in 1843 a problem must have arisen in replacing, probably in the 1850's, some at least of his balances. One of those purchased was the De Grave balance mentioned earlier (35) now in the Science Museum Collection, which like the balances of John Field's own design is a mixture of new and old ideas. Another which is more difficult to date as no information has been found on the manufacturer, bears very close resemblence in its arrestment system, a press lever under the floor raising a plane, to Field's own balance. It is possible that this balance was Field's original inspiration and was used consecutively with his own designs. This suggestion is somewhat supported by the fact that the manufacturer Harbaut may have been French (36).

The French connection with developments in the design of assay balances is tenuous but persistent. It is always very difficult to decide how much of any design innovation is

due to one person, place, event or just a sudden need , when faced with a lack of written evidence. Even the existence of documentary support for originality does not preclude simultaneous innovation in two places, and the existence of a state of war between England and France did not in the late eighteenth century and early nineteenth century prevent the official exchange of information, or prevent travel during periods of truce. It is noticeable however, that although not a great number of assay balances with simple genuine arrestment systems which move only a part of the balance of the type just described in fact survive, half of those which do are from French manufacturers. Even when every allowance has been made for chance of survival it is still a surprisingly large proportion and suggests a definite preference for this design of arrestment among manufacturers abroad, during the late eighteenth century and first decades of the nineteenth century. In England, De Graves were the largest manufacturer of scales of this same period, and they tended to follow the tradition of the hand balance, or the designs common in earlier centuries described in Agricola, and only later in the century did the firm introduce beam "rests" and a proper arrestment system in their products. Although difficult to quantify, French influence is undoubtedly important in this period, and perhaps the earliest surviving examples, and certainly the best documented are the balances made for Lavoisier by Mégnié.

Lavoisier was one of a small but invaluable group of users of scientific instruments who chose to describe their apparatus in print, and give some indication of the construction of certain items and even name manufacturers. This useful trait is of great benefit when trying to establish the purpose for which one type of balance was actually used in place of another and the experiments for which it was considered suitable. This information also helps to prevent too much generalisation across a long time scale. What is acceptable practice in one generation or for one type of experimental work may not necessarily be so at other times; specific statements and even hints may reinforce or counteract assumptions. In the case of Lavoisier not only do his own references to apparatus survive, but also the inventory made of his equipment. From these can be

derived some details of the two balances by Mégnié.(40).

> "Indépendamment de cette forte balance (41),
> j'en ai deux autres, qui sont bennies comme la
> première du laboratoire, l'une pése jusque' à 18
> ou 20 onces, à la précision dué dixième de grain,
> la troisième ne pèse que jusqu' à un gros, et les
> 512e de grain y sont tres sensibles"
>
> "Une autre balance construite par Méyniér l'aîné, [sic]
> pesant junqu' à une livre;
> Une balance d'essai du même auteur ..." (42)

Both these balances are preserved in Paris together with much of Lavoisier's other apparatus. The larger of the two has a steel beam of 50 cms housed in a glass case with two drawers beneath. The arrestment system consists of a vertical shaft inside the centre pillar. As this rises it lifts the plane and raises the beam (43). A diagram of this mechanism (44) shows a long lever pivoted half way up the back of the pillar. The lever for the rest of its length is not connected with the pillar or contained within it but runs parallel down the back of the pillar. The short section beyond the pivot passes inside the pillar to connect with and raise the inside shaft carrying the plane. The bulk of the lever is vertically behind the pillar and is activated by a knob in front of the pillar by sliding it forward and back.

This ingenious device which has really replaced half of Agricola's length of cord by a stiff metal rod is said to be somewhat unstable and difficult to move smoothly into use (45). The beam is provided with two arms on which to 'rest'. Although the photograph supplied by the Museum does not unfortunately show the present state of the arrestment system at all clearly, it does show the magnifying glass which also appears in the diagram. This is at the top of the case and focussed on the pointer tip which passes over a graduated scale. Such care over a precise reading of the pointer suggests that considerable accuracy could be expected from this instrument. Lavoisier's figures suggest that with a capacity of 613 grammes it could turn with .005g. a very high degree of sensitivity, and well entitles it to be described by Daumas as one of the first precision balances ever to have been constructed (45).

Its exact date of manufacture can be established within reasonable limits, even if, unlike the Fortin balance which Lavoisier also owned, it cannot be allocated to an exact year. Daumas has established the existence of two manufacturers named Mégnié in the late eighteenth century and one of Lavoisier's balances was overhauled by them in 1787. It is reasonable to assume that it was one originally made by them and that it had had considerable use by that time which suggests a date of c 1775-80. It cannot now be decided with certainty which balance of the two attributed to Mégnié was made first. The other balance is only half the size of the one just described. This smaller balance (46) is of a size much more in keeping with what is usually regarded as an assay balance. The pans are about 2.5 cm and of glass and hang from simple hooks at the end of the slim beam, but the arrestment system is identical with that of the previous balance, a lever mechanism (47). Its capacity was 3.5 grammes and Lavoisier claimed it was sensitive to .0001 g. which is remarkable. Despite the greater capacity of the larger balance it is included at this point in the survey along with more truly small scale instruments because it was traditionally used in the work done to establish a new system of weights and measures. In this respect it is very similar in function as well as much of its design to the balances of John Field which were also closely concerned with the establishment and maintenance of standard weights. In the case of Field they were specifically for the weighing of coin and coin weights, whereas those of Lavoisier were more concerned with new primary standards. There is, of course, no proof whatever that Lavoisier did not use either or both of these fine balances in his work on chemical analysis at some time. The difficulties of classification of scales by usage have already been referred to, and Lavoisier is a good example of a person of wide and varied interests which altered during his working life. Apparatus originally designed for one task might prove ideal in another field a few years later. What is quite certain however is Lavoisier's own realisation of the importance of a 'good' balance, one that was reliable, accurate and suitable for the work in hand. One suspects that like Field he had suffered from unsuitable or

temperamental instruments. In addition to the balances mentioned he had several others suitable for rough weighing, of considerable capacity, capable of carrying 40 or 50 livres, and even a hand balance. He wrote

> "Mais ce n'est pas encore assez d'avoir d'excellentes balances, il faut les connaître, les avoir étudiées, savoir s'en servir, et l'on n'y parvient que par un long usage et avec beaucoup d'attention." (40)

Lavoisier's view that only long experience would enable the user to get the best out of his instrument, and by implication learn what might be required to make the work easier has an interesting corollary. If this view is correct, then those whose work demanded that they spend long hours using balances were the people most likely to initiate improvements in design, which if incorporated with careful adjustment would produce greater reliability. The vast majority of such users have left no record of their work and practice, but it is noticeable that two other fine small balances of the late eighteenth century and early nineteenth century which survive in Paris can be connected with work of this kind. One is described in the catalogue as

> "... construite per Abraham Bréguet, pour peser les masses de balanciers de chronomètres, (avant 1823...)" (48)

and the other is an assay balance by Gondolfi (49). No dates of possible manufacture are given for this balance, but Gondolfi is also said to have made a brass kilogramme in accordance with the Law of 1795 (50). Both men would appear to have had an interest in very exact weighing and their balances reflect this. The arrestment system of the former is unfortunately now too stiff to operate, but appears to incorporate an early form of pan arrestment and as such is most unusual at this early date. The Gondolfi balance is similar in general appearance to the Mégié. The case is held shut by a 'secret' catch and the arrestment operates on a pull string to lift the plane. These changes in approach to small scale balance design did not remove all other types of scales from the market either in the late eighteenth century or even by the late nineteenth century, but they did offer ideas from which others could draw whose work and livelihood also

depended on weighings that combined speed with accuracy. John Field was typical of those who operated in this area. His approach to his work was recorded in print and serves to illustrate the attitudes of others of similar interests whose opinions were not recorded.

It is obviously not now possible to decide to what extent Field was influenced in his designs by ideas developed abroad, during his lifetime, and still less to decide how far or fast these designs may have spread helped by the fame of Lavoisier's name or by the skills of French immigrants. Field may have considered that he designed purely to suit his own specialised needs without external influence and using skills he had developed as an apprentice under the great Edward Nairne. There is, however, one small incident recorded concerning another skilled balance user which suggests that French influence in the area of balance making was well-known in the early nineteenth century, but that reaction to this influence was somewhat mixed, and not always favourable.

John Johnson 1765-1831 inherited his father's firm as an independent assayer in Maiden Lane in 1781. He built up a thriving business and, as can be seen from the surviving account books of this period, performed each week a very large number of gold and silver assays. His success and reputation is the more notable as the premises were within five minutes walk of the Goldsmith's Hall and Assay Office to which his customers could as easily have taken their work (51). He and his wife, Mary, had a large family and in the normal course of events could have expected to leave the shop increasingly in the care of one of their sons and retire to their new home in Stoke Newington. However, the death of the eldest son in 1807 and in ~~1811~~ 1815 of the next son who had been in the army after Waterloo, forced a change of plan. The third son, Percival Newton Johnson, expressed his intention of setting up his own business in 1817, which as a younger son he would have normally been obliged to do. Unfortunately the fourth son who was then expected to take an increasing share of the work at Maiden Lane preferred instead to emigrate to South America, and the youngest son who had been born in 1807 was not then old enough to begin his

seven year apprenticeship. Percival Norton Johnson (1792-1866) was left in the difficult position of having to postpone his own plans to move to Hatton Garden and an independent career until 1821 when George could begin his apprenticeship to his father and so release his elder brother from being in constant attendance at the family firm. In this rather tense family situation an argument developed regarding equipment. As the profits and prestige of the firm, both of which were substantial, were based on the skill and consistent accuracy of the assays they performed, it was not surprising that Percival's request for new and modern equipment was refused by his more traditionally minded father. John Johnson claimed that higher degrees of accuracy than those traditionally offered by assayers were not wanted by the trade, would not be appreciated and would cause a decline in receipts. According to family tradition which has no reason to invent such an unexpected detail, what Percival wanted to buy was a French designed balance. He did buy it and did in due time move to Hatton Garden founding the firm which later became Johnson & Matthey. However, his father's prediction proved correct. There was resistance among dealers to the greater degrees of accuracy which the new firm offered with the new balance and this, coupled with the longer journey from city to Hatton Garden, caused considerable decline in trade for the junior branch of the firm. This in its turn caused Percival to renew his interest in the development of platinum group metals. From the processing of these metals the fortunes of the new firm eventually derived, but his father's resistance to the new balance had been well founded.

The balance itself still survives. The glass case was shattered when the firms' premises were damaged during the war, and there is now no indication of the name of the manufacturer whose trade card may well have been in the case. The balance does however show many features that would have been familiar both to Lavoisier and to Field, and does not appear to be strikingly different from the traditional scales that John Johnson would have already possessed. It was its reputed accuracy rather than its general appearance which caused anxiety.

John Johnson's reasons for opposing the introduction of

a more accurate balance into his shop was based on many years experience in the assay business. Since no assayer could risk claiming that a higher percentage of precious metal was present in an alloy than would be found to be there if the entire item was smelted and the assay repeated, the tendency was to underestimate the precious metal content. The actual proportion of metal as recovered in later smelting might reasonably be expected to exceed the quantity claimed by the assay by some small but significant amount: the larger the consignment in question the more this small percentage would amount to in actual metal, and this difference represented an additional profit margin to those engaged in metal processing trades. Any small increase confidently claimed by the assayer in the actual precious metal content of a sample would raise the buying price and decrease the profit margin, a move not likely to be popular with merchants. Varying degrees of accuracy in weighing were therefore acceptable to people depending on their occupation. To cater for these diverse standards scales were produced in a variety of designs, but nevertheless within this variety an increasing and persistent trend towards greater accuracy does seem to occur during the first half of the nineteenth century. The balance bought by Percival Johnson and used by him during much of this period embodies a range of design features both old and new. Some features may indeed owe their development to ideas introduced by Continental manufacturers. The whole instrument however, probably represents the limits of accuracy commonly available during the early part of the century and only a fairly radical change of approach towards design of assay balances would alter the expectation or attainment of standards obtained from scales used for small scale work, (later in the century). For this reason Johnson's balance occupies an interesting place in nineteenth century development.

The arrestment system of Johnson's balance (52) is worked by a pull string which passes under the base board of the balance. The original case was damaged beyond repair in 1940, but the presence of grooves along the sides of the base suggests that it was originally intended to slide forwards beyond hinged or sliding doors. The pull string, which has now been replaced

by wire, causes a rod within the centre pillar to lift thus raising the plane until it engages on the centre knife of the beam. Except that the whole of the mechanism is enclosed within the centre pillar, this system is very similar to that found in the earlier Mégnié balances already mentioned, and also the first balance of John Field which was made at about the same time as Johnson's, i.e. c.1820 (53). In addition, as in Field's balance two little disks, in this case of ivory are provided for the pans to rest on when not in use. They are slightly convex and ensure that the pans are raised a little above the floor of the case and do not sway uncontrollably when being loaded. By making the centre of the dome fall directly beneath the hook from which the pan hangs, the pan is encouraged to come to rest perpendicularly beneath the hook. The possibility of this point of contact between pan and hook varying with each weighing or between one arrestment and the next is therefore minimised, as is the wear caused by such friction and the resultant loss of sensitivity. The obvious next development from the stationary pan stabiliser was to develop a system by which the ivory domes could be raised and lowered as well as the beam. This would give the same stability and also enable transfer of load from rested beam to swinging beam to be done more gradually. Although Ramsden and other makers of larger balances with double cone beams did incorporate a moveable pan arrestment system in their balances of the early nineteenth century which will be discussed later, it was not apparently until mid nineteenth century that the idea was developed. Then the pan and beam arrestment were both made controllable by one single knob, and not by two separately operated handles as in Ramden's design. This development and much else that was of great importance to the improvement of small scale weighing techniques was due to George Hogarth Makins. (54) 1815-1893.

Makins had qualified as a surgeon in 1840 (55) and became interested in the preparation of gold for dental work. This had led to an association with Henry Field of the Royal Mint (56). Field had been appointed resident Assayer in 1851 and Queen's Assay Master. The newly a ppointed Master of the Mint Sir John Herschell was concerned to improve the standard of

gold coinage then in circulation. The only satisfactory method that had been devised for the quality control of 22 carat sovereigns and half sovereigns then current, had been to continue the old practice of batch sampling known as the Trial of the Pyx. In practice of course this trial only established whether or not the sample chosen was of equal quality to the original trial plate. These plates were carefully preserved and pieces from them used time and again but the quality of one carefully manufactured plate could prove superior to the quality of the same alloy prepared on a mass production basis. Field was given the task of improving the quality of fineness of the bullion in use, and for this, very accurate assays would be required (56). The difference between an alloy of 22 carat and 23 carat is only 4.16% by weight. Given the very small samples used in assaying and the high s.g. of gold, the difference in actual weight of two alloy samples, which themselves might differ by only a fraction of a carat is very small and demands great experimental skill and a very delicate balance in order that such small tolerances may be observed at all. Until a standard 'pure' plate was obtained there would be doubts about the relative standard of alloys derived from it. It was in this delicate work that Field was assisted by Makins: Makins was commended for the accuracy of his work and it led to his being appointed Assayer of the Bank of England. As his published papers make clear Makins suspected that smelting techniques themselves caused losses of bullion in both quality and quantity (57) and in his efforts to remedy these problems he found himself in need of a good assay balance.

Makins' account given to the Chemical Society in 1854 describes how he first became dissatisfied with assay balances offered for sale in this country (58). He listed the characteristics of the ideal balance; that it should be "constant" i.e. consistent in weighing, that it should be quick, and that it should be "sensible" i.e. sensitive to small changes in weight. He appreciated that these last two requirements were somewhat incompatible since to increase the one by making the balance come to rest rapidly also decreased the other and encouraged it not to register fine degrees of changes in

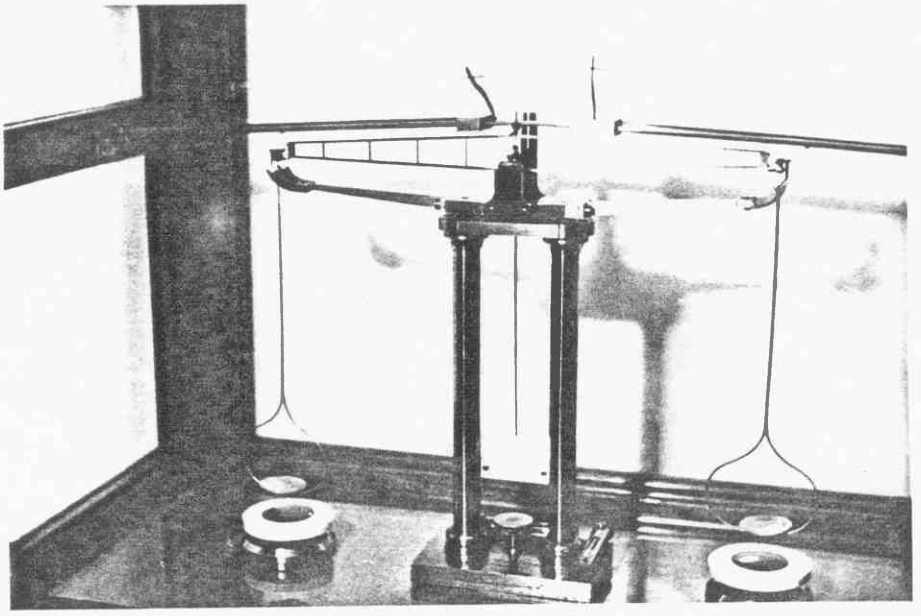


Fig. 3 Oertling Assay

weight. However, assisted by Mr Oertling then a relative new comer to the instrument making trade in London, he designed and built 'An Improved Assay Balance'. So numerous were the improvements, and so totally successful the design that this balance became the prototype for every Assay Balance sold by Oertling's thereafter for high quality work for the next century. They were supplied to Assay Offices in this country and abroad and many are still in use (59).

Makins was anxious to use a very much lighter weight beam in his balance than those commonly in use for assay balances at that time, which then usually consisted of a light steel rod. His lattice beam of brass was so light that any jarring in the arrestment system would have upset so delicate a structure and caused it to become unreliable. He therefore devised a system to overcome this. The twin pillars contain rods which slide up and down within the pillars and carry not the agate centre plane which remains stationary, but the arm rests for the beam.

> "The movement lever on being depressed, first, however, acts upon the arms of two rollers which are fixed under the lantern" [i.e. the base board on which the pillars are mounted]"and whose opposite arms depress the ivory tables which support the pans, this roller action is particularly free and pleasant in use. By the time the tables are well away, the lever has reached a connecting stirrup between movement rods and begins to drop the beam upon the agates."

Once the weighing is completed, or the amount of change in the weights required roughly determined, the whole instrument can be arrested by reversing the lever. This lifts the beam off the agates smoothly and also stabilises the dished pans which if they should swing will be caught by the concave upper surface of the ivory pan rests. (60).

This ingenious system of arrestment became common to all good balances for chemical or assay work by the end of the century Many variations occurred. The lever was sometimes replaced by a turn knob and the beam could be designed to allow the centre plane to be raised to meet the knife rather than the knife be lowered. The balance itself remains a remarkable achievement and a further example of a design first produced to meet a

specific need, and then later influencing over many decades many other instruments quite outside its field.

Undoubtedly Makins had good reason to be well satisfied with the quality of the assay balance which he had designed with the acknowledged assistance of Oertling. No doubt other members of the Chemical Society to whom he demonstrated the new balance in 1854 were equally impressed. The lattice work beam was ...

> "10 inches long, ½ an inch deep at the fulcrum tapering off to ⅓ at each end. It is about 1/16 of an inch thick at the centre, decreasing in the same way to 1/20 of an inch. As little metal as possible is left in it;" (61)

This "skeleton beam" as Makins calls it, appears to have been a new idea when applied exclusively to assay balances, despite its existence as a design feature in the chemical balances made by Robinson. The arrestment system Makins describes however, with the pans arresters dropping down just before the central fulcrum and centre plane moved to meet with a minimum of force, may have already been a design feature of existing Oertling balances. One Oertling assay balance from this early period survives and is now preserved in the Royal Scottish Museum (62). It was traditionally purchased by Johnson and Matthey for use in their bullion and assay business at or just after the 1851 Exhibition at which both firms had exhibited. It was no doubt used to replace the now outdated balance that Johnson himself had bought c.1820. This Oertling Assay balance has a solid brass beam, but the arrestment system is very similar to that employed in Makins' design. The balance was used by Johnson and Matthey for many years and would have been kept in first class order. It is unlikely that so radical an alteration as installing a new arrestment system would have been contemplated, or done without leaving any sign on the case work itself. If this arrestment system is therefore the original, balances with this feature were offered for sale by Oertling before 1854. The actual assay balance which Oertling exhibited in 1851 has not been traced and may indeed not survive, leaving the Johnson and Matthey balance as the oldest assay balance by Oertling in existance, whose date can be established with

reasonable accuracy (63). The amalgamation of design features, both the innovatory ideas from Makins and the items available from stock designs by Oertling, would seem the most likely origin for the new assay balance of 1854. A catalogue issued by Oertling between the period 1849-54 (64) does mention for one design of balance that a system could be provided,

> "with apparatus for steadying the pans connected with the same axis which moves the beam, so that one movement first releases the pans and then the beam"

This optional extra raised the cost of the balance for which it was designed, a 16" chemical balance, from £15.0.0. to £16.16.0, and one cannot assume that many of these were purchased. The only assay balance specifically mentioned in this very modest catalogue does not describe its arrestment system at all, nor unfortunately did the Jury of the 1851 Exhibition who praised Mr Oertling's workmanship but gave few details of construction of his instrument. The catalogue does however state that the assay balance also had agate knives both at the fulcrum and from which to hang the pans, and the Johnson and Matthey assay balance is of this type. It is notable that Johnson's original balance also had agate planes a remarkable circumstance for such an early instrument and the introduction of agate will be discussed later. Makins in his design however, while using agate for the centre plane, the agate slightly domed to make a minimum area of contact with the knife, preferred the pans to be suspended from supports terminating in two steel needle points. This stress on system that involved a minimum area of contact between points would help to reduce the possible friction that would be created by a larger though non-corrodable agate edge.

Like all designers, Makins' attempted to select from a group of possible design features, some by their presence automatically excluded others, those features that were the most essential in promoting his declared aims of constancy, accuracy and reasonable speed. The extremely long life of his fundamental design which with only minor changes remains in use to the present day, suggests the priorities he established were those which assayers in all branches of the industry considered important. The Makins balance was expensive. It first

appears in an Oertling catalogue of the mid 1860's (65) at £25.0.0. a considerable sum. (It is substantially dearer than all the other chemical and assay balances then offered, whose average price was £10.00 and only the massive bullion balances with beams of 30" and upwards were more expensive). It is a measure of ~~the~~ its success that of all the assay balances included in this survey two fifths are of this design with only slight modifications. The 10" Makins beam became the 6" short beam once the development of the short beam balance pioneered by Bunge in 1866 (66) began to affect designs for all types of balance work. The centre steel knife of the Makins fulcrum was replaced by an entirely agate based system. The centre knife in later models is usually a sliver of agate set in a stronger brass mounting leaving exposed only one corner of a knife of triangular cross section. The pans however, are hung from flakes of agate drilled to take the hooks of the suspended pan but containing no other metal parts. The total amount of weight these pans would be expected to carry would be so small that this fragile mounting would be sufficient, and Makins claim of a maximum load requirement of 25 grains (1.625g) remains undisputed in later catalogues showing this type of assay balance.

The length of the beam chosen for the original model was 10" and it is noticeable that the vast majority of assay balances before the development of short beam designs had beams that were either 8" or 10". Those with beams greatly in excess of these lengths of c 20 cm. or c 25 cm are almost invariably found on balances designed not for pure assay work but for weighing of bullion, coin or for weights and measures estimations. The balances by Mégnié and Field come into this category. The aim was obviously not to produce a bar of any greater length than was essential for the beam. More length would mean more weight and greater inertia to be overcome by a very small load and would tend to promote inaccuracy. Too short a beam on the other hand would not be easily affected by small differences in load and would again cause problems. The pans could be kept to a very small size, not usually exceeding 4 cm. diam. with sizes of 1 - 1½" being quite usual. Such tiny pans saved weight and wear on the fulcrum, but could not easily be hung from the

traditional three strands of silk thread often employed in balances designed to be packed into a box. This thread which was easily tangled by the close proximity of the three strands was replaced sometimes by fine platinum wire formed into delicate chains, or more usually in the latter half of the century by a single metal strip terminating in a stirrup with the pan set in its base. The rigid bow of the stirrup made room for the operator to place sample with a scoop into the pan without undue difficulty. So consistent was the general size and shape of the assay balance throughout this entire period however, that little change took place in the length of many of the components. The pan hangers just mentioned tend to be about 6"-7" long. This enables them to hang from a beam which rests on a plane set in a pillar about 20 cm or 8" high. When the Johnson balance of c 1820 previously mentioned was recovered from the firms damaged premises in Hatton Garden, the case was naturally destroyed, and the pans were lost. Rather than leave the balance incomplete in its new case, a pair of pans and hangers from a (relatively) modern 12 s.b. balance were suspended from the ends of the old steel beam. They fitted "as if they had been made for it" (67). Like assaying itself, change is a very slow process in the assay balance. Beams made of steel remained popular throughout much of this period, and it was really only the development and subsequent popularity of Makins "skeleton beam" of brass that changed this situation. Nearly half of the balances seen had steel beams of the plain light rod type, terminating in either a swan neck end, or a 'boxed' end. With a boxed beam the end fastening for the pans is fixed permanently through both pan loop and beam and "boxed" in; an alternative was a beam with a two pronged fork end, where the pan hangs from a thin wire joining the two prongs. Whatever the end fastening of the pans may be, the vast majority of the steel beam balances where they have any kind of centre plane still also turn on steel, and the pans are hung from steel hooks. Against this almost total uniformity the Johnson balance of c 1820 stands out with its agate centre plane.

The introduction of agate and the replacement of steel by brass for beam construction both appear to take place concurrently and at an increasing rate from the late 1840's

onwards. The fact that these two events seem to occur simultaneously may indicate nothing more than the fact that it is easier to set a brittle substance like agate into a relatively soft material such as brass rather than into a hard material like iron. The move from a solid steel beam to a solid brass beam and so eventually to a lattice beam of brass may also indicate improved supplies of good quality brass suitable for fine machining. The move to brass and agate purely as a method of avoiding corrosion does not appear to have been of paramount importance to assayers. Despite the unpleasant and corrosive fumes of oxides of nitrogen emitted when silver is being parted from gold by boiling in hot and concentrated nitric acid, the samples of metal being processed are small, the furnace provides a constant upwards draught, and the precious balance is enclosed in its glass case. When Oertling recommends in his 1860's catalogue that

> "the three edges of the beam are made of agate, so that all the working parts of the instrument are most effectively protected against the fumes of the laboratory, or the effects of a damp climate ..."(65)

the item he is selling is a chemical balance. Assay balances were offered with agate systems, but this selling point was not mentioned. Other considerations were more important it would seem, and chief among those must have been the consideration of sensitivity. Makins despite his detailed description of his new balance, never in fact states how finely it could weigh; the first mention of it in a catalogue speaks of 1/1000 grain(.00006g) and the importance of this factor must now be considered.

The sensitivity of a balance is defined as the ratio between the change in position of the rest point of the pointer moving over a finely divided scale, and the change in mass which induced this change. The smaller the units involved the greater the sensitivity of the balance. In describing the performance of a balance it is usual to make some reference to sensitivity, describing it as perhaps "0.1 mg", implying that that unit of mass will cause a change in rest point of one division on the type of graduated scale in use (68) on that instrument. Various factors affect sensitivity. A heavy beam will be less sensitive than a light one. The greater mass of metal

to be moved will produce greater inertia to be overcome and very small changes in weight may not register. Unfortunately, a very light beam may itself distort slightly when well loaded and the sensitivity may therefore vary with load, and not be a constant factor. Sensitivity is also affected by the centre of gravity of the beam. Provision is often made to adjust the centre of gravity of a beam artificially. Where the centre of mass of the beam is either by virtue of the design of the beam or by adjusting a weight attached to the vertical centre of the beam well below the central line passing through the beam horizontally, the balance will come to rest more quickly than if the centre of mass nearly corresponds to the actual centre of the beam. As Makins remarked, speed and sensitivity tend to be mutually exclusive in a balance. That which promotes the one reduces the other. The degree of sensitivity in a balance is an important consideration to the user, but is of no practical advantage if the accuracy of the instrument is an unknown factor. Many influences affect a balances accuracy, including the temperature and humidity of its surroundings. Nowadays, one is advised to leave an instrument after adjusting it for a considerable time, even several hours to allow everything to settle down (69). The degree of maintenance or lack of it, and the amount of unskilled use an instrument has received will also affect it. The accuracy of the adjustment of beam length, of knives, centre of mass, the weight of pans and their hangers, the quality of the weights themselves should all be taken into consideration when calculating the accuracy of a balance. The application of these desirable standards must however be undertaken with moderation on old instruments. Too fine a degree of discrimination made between the standard found in one instrument and that found in another in the same collection may produce theories based on apparent differences in quality between one balance and the next, which have far more to do with their often totally unknown past history than with the wishes or aspirations of their manufacturer or user. Within reasonable limits however, some general estimations of standards can be observed.

Of the assay balances covered in this survey about 3/5 were in sufficiently good order for some estimation of their

sensitivity to be established. Since the tendency is for balances to reach museums collections only at the end of a considerable period of use, it is not surprising that some were found to be incomplete or the arrestment mechanism too stiff for any estimation to be made. Those in reasonable working order, and this includes a fair number of instruments still in daily use, were found to divide themselves into two main groups, those manufactured before the mid nineteenth century and those produced later. The sensitivity of the earlier group was such that masses of 0.005 gramme would produce some degree of movement of the beam as seen by the pointer deflection in nearly all of them. As all the balances in this first group were in museum collections and had frequently been stored for very considerable periods often under indifferent conditions, they would have required considerable adjustment to give of their best. These figures could be taken as the minimum obtainable using the balance exactly "as found", and making no allowance for the often very considerable wear and tear to which the knives had been exposed in a long working life. No attempt could be made in the very limited time available to determine the number of divisions of scale over which small known masses might cause movement. Even had time been available, this exercise would have been unrewarding as it would have assumed a degree of accuracy under load in the instrument which was not in fact verified. These figures reflect, though imperfectly, the state in which the last user chose to operate his balance. Since sensitivity can be adjusted by movement of weighed finials frequently provided by the manufacturer, it is quite possible for many of these instruments to be reset to produce different degrees of sensitivity depending on the needs of the user. Faced with so many variables and so many unknown factors one can only conclude that a sensitivity of the order suggested would appear to be the one acceptable to users of assay balances from the last quarter of the eighteenth century until about the middle of the nineteenth century.

This group of instruments includes two used at the Royal Mint, one being made by Field, two formerly used in the Assay Office in Edinburgh, as well as the larger of the two instruments made by Mégnié for Lavoisier and also that purchased by

Percival Johnson for his new business. The second group of balances exhibits a marked change in estimated sensitivity however and the possible causes of this change are of interest. In many respects determining the sensitivity of the assay balances manufactured during the second half of the century is an easier task. The vast majority of these were made by the firm of Oertling and his catalogues for this later period contain fairly full descriptions of his firms products. As has been mentioned, several designs of assay balance were produced based on Makins original pattern of 1853 and the descendants of this balance remained in production and in use over a very long period.

A typical description from the catalogue of 1891 (70) describes the 12 s.b.a. as a

> "Balance with 6" horizontal beam, divided into one hundred parts; to carry 2 grammes in each pan and turn with 0.01 milligramme ..."

The original Makins design had been first advertised as turning at 1/1000 of a grain or .00006 g. Since the 1850's his design had been modified slightly and converted to a short beam the "12 s.b.a" with somewhat greater sensitivity; the really marked change is from the sensitivity of about .005g in balances pre 1850 to one of .00005g shortly after. In addition, the 1891 catalogue offers another superior assay balance. One balance of this pattern is preserved in the Birmingham Assay Office to whom it was supplied in 1894.

> "... with 6" horizontal beam to carry 1 gramme in each pan and turn with 0.005 milligramme ..." (70) (0.000005g)

The popularity of these late assay balances as shown by the considerable numbers surviving suggests that this degree of sensitivity was required by purchasers, and that the balances were also found to be reliable and accurate in use over long periods. It would be convenient to suggest that greater technical skill was developed during the latter half of the century by balance makers and this suddenly enabled assayers to have an instrument to a new standard which had never before been available. Undoubtedly technical innovation played a considerable part in producing high quality instruments during this later period but this cannot be the complete answer.

Mention has been made of the two balances made for Lavoisier by Mégnié in the last quarter of the eighteenth century. Lavoisier was particularly pleased with their performance. One would weigh

> "jusqu' à 18 ou 20 onces, à la précision du dixième de grain." the other ..."ne pèse que jusqu' à un gros, et les 512es de grain y sonts très sensibles ..." (71)

This gives a sensitivity for the former of .005g, but for the latter of .0001g. If such figures could be obtained at this early date, and there is no reason to doubt Lavoisier's account, and if as will be mentioned later T.C. Robinson could offer for sale balances in the second quarter of the nineteenth century which

"will indicate 0.001 of a grain with 1000 grain" (72)

it would seem that technical expertise was available at an earlier date than surviving assay balances would suggest, and greater degrees of sensitivity than .005g were available if required. The majority of the assay balances covered by by this survey can be confidentially ascribed to a particular manufacturer or purchaser or to a large organisation, and in every case the reputation for quality of work linked with that name is beyond dispute. If the majority of those using assay balances did not require a higher standard in the early part of the century, they must have considered the instrument they used to be adequate. The successful manufacturer was giving the customer what the customer required, and those requirements apparently changed fairly suddenly and dramatically in mid century. Since assaying is a very traditional art relying for its status on its unvarying standards of quality, any change in attitude to the standards of the instruments used would not be the result of passing fashion but carefully considered need. Any suggestions of the causes of change in requirements must be seen against the background of what exactly was being weighed and for what purpose in the normal course of events during the first part of the nineteenth century, by all groups of users of small scale balances.

Any instrument designed for determining the weight of a substance is produced with the requirements of the customer in mind. This is true of the whole range of manufactured

goods, and however much the customer may be encouraged to match his requirements to the convenience of the designer, long term trends persist and can be recognised in sales records or surviving artifacts.

The availability of new materials and the introduction of new machinery will influence the components of the product. Changes in product performance however, which eventually affect the majority of products purchased in any one field, suggest that despite the range of individual requirements being catered for by a wide range of models, a majority of customers found the change in performance valuable, whether or not they personally were responsible for initiating this change. The converse is equally true, that a lack of any basic change in a product suggests that existing designs satisfy all requirements. It does not follow that such unchanging patterns represent a moribund industry or unenterprizing purchasers. The vast range of materials and finishes in which the ordinary domestic teapot is now available do not disguise the common features of its design which has seen few changes over a very long period, and despite the introduction of the ubiquitous tea bag. Small scale weighing instruments of the eighteenth - nineteenth century contain both designs in which very little change in sensitivity occurred over a long period, and also instances where a very marked change occurred, and persisted to the gradual exclusion of other patterns. The reasons that will be suggested for these events also throw some light on the practice of weighing during the nineteenth century.

A small number of dispensing scales have been covered in this survey and their basic features already discussed. Very little change took place in their design during this period and both free standing and hand held patterns continued to be used throughout the century, even though the use of such designs by groups other than dispensers gradually declined. The sensitivity of the dispensing balance where this can be determined from surviving examples is lower than that for other groups and this is to be expected. This sensitivity tends to lie in the region of .3 grammes. As many dispensing scales do not have graduated ivory scales over which a pointer may move, these sensitivities were determined by establishing very roughly the minimum weight which would overcome the often considerable

inertia to be found in an old and sometimes poorly maintained steel beam. Beam movement as has been suggested does not imply accuracy in the instrument, nor does it do more than reflect the probable original sensitivity of the scale; it gives a lowest common denominator at best. When this figure of .3 grammes is converted into grains however, the units which along with scruples and drachms were those with which the scale was designed to be used, it suggests that sensitivities down to 5 grains, (a quarter of a scruple or better) could easily be obtained. It seems unlikely that masses of solid material medica of less than 5 grains (.3g) would be required in dispensing. If a batch of pills was prescribed, manageable quantities of the ingredients would be needed as these had first to be mixed and compressed with a pestle and mortar before being divided into convenient units and coated (73). Grain weights as well as weights marked in units of scruples and drachms are found associated with dispensing scales, (74) and as has been mentioned these grain weights would have been of benefit enabling the dispenser to check the quality of the gold and silver coinage he was offered. Grain weights of very small denominations do not seem to have been common however, and weights below 1 grain in mass do not seem to have been in use in association with dispensing scales (75). Against this background the balance purchased by Beale in 1847 described earlier designed which would "turn with 1/50 of a grain" (76) must be seen as an exception.

The Beale balance is in general appearance a traditional dispensing scale. It can be packed away into a fitted drawer and is operated by a simple press lever which raises the steel plane and lifts the beam and its pans in one movement. It does have a graduated scale over which the pointer can travel unlike some scales where only a mid point is marked against which the pointer must be lined up. As the manufacturer of this scale, Oertling also offered in his same catalogue sets of grain weights covering the range 600 gr to 1/100 grain for £1.10.0. in addition to more extensive sets, there was no question of 1/50 of a grain being too small a unit of mass to be conveniently weighed out on a scale of this period. Had the scale not in fact been capable of turning at 1/50 gr. as claimed, this fact

would have been easily realised, but in fact this particular design persists for several decades in Oertling catalogues. If this relatively high degree of sensitivity compared to that found in other dispensing scales could be easily provided, one must assume that other dispensers did not require this standard, and not that the standard was not available. The difference between an average sensitivity of 5 grains and 1/50 grains is considerable and Mr Beale no doubt had good reason for selecting the higher one. It suggests that a greater range of analytical work was undertaken on his premises than was usual for a general dispensing chemist. The scale itself is not specifically described as suitable for dispensing by the manufacturer who never specialised in this type of work, but its existence does show that a wide range of requirements could be met by manufacturers of scales and balances, though the majority of dispensing chemists did not require a sensitivity of less than one grain, five grains being a more usual minimum measure.

A similar range of considerations also concerned those whose primary concern was the selling of gold, diamonds or other stones. Because the specification of the scales used by both groups was similar, almost identical designs could be used, and only a clear indication of the provenance of an object enables some scales to be clearly categorised into dispensing or jewellers scales. The sensitivity of the group of small scales not apparently associated with dispensing and datable to the first half of the nineteenth century or earlier is in the region of .005g and may be presumed to have been marginally better when the instruments were first made and in good order. This is substantially higher than that required by the majority of dispensing scales at .3g, but not as high as the Beale balance of the mid-1840's, (at .001g), nor the chemical balances made during the preceding twenty years by T.C. Robinson nor the small assay balance made for Lavoisier by Megnie in the late eighteenth century. Again a definite requirement by purchasers must have been the consideration here rather than a limitation in design capability preventing goldsmiths and jewellers from obtaining higher sensitivities had they wanted them.

The balances used by goldsmiths and jewellers were not intended to be used with gramme weights. A system of weights based on carats, grains and Troy ounces was the one commonly in use in the nineteenth century and remained in use well into the present century (77). Diamonds and other precious stones were and are bought and sold by weight and this weight was measured in carats. The correlation of the mass of a carat with that of a gramme varied during the nineteenth century, as undoubtedly had the relationship between the carat and the grain in previous centuries. These figures also varied from country to country, and attempts to get a more uniform system did not really materialise until the "metric carat" (= .2g) was adopted internationally in 1932 (78). Before that time 205-206 mg was a more usual figure (79). A box of carat weights made in the late 1850's (80) comprises a set of specific carat units and fractions of a carat. Its contents exactly bear out the statement made at the end of the century that,

> "The Fractions of the carat used in weighing precious stones are $\frac{1}{2}$, $\frac{1}{4}$, etc., down to 1/64, smaller fractions than these being neglected" (81)

If these carat fractions are converted into grammes using the heavier pre-metric conversion rate, an interesting pattern emerges. The two smallest required carat weights, the 1/32c and the 1/64c becoming approximately equal to .006g and .003g respectively. Any balance with a sensitivity at present in the range of .005g would almost certainly have proved when new, capable of registering these small changes of units of carat satisfactorily, and the selection of this particular degree of sensitivity becomes a matter not of chance or availability but deliberate choice (82). Three quarters of the pre-1850 assay balances covered in this survey fell into this category. The use of the carat remained unchanged throughout the century, but despite this the sensitivity of goldsmith's balances underwent a considerable change in the second half of the century producing a new range of balances with a sensitivity far in excess of that required by diamond merchants and probably caused by changes in the requirements of the assayers.

The requirements of an assayers' balance differed somewhat

from those required of a balance used solely for the buying and selling of precious stones or gold bullion. An establishment engaging in all branches of the gold trade would probably invest in a range of balances with different capacities and sensitivites just as Agricola had advised in the sixteenth century. The assaying of any ore involves determining the proportion by weight of any metals contained in it. The assaying of gold and silver is concerned to establish the proportion of base metal to precious metal which circumscribes the range over which the balance must be accurate. The results of this type of assay could be expected to fall within certain traditional limits. Both types of assay however depended on establishing the ratio of the metal selected for testing to the rest of the sample. The actual weight to be determined at the end of the assay would depend not only on the quality of the sample, but also the size of the sample originally taken.

The assay of precious metals for the purposes of granting a hallmark to the item in question must take into consideration the degree of damage likely to be done to the object by removing a large sample of metal from it. For this reason a small sample would be preferred. In the case of silver it was well-known that the traditional method of fine assay using a cupel was prone to inaccuracies caused by the "spitting" of the metal as it cooled(83)The method developed by Guy Lussac and published by him in 1832 (84) and known as the wet or humid method had much to commend it. Not only was it very much more accurate, it could also be performed with very small samples of metal (1 gramme) and did not require the metal to be wrapped in a supply of sheet lead with a very low and known silver content (85). The new process depended on

> "the precipitation of the silver in the form of an insoluble chloride, and the measurement of the amount of a standard solution of chloride of sodium which is required to effect the complete precipitation of the silver in a given weight of the alloy". (86)

Although Miller in his description assumed that the amount of standard salt solution used should be calculated by weighing the container before and after adding some of the solution to the silver dissolved in nitric acid and Gay-Lussac

gave illustrations depicting a balance adapted to support a burette, in fact volumetric glassware could be used, and the volume of solution calculated from the calibrations in the normal manner. The burette designed by Gay-Lussac for this purpose consisted of a long thin glass U tube, one arm being wider than the other. The wide arm was calibrated and the whole kept upright by being wedged in a wooden stand when not in use. The narrow arm terminated in a narrow nozzle through which the standard solution could be poured. Control was by thumb pressure on the wider arm. The great advantage of this design lay in the fact that any standard liquid could be used in it. There were no metal sections to react with corrosive reagents (87). By 1866 Griffins were devoting ten pages of their extensive catalogue solely to various designs of burettes (88).

The use of calibrated glassware removed the need for any final weighing of the silver sample, as well as reducing the size of the original sample required. The system was adopted by the Mints of France, Britain, America and large parts of Europe by the 1850's (86) and would have had a gradual but significant effect on the demands made on assay balances, stressing the importance of the smaller units of weight and removing the need for any great capacity to be kept in mind when designing the beam. By itself, however, this change could not have accounted for the very considerable move towards much finer sensitivities that occurred in assay work about mid century. An additional move towards finer weighing would have been encouraged by the realisation that volumetric analysis though extremely accurate, is only as good as quality of the "standard" solution employed. "Standard" solutions could be purchased: sodium chloride solution was 2/- per pint (88), but as the dry chemical was 1/6 lb. the inducement to make up ones own standard solution was considerable and helped by accurate weighing. This stock solution would then have to be checked against some silver of known purity.

Another more important move towards fine weighing was due to changes in the use of gold. The purity of gold is

expressed in carats. Completely pure gold is given the value of 24C and all gold alloys are described in terms of the number of twentyfourth parts of pure metal contained in them; hence 18 carat gold contains 18/24ths or $\frac{3}{4}$ gold plus $\frac{1}{4}$ other metals, usually silver and copper. Because completely pure gold is very soft and unsuitable for any degree of wear and tear such as would be experienced by coinage or plate, two standard alloys had been evolved, one for coinage at 22 carat and one for plate and jewellery at 18 carat. Such items were always expensive being "worth their weight" in gold, but despite the convenience of customers being able to trade in the valuable family heirlooms in time of necessity, it was considered by jewellers that a substantial market in cheap jewellery could be opened up if gold of a lower carat rating was made a legal standard. In 1854 three further standards of 15, 12 and 9 carat were introduced, with 9 carat rapidly becoming, and remaining extremely popular (89). In order that nine carat gold, or even lower carat gold could be tested for hallmarking, it was necessary to be able to weigh final assays having only 37.5% of the original weight of the sample. Increasing the size of the sample was not considered desirable, and would also cause further practical problems. The lead foil in which the sample was wrapped had already to be increased in weight to ensure that it was sufficient to absorb all the extra copper present, and sufficient extra silver would also have to be added to encourage the gold to develop a sponge like structure when the silver was finally removed. Any parcel of metal allowed to get too bulky would run into difficulties with the very small scale apparatus commonly used.

The apparatus used for gold assaying has changed very little since the last century. Indeed some of the apparatus currently in use in the London Assay Office was originally purchased in the nineteenth century. This includes the nitric acid boiler into which the parting cups containing the gold cornets are placed. This boiler was made of platinum and has only in part been replaced by glass (90). The present size of gold samples taken is 160 m.g. This apparently somewhat arbitrary figure, if converted to grains = 2.469gr. suggesting that a simple system was originally devised which had been

based on a convenient starting figure. A sample of 2.4 - 2.5 grains was taken to be equivalent to 24 carat, because 2.4gr. would remain after assay. A final weight of 2.2+ gr. would designate 22 carat fine, etc. This convenient system was easily adapted to an increased range of standards; ·9gr. would be the result of an assay of 9 carat gold. The problem would arise in differentiating between one carat (and price) range and the next. The difference between one carat and the next would be only .006 grammes per carat and it was essential that the balance used should indicate changes of weight of this order consistently, and as a minimum requirement. Another decimal place available on the balance in excess of that actually needed is a further advantage. It is understandable that an instrument constantly working at the limits of its range is prone to errors which cannot be detected because there is no means of calibrating them. The balance itself requires some modification before it can extend its range because the problem is not merely one of weighing smaller quantities. There is a physical limit to the size of the weights that the operator can manipulate and place on the scale pan. Platinum wire has always been popular since it was first introduced for this purpose c1820 because of its non-corrosive properties, but platinum also has a high specific gravity and even a short length of thin wire would have too great a mass for the very fine weight differences now required. The most common method employed for registering small units of weight was by calibrating a very finely divided ivory scale over which the pointer passed. The development of the rider however, also gave greatly increased range to balances and became increasingly common from mid-century onwards. Basically, the rider is a length of platinum wire of known mass which can be placed at marked points along the beam. If the beam is divided into ten marked sections, movement of the rider between one mark and the next alters the load by a factor of 1/10th of the rider's total weight. The move from a solid steel beam to a more easily calibrated brass lattice beam was encouraged by the development of the rider. Provided the division of the beam has been made accurately, it becomes possible to weigh down to 1/1000 grain (or .00006g) as claimed by the manufacturers of the period (91).

Such an instrument was always at the top of the price range of balances due to the labour required in such an elaborate design. Similar balances without a rider and relying

for their sensitivity on the reading of the graduated scale were considerably cheaper. However it was achieved, the sensitivity aimed for by a good assay balance in the second half of the century would seem to have been 1/1000 grain and ¾ of those assay balances covered in this survey are in that range. This degree of sensitivity had been available in the eighteenth century. John Whitehurst described his experiments on the effect of heat on gold and iron using a balance of which

> "... the beam used in these experiments was sensibly affected by the 1/2000th part of a grain ..." (92)

Had Whitehurst considered such sensitivity necessary to his later work at the Mint, he would have introduced balances of this range but there is no evidence that he did so. The first real need for change was expressed by George Makins and to this reference has already been made. His need for a very high degree of sensitivity was an outcome of his work with Field at the Mint to establish higher degrees of purity for the "standard" plates from which all other standards for gold and hallmarking ultimately derived. The balance he demonstrated to his fellow members of the Chemical Society in 1853 though designed and made purely for his own researches, arrived on the market at a time when a general need for assays to be more accurately expressed was becoming felt. Much research was being undertaken on analysis of all metal ores at that time, and not into merely the traditional precious metals. The ever increasing search for and exploitation of minerals demanded accurate analysis of all the components of an ore sample, not just the principal metal contained. The damage done by very small quantitites of contaminants to a batch of metal was becoming better understood. Percy devoted a substantial section of his long work on iron and steel to publishing and annotating analyses of British Iron Ores. His advice to those engaged in mining was,

> "never throw anything away ... During the last few years I have known several instances in which ironstones previously rejected as worthless have been found on examination to contain a large amount of iron, and, consequently, to posess considerable value." (93)

In the mid eighteenth century from which period surviving balances can be fairly reliably dated, there is so little real difference between the various types of scales and balances used for small scale weighing that they are often difficult to classify. Such differences as do appear to exist may well be based on hindsight, or a knowledge of the occupation and interests of their owner; on the size of the pans, which may well be replacements; on the claims of some innovators, whose innovations may have never left the stage of being an artists impression. They are differences of degree, but not of kind. By the end of tne nineteenth century however, the change has been considerable. Various groups of instruments are more clearly defined and produced with clear specifications in mind, in the same way that their owners have become grouped, organised and tended by learned Societies. The all purpose balance like the polymath has vanished. The simple pillar balance for dispensing altered little throughout the period. It performed the task for which it was designed with efficiency and a minimum of trouble or maintenance. In this respect it resembles a moorland pony, not elegant but very hardy and requiring little upkeep. The assay balance with its numerous fine adjustments and demand for careful handling if it is to achieve the sensitivities for which it was designed, is by contrast a race horse. The overall impression left by a group of assay balances is of lightness. Every piece of metal has been reduced in diameter to such an extent that the whole has an air of fragility and demands the shelter of its glass case. Assay balances were and are expensive to buy and maintain, demanding constant maintenance to achieve constant performance. Their pedigrees can be traced back many decades through catalogues and some are even adorned with discrete plaques announcing their date of purchase or of presentation by their proud owner. Some may be lent (even permanently) to suitable organisations for display and safe keeping. Many are quietly stored. Very few are ever sold (94).

This degree of attachment to what is after all only a very high quality piece of precision engineering is unexpected. It is perhaps a recognition of the fact that although the assay balance may not have revolutionised the world of science, it has enabled substances to be analysised with a high degree of

certainty. On this knowledge some fortunes and many thriving industries have been based. Quality control by assay is a very old technique. The spread of these techniques first to all minerals with increasing accuracy, and then to an increasing range of pharmaceutical products brought the two ends of this use of analysis back together again. Many techniques now exist other than weighing for the analysis of substances, but the analytical chemist is in one sense the product both of the world of mineral and the world of organic analysis. Control of standards remains paramount to both spheres. Analytical chemistry came to be seen as a branch of the wider study of the chemistry for which many balances were specifically made in quantity and which must now be considered. The regard of the assayer for his tools, has evolved into a regard for the standards of accuracy which the tools enabled him to obtain. These standards moved into other branches of chemistry, and even though the tools became different, the influence remained.

1. Wellcome Collection. ~~Old Inventory No. 193447~~.(2)

2. Assay Office London. No. 10.

3. Assay Office No 1.

4. Private communication from Mr Ruttman, Goldsmith.

5. Private communication from Mr Dalladay of the Assay Office.

6. TAYLOR E.G.R. The Mathematical Practioners of Hanoveraian England 1714 - 1810. pub. Camb. Univ. Press. 1966.

7. Evidence given to the Select Committee on the Royal Mint under Henry Labouchere, by John Field, May 4 1837. p.63.

8. "18 Oct 1779 John Field, son of John Field Cir. and Apothecary was this day bound Appr. to Edw. Nairne for 7 years in cons. of £150".

   Court Minutes of the Spectacle Makers Company Vol 3. 1739 - 1784.

   "Free John Field late Appr of Edward Nairne ... this day ..." 8.12.1787 Vol.4.

9. The anotated catalogue forms part of a set of bound catalogues of the period, mentioned by G. L'E TURNER in appendix to article on the Sale of the Earl of Butes instrument collection in 1793. Annals of Sc. Vol 23 1967 No. 3.

   Field's sale realised in the region of £700.

10. WAYLEN JAMES. "The House of Cromwell". new edition revised by J.G. CROMWELL pub Elliot Stock London 1897 p.70 ff. John Field's father married Anne Cromwell, great great granddaughter of Oliver Cromwell.

11. John Field senior also founded the London Annuity Society for the benefit of widows of Apothecaries, finally wound up in 1890. Post Magazine and Insurance Monitor 30th August 1890. p.643.

12. Henry Field, in addition to various administrative offices in the Society, was the first examiner appointed in 1815 when Licentiate examinations for qualified Apothecaries were set up. His portrait remains at the Apothecaries Hall.

13. Records of the Spectacle Makers Company. Court Minutes Vol. 4 1784 - 1824. Guildhall. London.
    Private communication from Major O'leary, Clerk to the Society of Apothecaries.

14. Waylen op.cit.

15. CRAIG SIR JOHN. The Mint. pub. Camp Univ. Press 1953.

16. Craig op. cit p.261.

17. Craig op cit, p.247-253.

18. Craig ibid

19. Craig ibid p.263-267.

20. DYER G. The Office of Stamper of Money Weights 1774-1870 p.2. Libra Vol. 5.

21. GRIBBS F.W. Joseph Priestley. pub. Nelson 1965. p.142.

22. TAYLOR E.G.R. Math. Practitioners 1714-1840...p.194.

23. This connection between Whitehurst and Boulton may have been the origin of Boulton's interest in the operation of the Mint and the whole process of coin production.

24. ROEBUCK DR. (J) Experiments on ignited bodies. Phil. Trans. LXVI 1776 p.509-11.

25. Ibid p.576 which describes further experiments by John Whitehurst.

26. DYER loc cit ref.20.

27. Daumas Maurice "Les Instruments Scientifique aux XVII et XVIII Siècles." pub. Presses Universitaires de France 1953 Fig 130. "signée" Witheurst Derby". [sic] (Leyde)".

28. Dyer loc cit. ref. 20 above.

29. Evidence of John Field to Select Committee on Royal Mint May 1837. p.63-66.

29b. Mint Records Class 5/113 P.R.O.

30. Sc. Mus. London Chemistry collection. Inventory No. 1925/40.

31 At the Royal Mint, Tower Hill.

32. Assay Office Birmingham. Assay balance made by Wm. Ainsworth & Sons, Denver.

33. Wellcome Collection. Old Inventory No. A48817, made by O.Wolters, London.

34. Assay Balance in Board Room of Assay Office, Edinburgh. Has the carved initials D.S.C. which may represent one of the Cardwell family. Many members of this family worked at the Assay Office. Private communication from Mr L Self. Assay Master.

It is interesting to note an illustration in L. Erchers book which shows a method of calculating the possible gold content of a piece of silver by comparing the density of the unknown sample with that of a piece of pure silver.

[cont.]

To this end the entire balance and its two loaded pans has been removed from its stand, (it appears too large to have been a hand balance and Erchter had gone to great pains to describe a free standing balance), and carefully immersed in a barrel of water. A more complicated arrestment system would have made this very difficult.

35. a) Science Museum Inventory No. 1925/41. This balance was originally at the Royal Mint, b) Avery's Museum. W. & T Avery Limited, Warley, West Midlands.
Both are signed De Grave, Short & Fanner, a partnership with the old established firm of De Graves first noted in Trade Directories in 1845.

36. a) Wellcome Collection. Avery's manufacture. No catalogue number. b) Science Museum Collection made by Harbaut. Inventory No. 1925/39. This balance also came from the Royal Mint.

37. Notably in the balances made by Mégnié to be discussed later.

38. "... the bad construction of the office, being exposed to draught of air, caused me that lameness which I now experience from chronic rheumatism, which I have suffered from, for 15 years". Evidence of J. Field, para. 1010.

39. Letter from Master of the Mint W.E. Gladstone to Trevelyan at the Treasury. 19.1.1842. Mint Records Batch I. P.R.O. Kew Mint 1/37.

40. Oeuvres de Lavoisier Tome Premier. Traité Elémentaire de chimie. Paris 1864. p.252.

41. This refers to the balance by Fortin which will be discussed in a later chapter.

42. Procès - Verbaux du Comité d'Instruction publique, publiés par Guillaume Tome III p.242.
"Procès - verbal de la levée des scallés pour tirer de chez le citoyen Lavoisier les effets appartement à la Commission des poids et mesures du 19 Nivôse an II". (1793.- 4).
Quoted by M.Daumas. Lavoisier théoricien et expérimentateur 1955. Press . . Universitaire de France. Chapter VI p.135.

43. Musée du Conservatoire National des Arts et Métiers Inventory No. 19886.

44. Daumas M. op cit p.129 fig. 3. ref 42

45. Ibid p.136 ff.

46. Musée C.N.A.M. Inventory No. 19885.

47. Private communication from M.Daumas.

48. Musée C.N.A.M. catalogue 1941 p.183 fig. 44. Inventory No. 10513. Bréguet was a noted watch and clock maker.

49. Musée C.N.A.M. Inventory No. 12803.

50. Musée C.N.A.M. Inventory No. 3300.

51. D. McDonald. The Johnsons of Maiden Lane p.43. pub. Martins 1964. and D. McDonald Percival Norton Johnson. pub. Johnson & Matthey 1951.

52. This balance is in a private collection. A balance beam with forked beam ends of similar pattern is illustrated in Ganot's Physics as late as 1881. ed. Fig. 52.

53. Quite apart from the possibility of John Field and P.N. Johnson becoming acquainted in their daily work through a common interest in the processing of metals both their families had by the early nineteenth century moved to Stoke Newington and must have been near neighbours. In the light of this it is interesting to speculate which balance came first.

54. Chronologically the very fine balances made by T.C. Robinson between 1820-1842 should be considered at this point. However, although his instruments were of suitable size and had a high degree of accuracy suitable for assay work during this period, and may very well have been used for such purposes by their purchasers, they were intended by their designer and manufacturer for use in chemistry generally as well as mineralogy and will be considered later. The fact that Makins himself, who mentions Robinson's designs (see ref.55 below), did not consider that they suited his assaying purpose, encourages this arbitary decision. It is undoubtedly true however, that a balance to Robinson's design was used in work on new standard weights in the 1840's, which further demonstrates the difficulty of classifying balances until much later in the century when the various branches of analysis and metrology had become more distinctly separated.

55. Journal of Chem. Soc. Trans. 1893 p.754-56. Obituary of G.H. Makins.

56. Henry Field. 1803-1888 son of John Field previously mentioned. Obit. The Times, Monday June 17 1888.

57. Makins G.H. Quarterly Journal Chem. Soc. Vol.13 1860-1. p.97-102 - "On certain sources of loss of precious metal in some operations of assaying".

58. Making George H. "On an improved assay balance". Quarterly Journal of the Chem.Soc. Vol.6 1854 p.36-40.

59. These balances are known affectionately, though often without any idea of the origin of the name as "12 s.b.a.'s" An improved version of Makin's design was introduced by Oertling's in 1896, and "12 s.b.a." was simply the

[cont.]

catalogue number, i.e. "No.12, short beam, type (a)". It later became generic.

60. Sc. Museum London Chemistry Department. Inventory Number 1898/68.

61. Makins. ref. 58.

62. Royal Scottish Museum Edinburgh. Not yet catalogued.

63. The balance was presented by Johnson Matthey Limited to Oertlings Limited in 1964 who kept it in their private collection for many years.
Correspondence relating to this gift which was received with delight by Oertlings is extant. Private communication from Dr. L.B. Hunt.

64. Catalogue (a single sheet printed both sides) headed "L. Oertling (from Berlin) Manufacturers of balances. Mathematical & Philosophical Instruments, 13 Store Street, Bedford Square, London". Property of Oertlings Limited Archives.

65. Catalogue (double sheet printed 1½ sides i.e. 3 pages) headed "Ladd & Oertling.
Manufacturers of Bullion Chemical and Assay balances and hydrometers makers to the Board of Inland Revenue, 27 Moorgate Street, E.C. London". A catalogue covering the later 1850's in the firm's history has not yet come to light. Oertling Archives. This balance cost £120 by 1948.

66. Child E. The Tools of the Chemist. Their ancestry and American evolution. N.Y. 1940 p.84.

67. Private communication Mr Starr, Johnson Matthey Chemicals Limited.

68. Notes on Applied Science No. 7. Balances Weights and Precise Laboratory Weighing National Physical Laboratory HMSO 1954. Reprinted 1962. p.7.
Strictly speaking the inverse ratio, change of mass to change of rest point or sensitivity - reciprocal, should be quoted as "x milligrammes per - division". Trade catalogues seem to prefer the acceptable shorthand of stating only the mass involved, on the assumption that the 'division' will be a constant factor in a group of balances of similar construction, and the unit of mass will be the important consideration to the purchaser. This is further borne out by the observed practice of fine balance users who refer to their instruments as "a four nought" (or five or six) balance, meaning that it has a sensitivity such that changes of mass of the order of 0.00001g etc. can be measured.

69. Notes on Applied Sc. P.29.

70. Oertling catalogue 1891 Oertling Archives, Oertling Limited.

71. Lavoisier op cit p.252. ref.40.

72. Astronomiscle Nachrichten 7, 232 (1829); 8,48 (1831) quoted in Stock J.T. Thomas Charles Robinson and his balances. Journal of Chem. Education Vol.45 No. 4 April 1968 p.254.

73. Matthews L.G. History of Pharmacy in Britain, p.300 pub. London 1962.

74. CRELLIN & SCOTT. Drug Weighing .... **Medical History** Jan.1969 p.6

75. The work of Crellin based on the extensive collection of instruments in the Wellcome Collection makes no mention of any grain weight of less than 2 grains although over 1,100 weights were studied (p.59). Even allowing for the tendency of small weights to get "lost" during their working life, especially if they were not separately boxed, this does suggest that such small units were not commonly dispensed, or required.

76. Oertling catalogue, reference 64.

77. The Troy ounce was still a commonly used unit of weight among bullion dealers in London until the early 1970's and bullion prices are still quoted both per gramme and per ounce Troy.

78. Bauer Dr. M. Precious Stones. I and II. pub. Germany 1896. Trans. 1904. New ed. 1968.

79. The situation with regard to carats if furtner complicated by the practice of referring to a quarter of a carat as = "1 carat grain". As a carat was = to approximately 3 1/6 grains, it follows that the "carat grain" was always slightly less than 1 grain. "1 carat grain" = approx. .792 grains. Hence the necessity quite apart from convenience, of having a box of specially calibrated "carat grain" weights such as those described in reference 80 below. Box of set of carat weights signed L Oertling 12 Store Street, Bedford Square.

80. Property of Brit. Mus. (Nat. Hist.) Mineralogy Dept. Set comprises carats of 124, 64, 32, 16, 8, 4, 3, 2, 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, 1/16, 1/32, 1/64, 1/64.

81. Bauer op. cit. p.103.

82. Modern diamond balances are calibrated to read out directly in metric carats, no additional loose weights being required, and micro weights are added automatically. 1/100 metric carat or .002g. would now be the finest weight required.
Private communication from Mr. Ruttman.

83. See previous chapter.

84. Gay-Lussac: "Instruction sur l'essai des Matieres d'Argent par la voie humide". Paris 1832.

[cont.]

Gay-Lussac had published a general description of basic volumetric analysis techniques with diagrams of apparatus in 1828. The 1832 article was specifically devoted to silver. In 1835 however, he compared the results of assays by his method with traditional fire assays on the same samples. He detected errors in the old method of up to 5% and it was this figure which probably gave final encouragement to Mints to adopt his method. See Observation sur l'essai des matières d'argent par le voie humide. Ann. de Chimie et de Physique LVIII 1835 pp.218-224.

85. The Royal Commission investigating the workings of the Mint in 1837 were so impressed with this method that they included an account of it as an appendix to their report.

86. Miller Elements of Chemistry 1856. Vol.II p.1035.

87. There were also of course no ground glass joints fitted with ground glass taps. These have also been known to give trouble.

88. J.J. Griffin Chemical Handicraft 1866.

89. L.B. Hunt. The Worshipful Company of Goldsmiths p.99 Gold Bulletin No. 3 Vol.II 1978.

90. Private communication by Mr. Dalladay, London Assay Office.

91. Balance with beam 10 inches long ...; "to carry 30 grains in each pan, and turn with 1/1000 of a grain; the beam is divided, and apparatus fixed for moving sliding weights .... £25.0.0."
Oertling catalogue c1865.

92. Whitehurst J. Experiments on Ignited Substances. Phil.Trans. 1776 66 p.576.

93. Percy J. Metallurgy Sec. II Iron & Steel. p.203.

94. The possibility of moving a very old assay balance from one building to another was being discussed, opposed, and the plan was finally abandoned. The Chief Assayer explained his decision ."You see, it has never been out of the house".

CHAPTER 3

The development of the Chemical Balance.

Summary.

Interest in gases, minerals and plants outside the customary range led to problems of identification and analysis.

The hydrostatic balance.

The large capacity balance and the double cone.

Standards.

Balances associated with the work of Hawksbee, Fortin, Cavendish, Ramsden, Fidler, Troughton, Jones, Hassler, Bate and Kater.

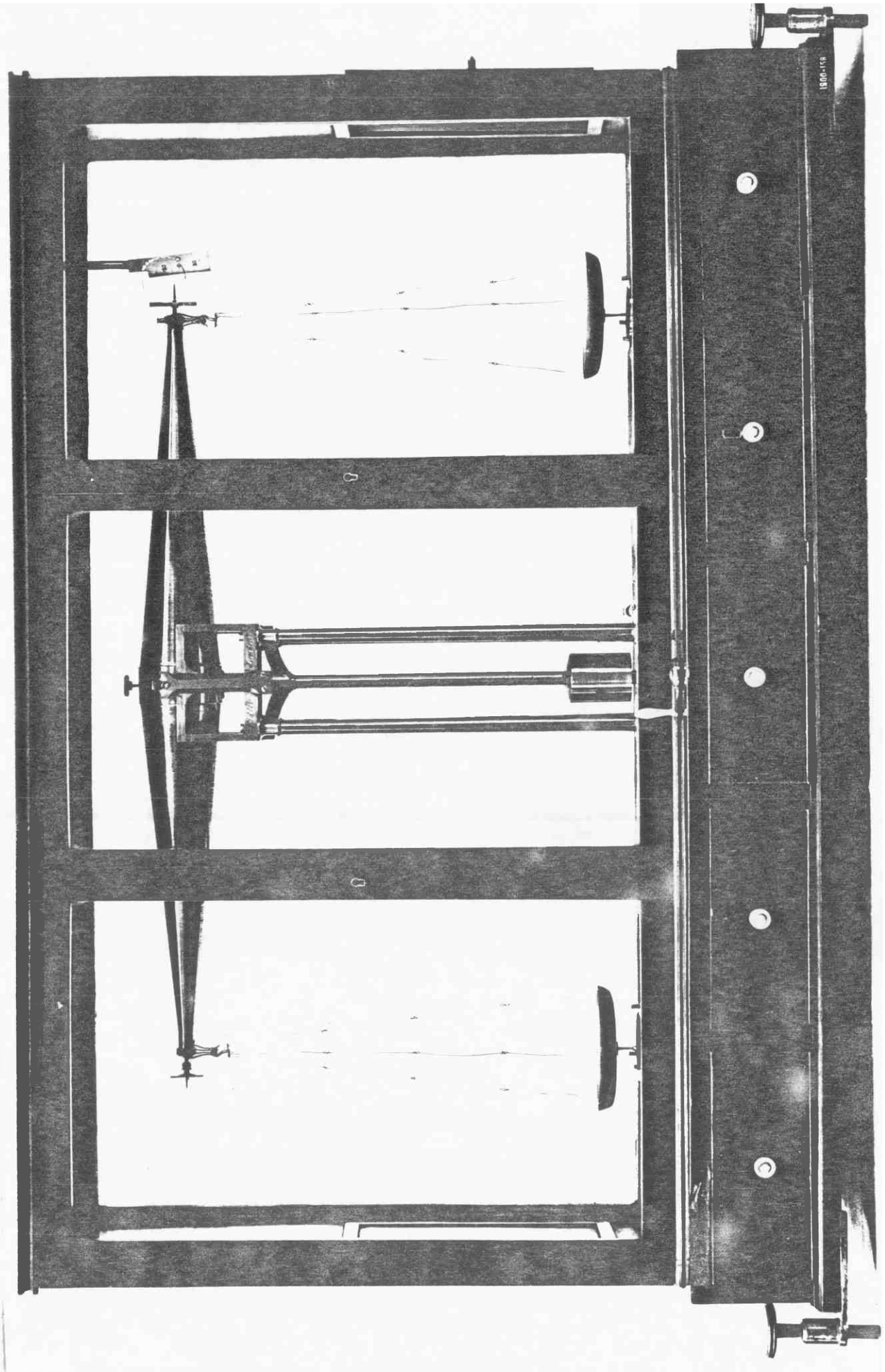


Fig. 4 Fidler

CHAPTER 3

THE DEVELOPMENT OF THE CHEMICAL BALANCE

Until the late eighteenth century the chemical balance as such was unknown. Chemists took over the balances used by assayers and apothecaries and found these suitable for their needs. Towards the end of the century however, advances in chemical analysis led to changes in the type of gravimetric problems being considered by some chemists and changes appeared in the instruments designed to solve these problems. From these changes the chemical balance as a separate entity gradually evolved.

The instruments used by assayers and apothecaries had been designed for quantative work to a high degree of accuracy. Standardisation of the quality of their products by careful control of the quantities involved helped to maintain standards. The substances commonly used by these two groups in their work had characteristics that were well understood but were highly selective. A relatively small number of metals were commonly in use in the eighteenth century. These metals were extracted from ores often only in a semi pure state in the first instance, and as in the case of iron, prolonged working of the metal was relied on to remove further impurities. Any other products of the process were of no real interest to the metal worker and substances such as gases were allowed to escape. In the same way the apothecary used a variety of plant materials and minerals in his work, but the exact nature of the composition of any one of the many ingredients he used was not always clearly understood.

Certain remedies had, however, been found useful in alleviating certain conditions and were made use of, even though the mechanism was unclear. The increased mineral exploitation which accompanied the early Industrial Revolution however, an interest in the exact content of such naturally occuring substances as mineral waters and the development of pneumatic chemistry all tended to move the interests of those concerned with chemical substances away from the range of products of long established merit into less well defined

areas. The valuable technique of weighing was naturally employed in these investigations and the instruments were adapted to accommodate the new interests as they arose. One old established analytical technique that continued to be used throughout the period, was that of hydrostatic weighing to determine specific gravity.

In the late seventeenth century, Robert BOYLE gave an illustration of a pillar balance which he had adapted for hydrostatic work (1). The simple pull string arrestment system was used, but the strings holding the pans were substantially shortened to enable objects to be suspended from the underside of the pan and immersed in water. Using this apparatus he was able to determine the specific gravity of substances and these results could be checked by others comparatively easily. The interest shown in this technique, which was applicable to a wide range of solids and liquids, can be seen by the inclusion of a similar operation in a series of demonstration lectures described in the early eighteenth century.

A written account of these lectures dates from 1710, but there is no reason to suppose that this was a new demonstration technique though the author did suggest that his apparatus showed the principle more clearly than some others had done. Francis Hawksbee described his

> Hydrostatical-Ballance for finding the Specifick Gravities of Liquids and Solids with ease and accuracy ....(2)

in 1710 and also published with illustrations the text of a course of experiments designed to be given by him in conjunction with William Whiston at about the same period. (3) The illustration to the hydrostatics sections are very similar in both publications. They show a simple free standing pillar balance with no means of arrestment. The weights are flat discs of brass designed to be placed on short holders at the ends of a plain beam which has swan neck ends. Glass "buckets" are provided, a glass cylinder and also glass counter poises. The whole is carefully designed to demonstrate the principles of hydrostatics. The weights of the items supplied have been arranged to make for a rapid result.

"K is the Glass Bucket, which in Air is in Aequilibrio with the Scale E"...
"Scale E" is one of the brass discs. Another disc is "Scale R" which if added,
"to the part H, by which the Bucket is suspended,
... that will restore the Equilibrium in Water
..." (3)

The upwards pointer has no scale behind it for calibration, the whole purpose of the apparatus being to demonstrate the difference in s.g. between quick silver and water, or between different irregularly shaped solids. The exact amount of their difference was not of great consequence to the demonstration although the principle was clearly set out and the apparatus would show,

"... the specifick Gravity of the Solid compared with Water."(3)

The tradition of using apparatus of similar simple construction to demonstrate hydrostatics continued throughout the eighteenth and nineteenth centuries. The addition by the late eighteenth century of a rachet mechanism to the central pillar enabled the beam and its objects to be raised or lowered smoothly into the jars of water. The solids chosen for comparison were selected from those likely to be both familar and also strikingly different in their densities. An experimental course of 1775, suggested the provision of pairs of masses,

"...d'yvoire, de même poids et de même volume ... de cuivre, de fer, d'etain, de plomb; toutes de même poids que chacune des billes d'yvoire et conséquemment de différens volumes."(4)

By the late nineteenth century however, the use of hydrostatic methods as a means if identifying substances had almost completely given way to other methods of analysis. The hydrostatic balance was still used to demonstrate buoyancy and methods of determining the volumes of irregular solids. Illustrations of the balance used in this later period show little alteration in the design from that illustrated by de le Fond a hundred years earlier. (5) The emphasis in the text however, shows more concern with the forces acting upon

substances than with the substances themselves.

Hydrostatic weighing was a useful technique which could be applied relatively easily to determine the density of solids and liquids. The application to gases was more difficult, and as the study of gases became an important part of the late eighteenth century chemistry the limitations of the simple hydrostatic balance would have been well known. The problem was one of containing the gases being investigated. Any container of suitable size and material would by its very nature be too bulky and heavy for the modest scale beams in common use. A much larger instrument would be required with a greater capacity. Such large scales already existed in the eighteenth century and were used in the market place for bulk purchases of food stuffs or cloth. Their sensitivity was naturally not critical, and was unlikely to be sufficient to show the small differences in mass between different samples of gases. A different type of balance was required to cope with this problem and if such a balance was not easily available problems involving gases would need to be approached volumetrically instead.

Even in the late nineteenth century the practical problems of weighing gases were still considerable. Rayleigh whose painstaking work on hydrogen, oxygen and later nitrogen to determine their exact atomic weights occupied many years, wrote sadly in 1882,

> "The glass balloons for weighing hydrogen etc. are come, but they are at least twice as heavy as they should be ... No delicate balance will carry more than about 2 pounds ..."(6)

Although the weighing of gases proved difficult, the hydrostatic balance was a useful tool for identifying solid substances, and could be adapted for use with different types of liquids. This aspect of its use received particular prominence during that latter part of the eighteenth century when the properties of liquids other than water became important. The large scale industrial manufacture of sulphuric acid and bleach for the textile industry based on the processes of Roebuck and Tennants expanded during the last part of the century. It may be debatable how much influence scientific investigation had on

the development of industrial processes, but the importance of acids and alkalis as substances worthy of investigation was clearly understood (7) and there was continued interest in finding a process for the production of soda resulting in the Leblanc process. ~~of the 1820's~~. It was no longer sufficient to be able to group substances in classes. There was now a need to be able to determine the quality, purity or strength of the liquids produced (8). Towards this end Lavoisier developed a quantative method, which was based on the specific gravity of the liquids concerned which were compared with distilled water. This method could also be used to indicate the presence of small quantities of dissolved salts in a pure solution. Lavoisier himself was convinced of the benefits to be gained from this information.

> "Je ne m'étendrai pas davantage sur les moyens qui servent pour déterminer, soit le poids absolu, soit la pesanteur spécifique des solides et des liquides; les instruments qu'on emploie à ce genre d'expériences sont entre les mains de tout le monde, on peut se les procurer aisément, et de plus grands détails seraient inutiles."(9)

Lavoisier had supplied himself during the course of his work with a complete range of balances, each type offering some benefit to a particular aspect of his many interests and investigations and each representing one branch of the development of the chemical balance. The wide diversity of designs of balances used by Lavoisier and others in the investigation of chemical substances indicates both the diversity of the study of density itself and the difficulty one now faces in establishing exactly the development of the balance. Unlike the relatively uniform designs found in balances used for assay work, chemical balances exist in a multiplicity of patterns. Most of these patterns persist throughout the nineteenth century, changing in the scope of their usefulness or the technology of their bearings, but not in their basic structure. One type of balance which appeared to have every possible advantage to the study of chemistry and was even helped by a good press, in fact lasted in production for a relatively short time. This type is represented in Lavoisier's collection of balances and is by far the largest of them. Lavoisier was particularly proud of this

large balance.

> "Je ne crois pas que, à l'exception de celles de Ramsden, il en existe qui puissant leur être comparées pour la justesse et pour la précision."(10)

This magnificent brass balance was made for Lavoisier by Fortin and is preserved in the collection of Lavoisier's apparatus in Paris (11). It was designed to carry 15-20 livres without overstressing the beam (12) and Lavoisier appreciated its sensitivity under load.

> "Il n'est pas rare d'être obligé, dans des expériences chemiques, de déterminer à un demi-grain près ou un grain tout au plus la tare et le poids de très-grands vases et d'appareils très-pesants."(13)

This need for a balance that would cope with large pieces of apparatus, whose mass would often be infinitely greater than that of their contents, produced design problems which the manufacturers Fortin and Ramsden were exceptionally well able to overcome. Fortin's solution was a beam three feet long, a thin oblong in section resting on its edge. The central knife rests on a steel support inside the central brass column, and although there is no adjustment provided at this point, the two end knives can be moved by means of setting screws to ensure that all three knives are parallel. A lever at the base of the column lifts the inside column so that it engages on the central knife and lifts it clear of the supporting arm. These arms perform the additional function of carrying attachments for magnifying glasses. Through these can be seen the divided scale towards each end of the beam. Over these the pointer moves and the beam can then be seen to be in equilibrium. (14) No case seems to have been provided as an integral part of the apparatus although this may have been subsequently lost. Certainly other surviving balances by Fortin are cased, but due to their design and the large items they were intended to carry, the tendency to remove at least the entire case front for easier access, must have been very great. In addition the spy glasses demand that the operator be very close to the apparatus for good viewing, nearer in fact than might be considered desirable if draughts were to be totally avoided. Lavoisier himself merely stressed that the balance must be kept in a separate room away from corrosive

fumes which might damage the knives and affect the sensitivity.

It is always difficult to judge in the absence of contemporary evidence the degree of sensitivity which a balance might have had when new. Lavoisier himself expected a performance of ½ grain (.026 g) from this balance when loaded to 10 Kg or 2½ parts in 1,000,000 of load. A sensitivity to one part in one million of load would be considered quite normal by the mid nineteenth century, with far better figures available for specialised needs, but for the time at which is was produced (1788) this balance was remarkable for producing such a degree of accuracy as well as having considerable capacity. In this respect it was a great improvement on Lavoisier's other non assay balances. These other balances, probably made by Chemin, he described as being sensitive to 10-15 grains, (15) or even a demi-gros (36 grains). These he described as suitable for weighing,

"des terrines entières pleines de liquide, ..."(15)

Despite the apparent lack of great sensitivity in these balances /e by Chemin (16), it was apparatus of this type that Lavoisier would have used for his experiments on the composition of air and water since his work on this was completed before the Fortin balance was constructed. The degree of error in Lavoisier's analysis using these fairly simple balances has been calculated, and considering the technical problems involved in the weighings he had to undertake, the remarkable thing is not the degree of error, but the degree of accuracy obtained, with relatively clumsy equipment.(17)

Lavoisier was not alone in his interest in work on the composition of air and other gases and of water, mineral acids and alkalis. Cavendish, Black and Priestley also were notable for their researches in this field in the second half of the eighteenth century, but while Black and Priestley seem to have used balances of simple construction and no very great capacity (18), Cavendish employed a balance designed to carry large loads with a good degree of sensitivity. It is disappointing to find that unlike Lavoisier, Cavendish, did not include in his detailed descriptions of his experiments any mention of the large balance associated with him. (19). In his papers on Air, Cavendish mentions that he is working in Troy weights with 1 ounce = 480

grains, but no actual weighings of less than ¼ grain seem to be mentioned in the text. Most of his conclusions are drawn from calculations based upon the original larger weighings. This may reflect a lack of weights fine enough to permit units of material being used that were not in themselves fairly large.(20). The plate provided shows apparatus composed of large and no doubt heavy glass bottles, though no real scale is available. In his later experiments on the composition of water and nitric acid, most of the calculations are based on volumetric experiments. However, one of the vessels used is described as having a capacity of 24,000 grains (21). This is equivalent to 1½ litres of water, which together with the glass container would weigh perhaps 2-3 Kg. Cavendish was disappointed with the results of his experiments. He was repeating an experiment of Priestley's which involved igniting a mixture of common and inflammable air in a closed (and presumably sturdy!) container. Priestley claimed a loss in weight, but Cavendish

> "...could never perceive a loss of weight of more than 1/5 of a grain and commonly none at all."(21) (.013g)

This implies a sensitivity of one part in perhaps 300,000, and while less fine than the figures claimed by Lavoisier for Fortin's balance, it is a creditable performance. It is disappointing therefore to be unable to claim with certainty that the surviving balance associated with Cavendish was the one used by him for these experiments, or to be certain this important instrument was ever used for this or any other of Cavendish's experiments. There is no contemporary list of Cavendish's apparatus, nor is this surprising, for the list of Lavoisier's apparatus was made only because of his arrest by the revolutionary government. There was apparently no inventory made at Cavendish's death in 1810 and his apparatus seems to have been sold in at least two separate lots some time after his death.

There was an auction in June 1816 of "Mathematical, Philosophical, and Optical Instruments" (22) held in Sherrard Street, Golden Square, the instruments being described as being "Of A Gentleman, Deceased". Although the former owner is not named, the existence of a copy of this catalogue among

miscellaneous papers at Chatsworth House would seem to indicate that some at least of Cavendish's extensive collection of apparatus was now being dispersed. A wide variety of apparatus is listed including thermometers, clocks, telescopes and surveying equipment. The manufacturers, when named, include the most eminent instrument makers of the last quarter of the eighteenth century, Ramsden, Bird, and Nairn and Blunt who were in partnership from 1775-1793. They had supplied a dipping needle and an air pump; Ramsden

"A most capital theodolite" (22)

The only balance listed is a hydrostatic balance"in a waiscot box", suggesting that the apparatus auctioned in 1816 represents only part of Cavendish's collection. The possibility that this catalogue was merely a chance addition to the Cavendish papers, made by a member of the family who happened to visit that particular auction cannot be totally ruled out. It is however, made less likely by the existence among the same papers of a list of keys (23). These keys had been engraved with a simple code of strokes and dots to differentiate them from each other. The list merely records the code. It includes however, the key to

"Mrs Cavendish's jewells [sic] at Denne"

and one for the Bureau at Clapham and one "carried about me", and was presumably Cavendish's own list (23). Many of his larger items of apparatus had been supplied with lockable cases and these were also listed. They included the keys to "Bird's quadrant","Nairn's dipping needle", "Ramsden's theodolite", "Hadley's quadrant" and "Shelton's clock". (23). All these instruments also appear in the 1816 catalogue, the last mentioned being listed as,

"A spring minute clock with adjusting screw, by John Shelton"

It seems reasonably certain that these two papers both refer to the property of Henry Cavendish. Keys to a number of instruments are however, listed for which no corresponding piece of equipment appears in the auction catalogue. These include "Harris's reflecting telescope" and "Sisson's quadrant". The auction list probably only represents a residue of equipment for which no other home could be found, and many items had

already been disposed of by the time the auction took place. Wilson in his biography of Cavendish wrote,

> "Cavendish left behind an immense amount of apparatus which was inherited by Lord George Cavendish. From him it passed into the possession of various parties, but the Earl of Burlington, Sir Humphrey Davy and Mr Newman of Regent Street obtained the greater part of it. By them or their heirs it has to a great extent been dispersed among those likely to value it"(24)

A quantity of apparatus, not however itemised, certainly passed to Sir Humphrey Davy. The Minutes of the Royal Institution record both its arrival and the request by Davy that he should be reimbursed for the cost of carriage, presumably from Cavendish's house at Clapham, though this is not stated. (25)(26).

As this apparatus was only lent to the Royal Institution, there was no reason for it to remain there once Davy left the Royal Institution in 1813. Hence it is not surprising to find that in 1830 an instrument referred to as "the Cavendish Balance" was presented by John George Children to Alexander Garden,(who had formerly been a partner of Frederick Accum in his business supplying scientific apparatus). The letter of presentation (27) mentions that the balance was already in the care of Garden at that date, and encloses a note about the instrument's origins. Children stated that he was given the balance by Davy, who had received from Lord George Cavendish "the greater part of Mr Cavendish's philosophical apparatus". What became of the rest of the instruments is not mentioned, but the Minutes of the Royal Institution record that in 1868 Félix Garden the son of Alexander Garden presented the balance to the Royal Institution where it is now preserved (28). Fifty-eight years had then elapsed since Cavendish's death.

By this roundabout route the balance associated with Cavendish was restored to the Royal Institution and now forms part of the exhibition in the Faraday Museum. After such a long and varied working life it seems inevitable that some parts of the instrument must have been renewed or replaced. The basic structure may be assumed however, to be very much as originally designed, since any major reconstruction would have been considered uneconomic and the balance would thereby have been reduced to the level of an ornament. There is no indication

that this happened, and the instrument is still in working order. Any minor repairs needed could easily have been made by Garden.

The origins of the balance were given briefly by Children in his note to Garden, and the information must either have been based on personal knowledge, or on information given him by Cavendish's contemporary Davy.

> "This Balance of rude exterior but singular perfection was made by _____ Harrison according to the plan, and by order of Henry Cavendish, Esquire ..." (27)

The design is best described as functional rather than elegant. The balance is housed in a large wooden case, the front of which is provided with eight separate doors.(29) Since two large doors each enclosing one complete vertical section of the case in the manner of French windows would have been far easier to construct, one must assume that Cavendish was anxious to have separate access available to every section, from the underfloor mechanism to the knives and planes, but not at the expense of exposing the whole balance to draughts. Each small door fastens with a wooden turn button, and the whole stands on a wooden stand bringing the balance to working height. The wood (oak?) is unpolished and far removed from the mahogany perfection of the cabinet makers art used by Ramsden and others in the last quarter of the eighteenth century.

There is, of course, no proof that this balance was constructed as late as this. Born in 1731 Cavendish might well have had the balance built at any date after 1750 when the need for a robust weighing device presented itself. It is unfortunate that the manufacturers cannot be positively identified. Cavendish had invested in large quantities of apparatus, some of it by very well known manufacturers, but this instrument he designed himself. Had any suitable item been readily available he need not have bothered. If such large scale beams as could be readily purchased were not of sufficient sensitivity, he must have found himself in the same position as Lavoisier, obliged to find a manufacturer capable of producing one instrument to order at some date almost certainly prior to 1789. By 1789 both Ramsden and Fortin had completed balances of suitable designs and signed them. Cavendish's balance unfortunately

bears no signature. The ascribing of Harrison's name to this balance derives from Children's memorandum. It seems very unlikely that such a cumbersome object as Cavendish's Balance could have been produced by the eminent chronometer maker John Harrison or his son. John Harrison (1693-1776) had already received the Copley Medal in 1751, and was at work on his third chronometer by the time Cavendish was 20 years old. John Harrison's magnificent surviving work bears little resemblance to a rugged construction of this balance, and the advantage to Harrison of such a wealthy patron as Cavendish would surely have been acknowledged by a signature on the instrument had such patronage existed. A more likely contender must be Samuel Harrison of Birmingham 1758-1833 inventor and manufacturer of split key rings. He was a friend and associate of Joseph Priestley for whom he made an air pump which is still extant. (30)

The sturdy nature of this balance is revealed more by the design of the arrestment gear under the floor than by the beam. The beam has been designed to combine lightness with strength and consists of a hollow "box" of iron, the top surface apparently welded on. It is 2 cm. wide and the top edge slopes off slightly towards each end giving it a pitched roof appearance. Being hollow, the weight is less than that of a solid bar of similar dimensions. The greater depth from front to back given by this square section beam than that provided by a flat metal bar on edge found in the Fortin design, provides a more substantial housing for the centre knife. The whole beam is 47cm. long and provided with a length adjuster at the left hand end, and pointer at the right, which passes over a divided ivory scale. A weighed knob by which to adjust the centre of gravity of the beam is attached to the underside of the beam and to the right of centre. The maximum weight which this beam could accept without distortion is not recorded, but the robust construction of the relieving gear at the base of the balance suggested it was substantial.

It is usually only possible to investigate the underfloor arrestment system of a balance (where such a system exists) by completely dismantling the instrument and removing the floor. The system was usually a simple cam construction requiring no

attention or maintenance. The arrestment system of this balance is far more substantial and intended to be accessible. An ivory handle on the front of the case moves a gear wheel which in turn drives another gear at right angles to the first, producing rotation in a rod set horizontally across the case. This rotates two cams one at each end of the rod. These in turn raise and lower the pan arresters (flat brass plates on which the pans are designed to "sit"), and also move rods placed inside in vertical tubes at the back of the case. These lift the beam clear of the centre plane and lower it again. This substantial mechanism allows for very delicate control of the movement of the pans and beam and also by its inertia ensures that even when heavily laden the arrestment knob will not spin in the hand and bring the beam down suddenly. Such a heavy duty mechanism does not reappear in chemical balances covered in this survey but does occur in bullion balances where the same need for accurate control of movement under extreme load was found necessary.

The pans on which the loads would be carried in this balance are brass dishes 10 cms. in diameter. They are smaller than might have been expected, but are unlikely to be much smaller than the originals even supposing these to be replacements. In addition to the pan rests already mentioned, there are pan stays, two metal pins set in hinged metal strips which can be manipulated from outside the balance even with all the doors closed. The handles have been so placed that they pass under a door sill in a slit provided and a small arc of metal has been removed from one edge so that it shall not foul on the pan arrester. This particular type of pan stay useful both for preventing a laden pan from swinging uncontrollably and for bringing it to rest in the centre of the plate swiftly, is traditionally said to have been designed by Wollaston. This would seem to refer to the father of William Hyde Wollaston rather than the latter. The Rev. Francis Wollaston F.R.S. was a contemporary of Cavendish's whose interest in science led him to construct his own observatory at his rectory in Chislehurst incorporating instruments made by William Cary. (31)(31a).

This design feature reappears in the balances made by Robinson in the nineteenth century and is then attributed to Wollaston. The pans at present hang from 42 cm. wires which are noticeably too short for their purpose. These are replacements,

and probably not the first set to have been replaced. These thin wires would have been the first item to need repair. The gap between pan and pan arrester is approximately 5 cm., suggesting that the original wires were about 47 cm. The general rule of making the pan hangers the same length on the beam, thus producing a roughly "square" structure seems often to have been adopted. In a period that considered that a short beam produced inaccurate results and a lack of sensitivity, pans being well below the beam would lowerthe centre of gravity of the entire system encouraging the beam to come to rest. A very long beam such as Cavendish had chosen would therefore benefit from pan hangers of equal length. This also had the advantage of giving him reasonable space for bulky pieces of equipment.

Great care has been taken in the design when attaching the pans to the beam. Unlike the simple hook shaped like a question mark which was so often adopted, these pans are each attached by brass loops to a universal joint beneath a pair of iron hooks. By means of this joint the pan can rotate freely beneath the hooks. The two hooks which rest on the end knife, are on the front face of the beam and one on the rear, are joined by a horizontal bar beneath which the universal joint is fixed. The hooks are themselves flattened question marks making a minimum area of contact with the knife. They do lack however, any type of locating mechanism as does the centre knife itself and only careful usage would ensure that the beam located itself squarely in the middle of the centre plane every time it was used. Despite the fact that the balance has had a long and checkered history, considerable usage and requires some minor adjustment to enable the beam to level when unladen, it is still capable of registering a change in weight of .005 gramme which is a considerable achievement. Its accuracy when new can only be guessed at but would seem to compare favourably with the balance made by Fortin for Lavoisier, though not with the later balance made by Ramsden for the Royal Society.

This strange instrument has been dealt with in detail partly because it is unique. Small ideas in its construction do re-occur, noticeably after Cavendish's death. Such a solitary man as he would seem to have been,would not have been likely to encourage guided tours of his laboratory. The influence of this design until after his death and the arrival of the instrument at the

Royal Institution would therefore be minimal. It has no known ancestors, and no descendants. Its real interest lies in the approach made by one maker to solving a problem. As the problem was relatively new, the need to combine great strength with great accuracy, so the solution was novel. Others solved an identical problem in different ways. The Cavendish balance has the appearance of something made in the workshops of Bolton and Watt or Samuel Harrison, surrounded by a case made by the estate carpenter. It is a piece of engineering, and no doubt together with other balances now lost gave valuable results to Cavendish, some few of which he published. The cost of such highly specialised instruments ensured that only the very wealthy patrons or their learned Society were likely to commission them. Had the design become well known in Cavendish's lifetime, others might well have copied it. As it was, by the time it reached the Royal Institution in 1810 the day of large chemical balance was already over.

Very few large scale balances survive, for a variety of reasons. Large balances of the type used by Lavoisier and Cavendish were specially constructed in accordance with the requirements of their users. Such instruments combining large capacity with a high degree of accuracy could not be expected to command a large market, and like all items made to order would remain expensive and comparatively few in number. Many would-be purchasers might well have been deterred by the high cost involved or the long delay in delivery, and the small number of surviving large scale balances may be more indicative of the small number of wealthy patrons of science than of the amount of interest generated by such instruments. Sometimes, however, design features intended for a large instrument were found to be adaptable to a more modest market and some large instruments, having been purchased for use in large institutions became known among a wide circle of members, who themselves became a potential source of customers. One instrument which combined both these features was that made by Ramsden in the late 1780's.

The portrait of Jesse Ramsden at the Royal Society shows him with a pair of dividers in his hand and his dividing engine for accurate marking out of fine graduations on a metal circle beside him. In the background is sketched in an astronomical telescope supported in a circular framework of the type supplied to

Observatory at Dublin. It can be seen that the supports of the wheel holding the telescope are not simple spokes, but hollow cones, and this picture illustrates much that was important in Ramsden's work. His interest in the accurate measurement in mathematical instruments is shown by his dividing engine which enabled a greater degree of accuracy to be obtained in theodolites, sextants and similar instruments. This quality enabled him to build up a considerable reputation as an instrument maker in London in the last quarter of the eighteenth century. The cone reappears as a design feature in his balance. Ramsden was made a member of the Royal Society in 1786 and by 1788 had produced a fine large scale balance. It would seem that this instrument is the only balance associated with Ramsden, and it was made at the request of Sir Joseph Banks then President of the Royal Society.

A request had been made to Banks by the Government to find some method of calculating the correct Excise Duty for different types of spirituous liquors. Ramsden was requested to design and build a balance sufficiently large so that samples of liquid could be tested and their specific gravities determined to a high degree of accuracy. Since the s.g. of alcohol is less than that of water, different proportions in the alcohol/water mixture would, at the same temperature, give results that could be tabulated and used as a guide to alcohol content.(32)

A report on the experiments performed and results obtained was published in 1790, (33) but Ramsden's balance had already been described in detail in France in 1788 and the 1790 report only mentions the Journal de Physique (34). This contains an outline diagram and a detailed description of the balance, and begins with the most striking and original feature of the whole design, the double cone beam. What prompted Ramsden to adopt the cone as a structural device for his instruments cannot be certain, but the only previous known use of this device occurs in the Transit instrument used by Romer in Copenhagen earlier in the century.(35). Hollow metal cones had considerable advantages in structures. They were light, very rigid, and relatively easy to manufacture, requiring only one seam to be made in a sheet of brass. Being hollow they also allowed adjustable weights to be inserted within them and knives fixed to them with a minimum of difficulty. A solid metal beam is always likely to distort if a steel knife

is fixed rigidly through it. The French writer was most impressed with the design.

> "M. Ramsden dont la sagacité dans l'invention de nouveaux instrumens égale la grande perfection qu'il fait donner à tout ce qu'il fait, en a imaginé un d'une nouvelle forme" (34)

This instrument, now on loan to the Science Museum, is (36) still in its magnificent inlaid mahogany case, with three drawers in the back and ten in the front. There are doors in the case at each end as well as two in front elevation and a removable centre panel. The beam itself is 61 cm. between the two end knives, and adjustments are provided by which one end of the beam can be lengthened slightly to ensure that the two halves of the beam are equal. The opposite end has a small adjustable weight by means of which the two pointers one at each end, can be zeroed on their divided scales. The centre steel knife rests fore and aft on a polished agate plane in place of the steel fulcrum formerly used in balances. This was an important innovation and was to be much copied. Agate had great advantages for use as a plane, and the removal of corrosion problems without loss of strength must have greatly commended it to manufacturers.(37)

Four brass pillars supported the centre framework on which the beam rested. A small lever at the base of the pillars activates by a see-saw movement the fifth central pillar. This raises the agate planes until they connect with the steel knives. No other beam arrest mechanism is provided and this is undoubtedly a disadvantage to this design. Only the most careful use will ensure that the beam comes to rest or is lifted at exactly the same point each time. The weight of the beam was relied on to start the plane on its downward journey, the beam resting on two small notches. Any twisting in the beam due to uneven load would have caused problems. The pans are now missing but were formerly held by

> "fils d'acier, parce que les cordons de soie peuvent contracter de l'humidité" (34)

They are suspended from loops of steel. The loop is capped on the outer face which prevents the loop sliding inwards along the short knife and rubbing on the surface of the cone. The

dome shaped apex at the loop acts as a centering device to keep the pan swinging parallel to the line of the beam, but no complete pan arrestment is provided. A handle at each end of the case and intended to be used from outside with the case doors closed, raises and lowers pillars on whose platform top ivory pins are set and here the pans formerly rested. A rachet mechanism is provided enabling the height of the pillars to be fixed at any point. For hydrostatic work containers of water or other liquids could be placed under the floor of the balance suspended on wires passing through the pan arrest cylinders. An accuracy of 1/10.000.000 of the total load was claimed.(34)

The article in the Journal is unsigned but the author was certainly working from something more than the sketch given, but whether the description is based on his own observations or on those of another is impossible to tell. Certainly there is nothing in the sketch to show the important agate planes, but according to the author, Ramsden,

> "préfere ces plaques, parce qu'il a très bien observé que souvent le couteau ne tombe pas toujours dans la partie la plus basse de l'anneau, où on le place ordinairement, ce qui cause une erreur considérable".(34)

This does suggest if not a personal interview at least an accompanying letter from someone who knew Ramsden well to augment the diagram.

Once the essential task for which the balance had been designed was completed other members of the Royal Society were able to admire and even to use this valuable instrument. One account attributed to Wollaston and taking place many years after the balance first arrived, indicates both the quality and one inherent weakness in Ramsden's design.

> "A balance made by Ramsden for the Royal Society is capable of weighing 10 lbs. and turns at 1/100 grain (.0006 g) or 1/7.000.000 part of the weight. In pointing out the balance to me one evening, Dr. Wollaston told me it was so delicate that Mr Pond, then Astronomer Royal while making some observations with it found its indication affected by his relative position before it although it was enclosed in a glass case. When he stood opposite the right arm that end of the beam preponderated in consequence of the expansion due to the heat of his body ..." (38)

This quite unexpected flaw in the design would never have

been noticed had not the balance been so exceptionally sensitive. The same problems would of course affect all those many balances made by later manufacturers to Ramsden's design. It is also a mark of the increasing demand for accuracy that after 1811 this defect was noted. When it was first produced its exceptional quality compared with other balances then available brought it praise from the highest quarters. In the opinion of Lavoisier the balances of Fortin were without equal

> "pour la justesse et pour la précision", ...
> "a l'exception de celles de Ramsden." (39)

After the death of Sir Joseph Banks in 1820 the balance was passed to the Royal Society by his widow and it is listed in an inventory of 1834(40) An anecdote records that,

> "Upon the decease of Sir Joseph Banks, the Secretaries wrote to his widow apprising her that the balance was lying in the apartments of the Society and requesting to know her wishes respecting it : "Pay it into Coutt's", was her ladyship's reply"(41)

The death of Ramsden in 1800 although a loss to the instrument making trade did not inhibit the further development and expansion of that trade. Ramsden had organised a large and successful workshop with numerous apprentices, many of whom eventually established their own premises, often proudly proclaiming themselves.

> "pupils of the late Mr. Ramsden" (42)

Ramsden's influence and prestige had greatly benefitted the status of the instrument making trade. As a Fellow of the Royal Society he had come into contact with a large group of people interested in instrumentation in all fields whose patronage benefitted his business. His reputation, based as it was on the outstanding quality of his products, did much to enhance the usefulness of high precision instruments in the eyes of those who were prospective purchasers. This same reputation added a measure of gloss to all manufacturers whether or not they could claim to have been pupils of the great man. This general good will would, of course, have counted for nothing had not the instruments produced by Ramsden's successors reached the same high quality as those supplied by him. Fortunately the impetus which he provided and the design techniques which he developed were seized by others, reproduced, developed and

improved. There had long been an interest in scientific instruments which extended beyond the relatively small group of those engaged in some chosen field of investigation and research. Instruments as objects of instruction for the demonstration of established scientific principles, or for the verification of well known phenomena in for example the field of astromony had been designed for and purchased by a wide range of interested amateurs throughout the late seventeenth and eighteenth centuries. It would be however, true to say that the finest quality instruments produced throughout this period were also very costly. This was not necessarily because they were made of the most expensive materials, although elaborate inlays could be included in them. Generally the cost reflected rather the time taken to produce one individually designed item with only the simplest of tools. The decades following the death of Ramsden saw changes in production techniques which greatly benefitted the manufacture of scientific instruments of all types, and enabled the interest in high precision generated by Ramsden and others in the eighteenth century to be built upon, and a new market eventually evolved. Although Ramsden's designs were either abandoned as in the case of his balance, or superceeded by improved versions as in the case of his dividing engine, his extreme accuracy combined with a superb "finish" gave a status to mundane instruments and their makers which had a lasting effect on the industry.

Ramsden's innovation in balance design, the introduction of a cone shaped beam, while not his sole original contribution in this field was certainly the most striking. It was this feature which was taken up by other manufacturers together with end pointers and fairly simple looped end hangers for the pans. The most remarkable of the surviving cone beam balances because of its great similarity to Ramsden's balance is one made by Robert Fidler (43). This balance is at present on loan to the Science Museum from the Royal Society. The case of Fidler's balance has only five drawers under it, unlike Ramsden's instrument with its plethora of drawers. It is fortunate that the contents of these five drawers appear to consist of the original items which were designed to fit the drawers and

apparently never seriously disturbed since. The drawers of Fidler's balance contain among other things, a fitted set of large grain weights, a specific gravity bottle, the spare pan for s.g., counterpoises, a key by means of which a metal flag attached to the top of the pillar could be turned from outside the case, in order to level the beam, a spare divided scale, perhaps for use with the telescope for which provision was made through the glass front of the case, and various original accessories whose purpose can now not easly be deduced. The instrument was evidently still considered good enough to be in use at least fifty years after its probable date of manufacture, since it also contains micro weights labelled "Mr Oertling 1868", as well as some aluminium weights (much corroded). The beam is to within a centimetre the same length as Ramsden's and the arrestment system is identical. In the Fidler the pans have also survived together with the looped hangers from which the pans are suspended. Adjustment of beam length and weight is allowed for in the design. Like the Ramsden this balance was also intended for determining specific gravity and under the floor of the case are two small trap doors which cover the holes through which items would have been suspended. This very fine balance is of interest as indicating the probable design of those parts of Ramsden's balance which are now missing. It also shows the keen interest Ramsden had aroused in that a balance as so closely similar should have been constructed by another manufacturer.

The exact date of Fidler's balance is unknown but he was making another "Ramsden" type balance, this time for the Royal Institution in 1802, two years after Ramsden's death. Robert Fidler himself first appears in the Royal Institution's minutes in 1800 and seems to have ceased manufacturing by 1816. Both balances can therefore be dated to within this period, and probably to the first half of it.(81) As will be mentioned later, the drawback in this design caused it to be superseded comparatively quickly. The Royal Institution's Fidler balance is about two thirds the size of the other, but is otherwise very similar to those two already described. The agate centre plane of Ramsden's however, has been replaced by the more traditional steel. Fidler was paid 36 guineas for his balance

in 1802 which was intended for the use of Davy and T.Young (44). Davy himself spoke highly of it in his lectures describing it as accurate to 1/500 of a grain (.0001g).

> "The balance I employed was made for the Royal Institution by Mr Fidler, after the model of that belonging to the Royal Society".(45)

The great and well deserved success of Ramsden's manufacturing career should not be taken to imply that all manufacturers were equally skilled in business. Fidler's expertise as an instrument maker is not in doubt, but his career was not a long term success. He continued to make apparatus for the Royal Institution (46), no doubt among many other customers from his premises in Wigmore Street, and later from Foley Street off Portman Square (47). He received various sums of money from the Royal Institution in 1809 and seemed well set in his chosen career. However in 1816 he left Foley Street owing rates of £9.7s.11d (47) and the following year applied to the Royal Institution for money (48). This was refused, and he disappears from the instrument making trade. The reason for this commercial failure could have been a lack of business acumen, insufficient turnover, or extravagance. Certainly any financial difficulties Fidler may have had would not have been helped by the post war recession and generally difficult economic conditions and high food prices of the years 1816-18. In considering the famous names in instrument making, those who attained world wide reputations, and often founded firms with long and distinguished futures, one must not overlook the Fidlers who failed. The best of connections and the finest of mechanical skill were never sufficient foundations for a successful business, despite the undoubted value of such gifts. Long term success undoubtedly went to the innovators, the developers of ideas, those whose work included a wide variety of instruments. Small and limited firms too easily fell on hard times. One firm which undoubtedly appreciated the importance of development in this period, was that of Troughton.

John and Edward Troughton built up an instrument making business in Fleet Street "at the sign of the Orrery" in the late eighteenth century. Within a year of details of Ramsden's dividing engine being published, Edward Troughton produced in

1778 an improved version. Like Ramsden the firm specialised in surveying and astronomical equipment of a very high standard and built up an international reputation. After the death of John in 1808, Edward continued in business, eventually taking into partnership William Simms in 1828 who was himself already an established instrument maker specialising in marine compasses. As Troughton and Simms the firm continued to flourish throughout the century (49). Their interest in the manufacture of balances first appeared as a serious undertaking shortly after Ramsden produced his balance for the Royal Society. Although the firm are known to have made balances at various times during the late eighteenth century and early nineteenth century, none have been positively identified during the course of this survey, and most of those documented must now be presumed lost. It is fortunate that some accounts and drawings do exist which give an indication of the type of balance design the Troughtons' favoured, and the way in which they foresaw at an early date, the development of the large scale balance away from the field of chemical research, and into the then totally new and unexplored area of standards control.

The first balance made by Troughton of which a description survives was used by Sir George Shuckburgh-Evelyn in the last years of the eighteenth century. At this time both in France and England the need was felt for a more uniform system of units of measurement and that these should be based on accurate standards. In his account given to the Royal Society in 1798 Shuckburgh mentioned the earlier work of Whitehurst in this field. Whitehurst had worked at the Mint in the latter years of his life and his influence there has already been mentioned. Whitehurst had also worked on pendulums as befitted a former clock maker, endeavouring to use a pendulum with a swing of known time duration as a unit of length. Shuckburgh wished to take the work further and tackle the problem of standards of weight and for this he required an accurate balance.

> "I also procured to be made by Mr Troughton ... a very nice beam or hydrostatic balance sensible with the 1/100 of a grain when loaded with 6 lb. Troy ..."(50)

This was presumably not the first balance made by this firm and

the drawings suggest a very high degree of technical skill and careful study of the balance made in the previous decade by Ramsden. Various improvements to Ramsden's design can be noticed in this balance and the Troughtons must have had access either to his instruments, or to drawings of it, from which to construct one of their own design.

The beam of the Troughton balance is a double cone of Ramsden's pattern, and slightly longer than his, being 27" long against Ramsden's 24". Both are sensitive to 1/100 of a grain (.0006g) though the Ramsden has the greater capacity, 10 lbs. (Avoir) to 6 lb. Troy. The most striking difference in the designs to judge from the diagram given is in the centre pillar. Ramsden (and Fidler's) five pillars are here replaced by one massive column which becomes a feature of Troughton type balances later. The Troughtons retained the "crystal planes" on which the centre knife rested when in use. An inner pillar forms the arrestment and lifts the beam off the plane when not in use. An interesting additional feature is mentioned but not shown in the diagram. The Troughtons had obviously realised that by allowing the beam to fall onto the plane under its own weight, there was considerable risk of it swinging if unevenly loaded and bearing on a different section of the plane, or in moving out of position relative to the beam.

> "The axis [i.e. the centre knife made of hardened steel] is placed carefully at right angles to the beam; and by means of two small brass springs that press gently at the ends, is brought always to have the same bearing upon the crystal; so that no error need be feared from a small deviation from the right angular position of the axis to the beam ..." (50)

Other adjustments for centre of gravity and beam length are provided exactly as in the Ramsden balance, and their operation can be imagined because they are so similar to that found in extant models. It is unfortunate that this balance does not seem to have survived, as more detail as to the working of the brass springs would have been of interest. They were an attempt to overcome an inherent problem of double cone balances, namely the lack of any secure method of resting the beam and keeping it at right angles to the centre plane. It is noticeable that later Troughton balances gave up the unequal struggle in

favour of alternative designs. The cone beam did not in the end have a very long period of production. It proved to be an unrewarding design as far as development was concerned and despite its illustrious pedigree seemed to have faded from popularity after about 1815. This can be seen from the other smaller surviving examples of this type of balance.

Surviving examples of cone beam balances are not numerous. The collection of scales and balances in the Avery Museum contains one unsigned example (51), and another signed by Thomas Jones is in the collection of the Mineralogy Department of the British Museum (Natural History). (52). This contains a trade card giving the address of Thomas Jones as 21 Oxenden Street. There is however a second beam supplied with the balance of plain bar pattern which gives the address of the firm as 62 Charing Cross Road. The firm moved to the latter premises in 1816 which gives a probable date of manufacture of the instrument. Another balance by W & S Jones is in the Science Museum collection. (53). The brothers William and Samuel Jones were in business in Holborn from 1795 onwards for over half a century, but this balance would have dated from the early part of this period. All three of these balances are substantially smaller than those discussed earlier, being on average half the size of Ramsden's original, and containing some of the Troughton amendments. The substantial cylindrical centre pillar appears in all three, and that by T. Jones has agate centre planes and pan hangers more akin to Troughton's illustration than Ramsden's simple loops. All three are supplied with drawers in which parts of the balance can be fitted, and in addition that by W & S Jones has a drawer fitted to take glass bowls and bulbs suitable for specific gravity work and these are very reminiscent of early eighteenth century hydrostatic balances.

The arrestment system of these cone beam balances are varied. That by T. Jones has a turn knob which lifts the centre agate plane, as does the unsigned one, but the latter also has the graduated ivory scale attached to the centre mechanism so that it rises and falls with the beam. This refinement would have been a great advantage to the balance by W & S Jones. Here a knob pushes on a lever which activates a spring to raise the column inside the pillar. A cumbersome and separately operated

pan arrestment system is also present. Unfortunately, in allowing the beam carrying the end pointers to be forced up by a rising centre plane all these balances also move the beam upwards and across the fixed graduated end scales. The difficulty of ensuring that the unladen beam comes to rest at the centre point of the scale is considerable, as either the scale must be adjusted with the beam swinging, not a manoeuvre to be encouraged, or the displacement from zero guessed from the position of the beam and compensated for accordingly. The cone beam despite its great advantage in providing strength without undue weight had problems in use which eventually outweighed its usefulness. Alternative designs were sought which would continue the high degree of accuracy now obtained, but without the disadvantage which had become apparent in the use of the cone beam. Some of these alternatives were tried out by the Troughtons in the early years of the nineteenth century.

The move towards accurately verified standards and some degree of uniformity extended beyond units of length and weight. Surveys of coastlines and astronomical observations were undertaken as well as attempts to improve the overall standard of the currency. These endeavours continued despite war or revolution in Europe, but their influence was also felt in America. George Washington in 1791 urged that,

> "A uniformity in the weights and measures of the country is among the important objects submitted to you by the Constitution ..." (54)

Each of the various States of newly United States had in use standards mostly of English origin, brought over a different dates to the colonies, of very variable quality and based on Standards which had themselves often subsequently been superseded. The resulting confusion hampered trade and the need for uniform standards was appreciated, but not acted upon for many years. The problems likely to arise in imposing any system on such widely scattered communities in the newly independent colonies were immense, and the international problems that would be provoked by adopting a system incompatible with that used in Europe all tended to cause caution and delay. Not until 1828 was a start made on adopting nation wide standards with the arrival in Philadelphia of a copy of the Troy Pound Weight from London. Less contentious and equally urgent was the need for an

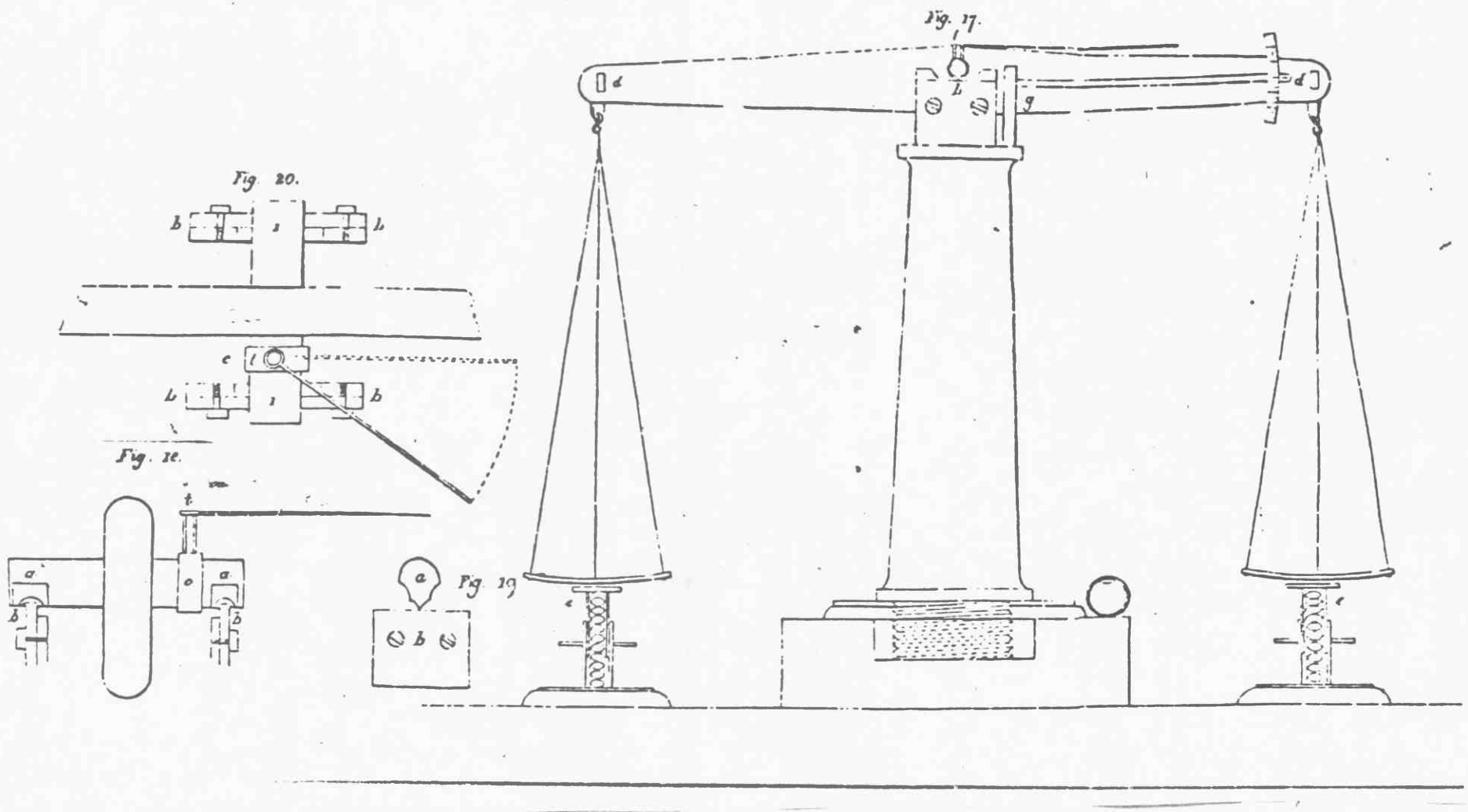


Fig. 5 Troughton

accurate survey of the coast line. Congress voted money for this in 1807 and Ferdinand Hassler was appointed Superintendent of the Coast Survey. (55).

Hassler was born in Switzerland in 1770, studied mathematics at Berne and became interested in surveying the area around the town as a hobby in an attempt to produce a local map. In 1805 he emigrated with is wife and family, taking his library and instruments with him. His partner speculated and lost the money entrusted to him, and Hassler was forced to sell much of his library to the American Philosphical Society. Supported by the Society he produced a plan for an accurate topographical survey of the coast which was accepted. Hassler insisted that only the best instruments were suitable.

> "... they must be made on command and by the best mechanicians ..."(55)

It was agreed that he should go to London with his family where during the war of 1812 he was detained as an alien. However, he obtained the instruments he required from Edward Troughton whose neighbour he became, and after whom his sixth son was named. In addition to the surveying equipment he required, Hassler realised that a standard system of weights and measures must eventually be introduced into America and he planned accordingly.

> "... when I was in Europe for the purpose of procuring instruments for the survey of the coast ... I procured also a balance constructed by Troughton with great care and accuracy and in general principle similar to that employed by Sir George Shuckburgh in his comparisons ..." (56)

The balance made by Troughton to which Hassler referred in his Report of 1833 is also illustrated in that paper. The diagram together with the written description gives a very clear indication of the type of balance used. Hassler says that he included the written account of the principal characteristics of balance because,

> "The peculiarities of this balance, though simple are not much known". (57)

The changes that had taken place in balance design between the Troughtons' first known attempt at making a balance in 1797 and the instrument produced in 1812 can be clearly seen. The first mentioned by Hassler and most striking of these is in the

beam.

> "The beam is of solid steel, blued, of one foot in length one quarter of an inch thick; its middle breadth, forming its height of beam, is a little over one inch, tapering out to half an inch at the ends ..."(1)

The cone beam has now disappeared, despite its distinguished record and been replaced by a traditional steel beam reminicent of those made by Fortin to such good effect in the previous century. Despite the traditional appearance of the beam however, there is nothing to suggest that the rest of the balance is merely a copy of old ideas. Although it is not clear from the text which parts of the design are due to Hassler and which to Troughton, there is evidence that each item had been clearly thought out and improvements made which satisfied both parties. The design of the crucial centre bearing illustrates this. The centre knife is split, i.e. one half projects from the front face of the beam and one half from the rear face. (58). In cross section the knife is tear drop shaped, a traditional design; sections have been cut away from the knife leaving the edge to stand proud but backed by a substantial mass of metal remaining for strength. To improve on this yet further, the knife edge has itself been partly cut away to reduce to a minimum the part in contact with the plane. The plane (also steel) is slightly domed in cross section;

> "By this means the oscillations take place, from a section of a large cylinder [the knife] upon the curved surface of a smaller one [the plane], thence with very little contact, and of greatest sensibility, and the strength of these parts is increased." (57)

This aim of minimising the area of contact at the crucial point of the balance in order to reduce friction showed an awareness of the nature of the problems involved in precision weighing. While each new design solved its problems in a different manner an understanding of the factors likely to promote accuracy was an essential prerequisite. Hassler included an improvement which he himself devised. He first stressed the necessity of obtaining a glass case for the balance. The front of the case however was to be made in one piece.

> "I rejected doors; they are in the way when the case is open, and, in shutting, they occasion a motion of the air within the case, which I have avoided by sliding the frame gently up into its place from below". (57)

Subsequent developments in balance design did not, fortunately, favour the case front formed from a framed sheet of glass slid upwards into place from below. The case front which slides downwards on a ratchet or is controlled by means of counter poised weights however became during the latter half of the nineteenth century so universally applied that it is easy to overlook the fact that the advantages of a sliding system were not apparent to manufacturers from the days of the very first balance. Glazed doors as such were provided for items of furniture like bureau bookcases, and which were made by the same cabinet makers for both uses, were the most natural solution to the problem of enclosing a balance. Sliding panels on the other hand on balances before the mid nineteenth century were rare, as surviving examples show, and glazed doors continued to be used throughout the century, though in decreasing numbers as the century progressed.(59)

A less successful inovation of Hassler's was the pan arrestment system which he devised. He objected to "rakwork", i.e. a ratchet mechanism for arresting pans such as Ramsden had used, on the grounds that it was too difficult to control. As far as an arrestment for the beam was concerned he preferred to have none at all rather than use a jerky mechanism. His beam was merely removed when not in use. The pans however were steadied by coiled springs, the coil being depressed by a hand lever so releasing the pans once the balance was ready for use. This system was not adopted by other users or manufacturers, and one can see that the failure of the coiled spring under constant load would be a probable hazard. The cam operated pan and beam release mechanism was ultimately developed and came into common useage later in the century. Although it had been recognised by Hassler that something more than a simple press lever mechanism for arrestment might be desirable, the coiled spring did not in the long term prove suitable, and only one other similar instance of its use has been noted in this survey, and will be referred to later.

Hassler was satisfied that his balance was sensitive to .01 of a grain (57), (.0006g) and when he used the balance to

compare the various sets of weights in use in America, or those specially purchased as 'Standards', he found considerable discrepancies between them. All these he detailed in his Report and the need for a uniform system of Standards to be applied by all Custom Houses to control trade was established. Since agreement on basic units of length, mass and capacity was of limited benefit unless those engaged in controlling trade had some means of regulating the measures in local use, it was decided by the Senate that a set of standards, including balances, should be made for each State and Custom House. Hassler's son, Edward, was employed to assist in making and checking the numerous sets of weights, capacity measures and measures of length that would be needed while Hassler himself was once more required by Congress to work on the coast survey which had been in abeyance for some years. Three balances were required to be made for each set, one of 50lb, one of 10lb., one of 1lb. capacity, and the work was not completed until about 1850, after Hassler's death in 1843.(60). Of these balances only one survives which is known to have been completed by the Hasslers.(61). This magnificent instrument with a beam approximately 3'6" long, ending in long pointers each about 6" long at either end of the beam bears a close resemblance to Hassler's original Troughton.

The remainder of the balances were completed by Hassler's successor Bache and his assistant Saxton, and were made very much to the original Hassler-Troughton design (62).

The coiled springs have been replaced however by a rod through which the pan suspensions pass at the top of the case. This seems from the illustration to enable the weight of the pans to be taken off the beam when not in use, so reducing wear on the centre knife. A set of these balances was exhibited at the 1851 Exhibition where the large balance was awarded a medal. A further set was presented to the French government and were enthusiastically received by Silbermann then Administrator of the Conservatoire des Arts et Métiers.

"They are what they are justly called, instruments of precision."(63,64).

The balances which were for the most part made by Saxton for the new Superintendent of the Office of Weights and Measures, Bache, incorporated improvements designed by Saxton, but were in

general appearance very similar to that balance originally brought from England in the early years of the nineteenth century. Hassler had incorporated certain improvements himself in the original Troughton design of 1812, and made further changes when he began to produce balances in quantity for every State, but these changes like those of Saxton later were intended to assist the user by making the operation easier, and the balance itself more sensitive. No attempt was made however to change the basic design, even though by mid century many alternative balance designs had been evolved, and an increase in trade and communication between America and Europe in the first half of the century ensured that ample opportunity existed for innovatory ideas to spread. The Troughton influence extended far in time and distance beyond any market which could have been seen by the manufacturers in 1812 indicating once more the persistance of a satisfactory design across decades of use and irrespective of competition.

The only other balance design associated with the firm of Troughton in this period suffered the same fate as the cone beam and quietly faded away. This balance was a further attempt to solve the weight problem in the beam, and produced a novel solution. The beam was made of wood. This balance in the Science Museum Collection is traditionally said to have been made by Troughton for Sir James Smith(65). It contains a mixture of features that can be seen in the other balances by this firm already described and also some new features. The beam is of mahogany and 62.5 cm. long. It tapers towards the ends just as the steel beam of Hassler's balance did, but the pan hangers are composed of threads hung over the shoulders of beam ends which are themselves protected by brass inlays. The tendency for the strings to slip round to the front or back face is considerable. The balance is fitted with agate for its centre plane, a feature absent in Hassler's design where it is a surprising omission, but obviously not considered by him to be an essential feature. The pans are spring loaded, but the movement of them is controlled by the lid of the case, a unique feature. Until the lid is closed the pans are held firmly. This unfortunately means that until the lid is left open the pans are not stable. The front is formed by three panes of glass

which slide sideways to enable the pans to be loaded. The left drawer contains a large set of weights, and the right drawer apparatus for specific gravity work.

The centre pillar has the massiveness associated with the Troughton balances, but like the beam is also made of wood. It is hollow, enabling a rod within it to operate the agate plane. This is moved by a simple metal lever. Despite the originality of the design, the drawbacks which must have been encountered by anyone attempting to use it must have been considerable. The beam had been made of a light material to reduce weight and probable central inertia, but did not offer enough advantage over a light steel beam to compensate for the frail end hangers. So small a piece of wood had not the strength of a piece of steel of comparable size. It could not take a massive load, yet was too frail to have comfortably accommodated any form of metal hook or hanger that needed to be screwed or drilled into its surface. As a solution to an ever present problem, it created more difficulties than it solved. The use of wood on a really large scale however, where such problems of fragility would not be encountered, and where the benefits of wood would outweigh the difficulties encountered in working it, did occur during the second quarter of the century, but in the hands of another manufacturer much concerned with Standards, Robert Brettell Bate.

Robert Brettell Bate came to London in the early years of the nineteenth century from Stourbridge, Worcestershire. He set up in business in Poultry by 1808 and remained there until his death or retirement about 1850 (66). By this time his enterprise had become so vast and his range of interests so diverse that no fewer than three firms were able to claim later that they were "Successors", (at least in part), to the late Mr Bate.(67).

Bate's name appears in the Records of the Spectacle Makers Company (68) in 1814 when he became "Free per Redemption". His address is given as 17 Poultry, and his occupation as Optician. He is further described as the son of Overs(?) Bate, late of Stourbridge, Worcs., Mercer, deceased. This entry records an event which brought to a head what must have been a long running dispute between some of the City Companies, and one which developed out of all proportion to the original event. Bate, on arrival in London had been faced with the same problem as that

which every country dweller experienced who wished to ply his trade inside the City boundaries or Wards immediately adjacent; namely he was expected to serve an apprenticeship to a London Freeman before being admitted to the Freedom of his chosen Company. Those who lived in London could be apprenticed to their fathers, as were John Field's sons, or to a well known Master of the craft they wished to learn, as John Field himself had been. Those without such valuable connections either traded outside the City limits, or like Bate obtained their freedom by Redemption i.e. payment to a Company. This process was frowned on by many Companies as it obviously did not necessarily ensure any competence at all in the craft undertaken, merely a deep purse. As the City Companies original purpose was to ensure good standards of training and practice their concern was understandable, and some Companies totally prohibited such dealings.(69). By the end of the eighteenth century however this system was coming under increasing pressure both from the relentless tide of newcomers moving into London, and from the increasing variety of trades which the Industrial Revolution had either created or totally transformed, and for which no suitable Company existed.(70).

Bate was far from being the first or only person to obtain Freedom by Redemption, but for reasons that can be suggested, though not proved, he did appear to be the focus of considerable feeling. After many years of dispute between the Spectacle Makers and the Companies, judgement was finally given for the Spectacle Makers who proudly recorded that,

> "all who take the Freedom of Redemption will if it be their choice be recorded free of this Company"(68)

The case against Bate could be seen as a last stand by some Companies against a flood tide of change which would radically (71) alter the entire structure of City life and their control of industry within it. It is more probable that his experience was only one of many similar episodes. Other craftsmen were no doubt less successful in their application to join a Company, or less determined to make an issue of the event. Few would appear to have set up shop in the heart of the main thoroughfare under such circumstances. Bate was fortunate in having the support of his Company throughout the dispute, and this suggests that the

excellence of his workmanship was beyond question. In the Records already mentioned there is no suggestion of allegations of incompetence only a question of principle. It was perhaps the exceptional quality of Bate's work that encouraged the Spectacle Makers to persue the case wholeheartedly, and their confidence was amply borne out by his subsequent career.(72)

The details of Bate's origins and training were undoubtedly well-known to his fellow members. For this reason there appears to be no record of where or from whom he obtained his basic training in optical work.(73). His success, however, can be gauged by his becoming in turn Optician to the King, Optician to the Queen, Chart Agent to the Admiralty, hydrometer and M.I.M., etc.(66) during his career, in addition to his work on Standards. Of Bate's origins nothing further is given beyond what has already been mentioned(68), but a family of some eminence of that name were Bankers in Stourbridge in the period of early nineteenth century, the partnership of "Bate and Robins" eventually forming part of the London Joint Stock Bank (74). If this family connection was able to supply substantial financial backing for the new enterprise in Poultry during the difficult early years of the nineteenth century, this could explain the success experienced by Bate in establishing himself in a highly specialised trade against considerable opposition.

By the early 1820's Bate's work was sufficiently well known for him to become involved in the task of producing new Standard Weights and Measures. An account of this was given by Kater in 1826(75). Bate was required to make several 'rough' copies of the Imperial Troy pound, leaving them "a little in excess". These were then adjusted accurately by Kater using a balance made by Robinson whose work will be described later.(76). Bate also made a complete set of Standards, including a Yard, Bushel, etc. So satisfactory were these sets that seven further sets were ordered for the County of Middlesex, and other Authorities may also have used the same manufacturer.(77). The accurate adjustment of the 'rough' measures to an exact length, mass or capacity was obviously an essential part of the process of obtaining and maintaining standards. Troy pound weights could be checked on a balance made by Robinson whose beam was 10" long. A large bushel measure posed different problems, and Kater describes how he

arrived at a solution to the design of a suitable beam;

> "I first tried cast iron; but although the beam was made as light as was consistent with the requisite degree of strength, the inertia of such a mass appeared so considerable that much time would have been lost before the balance would have answered to the small difference I wished to ascertain ... I therefore determined to employ wood ... The beam was made of a plank of mahogany about 70 inches long, 22 inches wide, and $2\frac{1}{4}$ thick, tapering from the middle to the extremities ..."(78)

This use of wood unlike the case of the wooden beamed balance associated with Troughton and mentioned earlier, proved entirely satisfactory. The wood was massive enough to enable triangular steel knives to be securely fixed on to block screwed into the thickness of the wood, as were the polished steel planes. The balance was designed to ensure that the whole length of the knife (6") rested on the plane and so took the considerable load involved. Kater found that the balance would turn with 1 grain (.065g) deflecting the index pointer 1/20" with a load of 250 lbs. The arrestment gear "to prevent unnecessary wear on the knife edge", is described as "A well-imagined contrivance .. applied by Mr Bate".(78). This contrivance is not described, but two balances similar to the one Kater designed are preserved and details can be seen there (79).

The success of Bate's work for Kater in establishing new Standards undoubtedly led to further commissions for balances as well as Troy pounds or bushel measures. Although no mahogany beam 70" long seems to have survived, one 48" signed "Bate London" has done so, and is now in the Weights and Measures Collection of the Science Museum. It was made for the Bank of England to weigh silver bars of 50-80 lbs. Troy weight and a drawing of it in use is given in an article in the Illustrated London News of 1845 (80). The workmanship in this large balance is excellent. Because of its size it is normally stored in sections and was reassembled for this survey. This otherwise daunting task was simplified by the fact that no two components could be accidentally interchanged. All bolt holes were slightly offset, or provided with shafts of varied length ensuring only one "fit" was possible. The article in the Illustrated London News shows two Bate balances, the other being for weighing dollars. The other surviving Bate type balance does not quite fit the illustration, suggesting a later purchase, or an

extensive rebuilding later in the balances life. Both however show clearly the "ingenious contrivance" of Mr Bate. By moving a handle horizontally across the base of the centre pillar a wheel is turned beneath the pillar. As the wheel is grooved but not of uniform thickness it acts as a cam, raising and lowering very slowly and carefully the heavy beam on its centre plane, until the plane is just clear of the base of the knife. Such a solid construction is unlikely to 'run wild' and bring the beam crashing down under load, and yet can be controlled to move smoothly and slowly to encourage a stable swing. The balance that would combine capacity with accuracy by mid century had reached far beyond the original requirements of those engaged in large scale analysis such as Cavendish and Fortin, but had also ceased to be a chemical balance.

By the second quarter of the nineteenth century the capacity of a balance had ceased to be an all important consideration to chemists. The possibility of obtaining accurate analyses from smaller samples had been accepted, newer techniques enabled products such as carbondioxide to be trapped in relatively light potashbulbs, and the facility for accommodating bulky items of equipment, though by no means ignored, was no longer vital. The large balance, costly and cumbersome, became a dinosaur. It was saved from extinction by the use that could be made of its capabilities in the field of Standards. This new area covered both the demand for evermore and even more exact Standard Weights and Measures, and also the standard of coinage. The exact Weight of ever larger consignments of bullion became an important consideration as the century and the Industrial Revolution progressed. The dinosaur balance continued to flourish in the new world. The effort that had been expanded by many manufacturers in producing beams and unusual materials, relieving gear that was smooth in operation, knives that would withstand great wear and over all the constant insistance on high sensitivity, all these aspects of the large balance remained. They remained in the memory and experience of the purchasers, designers, manufacturers and users of balances. Because this group of people gradually increased in number, a wide variety of new ideas could be tried and a much wider variety than before could remain in existence if found satisfactory, to accommodate the ever more

diverse requirements of users. The large balance, like the assay balance provided an essential portion of the background from which the chemical balance finally emerged.

1. Robert Boyle Philosophical Works. 1725 Vol.II Plate V.

2. Harris John Lexicon Technicum or a Universal English Dictionary of Arts and Sciences ...1710 Vol.II. (Alphabetical but no pagination).

3. Quoted in I.B. Cohen. Some early tools of American Science. pub. Harvard University Press 1958. p.32.

An advertisement in the Spectator January 15th 1712 announced

> "A course of Mechanical, Optical, Hydrostatical and Pneumatical Experiments To be performed by Francis Hauksbee and the explanatory lectures read by Wm. Whiston M.A."

4. Sigaud de la Fond. "Description et usage d'un Cabinet de physique expérimentale". Paris 1775. p.272.

5. Ganot "Eléments de physique". Trans. E Atkinson 1873.

6. Strutt R.J. Life of John Wm. Strutt. ed. 1968. p.158.

7. Thackray A. "Science and Technology in the Industrial Revolution". History of Science. Vol.9 1970. p.76-89.

8. Guerlac Henry. "Quantification in Chemistry". Isis vol. 52 1961 p.194-214.

9. Lavoisier A. "Traté Elémentaire de Chimie" part III p. 256.

10. Ibid. p.252.

11. C.N.A.M. No. 19887.

12. 21½ lbs., or nearly 10 Kg.

13. Lavoisier op cit. p.252.

14. Description based on that in Daumas M "Lavoisier Expérimentateur and Théorician" p.137-8 and photographs supplied by C.N.A.M.

15. Lavoisier loc cit.

16. C.N.A.M. No. 7545 and 19890.

17. For air 20% for water 5%. M Guichard, Essai Historique sur les Mesures en chimie II. Paris 1937 p.18-25.

18. Black also designed and used a balance of very great accuracy but small capacity which will be discussed later.

19. This balance is preserved in the Royal Institution.

20. Cavendish.H. Three papers containing experiments on factitious Air. Phil.Trans. Vol. LVI. 1766 p.141-184 (p.143).

21. Cavendish.H. Experiments on Air Phil.Trans. Vol.74 1784 p.119-153. p.12 of Alembic Club Reprint No. 3 1961.

22. "A catalogue of sundry very curious and valuable Mathematical, Philosophical and Optical Instruments, Electrifying Machines, Clocks and Maps ... Will be sold by Auction by Mr Willcock ... On Saturday the 15th June 1816 ..."
Miscellaneous papers. Chatsworth Archives.

23. Hand written list "Keys at London", among Miscellaneous papers at Chatsworth.

24. Wilson G. "Life of the Hon. Henry Cavendish" 1851 p.475. Mr Newman of Regent Street was Instrument Maker to the Royal Institution for many years until his retirement in 1860.
Manager's Minutes of Royal Institution. Vol.XI. Feb.6 1860 p.313. Facsimile edition 1975.

25. "Mr Davy requests permission of the Managers to place some Chemical Apparatus which belonged to the late Mr Cavendish in one of the garrets of the Royal Institution. It is Mr Davy's intention to employ them in the experiments and lectures of the Royal Institution".
Manager's Minutes of the Royal Institution. Vol.V - VI July 9 1810.

26. "... Mr Davy having kindly lent the Apparatus presented to him by Lord George Cavendish formerly the property of Mr Cavendish deceased for the lectures of the Royal Institution and the carriage of this amounting to £9..1..6."
Op.cit. Dec. 2nd 1810.

27. The letter from J.G. Children to Alexander Garden and an accompanying note, both dated Jan. 1st 1830 are in the possession of the Royal Institution. A photograph of these documents is in the Science Museum collection no. 4633-4.

28. Managers Minutes Vol.XII. May 18 1868.

29. The case is 74 cm. x 80 cm. x 30 cm. deep. Each pair of doors is of different depth and reading from the top pair are 13 cm., 21 cm., 27 cm. and 15 cm. respectively.

30. During the 1820's S. Harrison went into partnership with Josiah Mason and later encouraged Mason to take over the firm; the split ring business continued to be run along side Mason's successful steel pen manufactury. Harrison was still alive in 1830

30.(cont'd)
when Children presented the Cavendish balance to Garden and must have become well known in scientific circles.

I am greatly indebted to Miss D. McCulla, Librarian of the Local Studies Department of Birmingham library for this information regarding Harrison, and to Dr A. Newmark for drawing my attention to the air pump.

31. "List of observers of rocket fired at Loampit Hill Deptford to determine longitude from Greenwich." The list includes Frances Wollaston at Chislehurst (of where he became rector in 1769), Nevil Maskelyne at the Royal Observatory, and Ed. Ellicote at Highgate. Miscellaneous papers Chatsworth.

31a. Chaldecott J.A. "William Cary ... & W.H. Wollaston." Platinum metals review. Vol. 23 No. 3 July 1979. p.112.

32. From these figures hydrometer scales could be derived which would show not the % weight of alcohol in the sample, but the direct relation of the sample to the standard or 'proof'. A reading of x volumes underproof would cause duty to be levied at the rate for 100-x gallons. Beer was excluded from this scheme, perhaps because the % of alcohol in best London Porter at mid century was only 5.36 compared to 54.32 for Whiskey (sic) (Figures from English Cyclopaedia 1859).
The strength of beer was (and is) given as the original specific gravity, i.e. the s.g. of the wort before fermentation begins. This is basically a measure of the sugar content of the liquid, and the instrument is called a saccharometer; Tables and Directions for using the Saccharometer were published by Richardson in 1804. H.S. Corran History of Brewing 1875.

33. Blagden Charles 'Report on the best method of proportioning the Excise upon Spirituous Liquors'. Phil.Trans. Vol.80. 1790. p.321-345.

34. [ ] Description d'une nouvelle balance construite per M. Ramsden.
Observations sur la Physique, sur l'Hist.Naturelle et le Arts. XXXIII II Aout 1788. p.144-7.

35. Illustrated in A History of Science, Technology and Philosphy in sixteenth and seventeenth centuries. A Wolf. 2nd ed. 1850. p.176.

36. Science Museum Inventory number 1900/166.

37. The production of agate knives was a nineteenth century inovation. The problems of cutting irregular shapes in agate may have partly delayed introduction of this useful material, but other economic problems were probably more serious and will be dealt with later.

38. Ure Andrew Dictionary of Arts Manufacturers and Mines. 3rd ed. 1846. Pond became Astronomer Royal in 1811. Wollaston died 1828. The story presumably dates from C.1820? i.e. 30 years after it was first made.

39. Lavoisier. Traité. p.252. (rep)

40. [ ]Instruments and Apparatus belonging to the Royal Society Nov. 1834. No. 47. Hydrostatic balance by Ramsden with weights by Robinson presented to the Royal Society by Lady Banks.

41. Weld C.R. History of the Royal Society. pub. London 1848. Vol.II. p.116.

42. Trade card of Thos. Jones, 21 Oxendon Street, Haymarket, contained in Balance No. 5 British Museum.(Natural History) Mineralogy Department.

43. Science Museum Cat. No. 1900/158.

44. Royal Institution Minutes. June 7th 1802.

45. Davy Sir H. Collected works Vol. 5 ed. J. Davy pub. 1840.
Bakerian papers and miscellaneous papers 1806-1815.
Paper I. Phil.Trans. 1807 read 1806. p.17.
A further reference to a fine balance accurate to 1/2000 gr. is mentioned by Davy in a later lecture, but this balance is not positively identified as the Fidler.

46. Royal Institution Minutes 1809 show payments of £47..0..6, £17..16..0. and £14..19..0 during the year.

47. He moved to Wigmore Street in 1808, Rate Books Marylebone Local History Library.

48. Royal Institution Minutes 1817 May 5th.

49. Accounts of the history of the firm of Troughton and Simms are contained in:
Taylor E.W., Simms Wilson J and Scott Maxwell P.D. "At the sign of the Orrery". pub. c.1960.
Skempton A.W. and Brown J. "John and Edward Troughton M.I.M".
Notes and Records of the Royal Society. Vol. 27 1972-3 p.233-62.

50. Shuckburgh Evelyn Sir George.
"An account of some endeavours to ascertain a Standard Of Weight and Mesure"
Phil.Trans. Vol. LXXXVIII 1798. p.133-182.

51. Avery Museum W & T Avery Limited, Smethwick Warley, West Midlands.

52. Department of Mineralogy British Museum (Natural History) No. 5.

53. Science Museum Collection Inventory Number 1928/1042.

54. Annual message to Congress Oct. 1791 Quoted - Judson L.V. "Weights and Measures Standards of the United States". Nat. Bureau of Standards publication no. 447 pub. Oct. 1963. New edition 1976. p.3.

55. [ ] Ferdinand Rudolph Hassler First Superintendent of the Coast Survey and of Weights and Measures. C1960.

56. Professor T.C. Cochran (Ed) The New American State papers.
Science and Technology. Vol.3. Weights and Measures.
Report by F.R. Hassler to the Senate. June 1832.
Doc. No. 299 p.379-384.

57. E.T.C. Cochran (Ed) loc.cit.

58. It is possible to design a beam such that the knife can be in one continuous piece fixed to the underside of the beam and resting throughout its length on the plane beneath. This occurs particularly with agate knives later in the century, and will be discussed later.

59. One or two of the Fortin balances at the C.N.A.M. do have fronts which slide in from the top as does the reused case of the assay balance at the Mint, which may well be late eighteenth century.

60. Judson L.V. op cit. p.9. Ref.54

61. At Natural Museum of History and Technology Smithsonian Institution.
Illustrated in Frecier A.H. "United States Standards of Weights and Measures. Their creation and creators."
Pub. Smithsonian Institution 1978. No. 40. Studies in History and Technology. p.12.

62. Judson p.7. The inscription on the balances reads "BACHE-SAXTON".
Private communication from Mr W Weinstein. Historial Information Specialist. United States Department of Commerce, National Bureau of Standards, Washington D.C.

63. Letter quoted by Silliman B Jr and Goodrich C.R.(ed) "The World of Science Art and Industry. Illustrated from examples in the New York Exhibition 1853-4" pub. New York. 1854. p.121.
Silbermann used the smaller balance to adjust the platinum kilogramme weight before sending it to the 1851 Exhibition.
The catalogue of the C.N.A.M. lists two balances "...Don de l'Intendance de Poids et Mesure des Etats - Unis d'Amerique ..."
No. 4585 and 4586.

64. It has only been possible to give a very brief summary of the life and achievements of Hassler and his successors in this chapter. A full account of the early years of the National Bureau of Standards is contained in the articles cited, and extends far beyond the balances mentioned here.

65. Unsigned. Science Museum. Inv. No. 1876/227.

66. Kellys Directories for these years give his address as 17 Poultry until 1828 and No. 21 Poultry (larger premises?) thereafter. Bearing in mind the usual limitations of such directories the actual dates may predate those given by a year or two.

67. These were Buss, Ladd and Streatfield, and Oertling. Further reference will be made to these firms later.

68. Court Minutes Vols. 3 and 4 (1739-1784 and 1784-1824) and Book of Stamps of Worshipful Company of Spectacle Makers 1765-1814. Guildhall Library London.

69. The Bakers Company would appear to have been one of these but they were fortunate in that their trade was so large and vital and their Company so old established, that applicants could be carefully selected. The comparatively junior craft of Spectacle Making with its relatively small market was hardly in the same favoured position.

70. Two entries which appear in the Records mentioned in ref. 68 above will illustrate this problem.

"11th March 1778 Josiah Spode son of Josiah Spode of Stoke in Staffs, Potter, was this day admitted and sworn free per red(emption)."

"7.1.1853 Hendry Maudsley 4 Cheltenham Place Lambeth ...Redemption..Engineer."

71. These changes and their influence on the Companies involved is discussed at greater length in Joyce Brown "Guild Organsiation and the Instrument Making Trade 1550-1830 the Grocers and Clockmakers' Companies." Annals of Science, 36 (1979) 1-34 and includes the controversy over Bate.

72. The rate of change of organisation within the City was far slower than many had feared it might be, as can be seen from this information obtained from the Guildhall. "Until 1856 it was nominally necessary for anyone practicing a trade of profession in the City of London to hold the freedom of the City, which until 1835 could only be acquired through a livery company. Senior officers of the Corporation are still (1976) required to be free of the City."

73. A Trade Card may come to light stating that he was the pupil "of the late Mr X". That Mr X was Ramsden is a possibility that suggests itself, but as Ramsden was Dolland's son in law and Dolland was the much admired Master of the Spectacle Makers and "Father of the Company" for many years, Bate would surely have claimed the connection had it existed.

74. Private communication from Mr. Green, Archivist Midland Bank Limited, Poultry.

75. Kater Capt. H. FRS. An account of the construction and adjustment of the new Standards of Weight and Measure of the United Kingdom of Great Britain and Ireland.
Phil. Trans. Vol. CXVI 1826 p. 1-52.

76. One of these Pounds, signed by Bate and dated 1824 was sent to America where it remained a Standard for coinage until 1911. See Judson op.cit. illustration p.4. and Report ... 1833 p.27.

Another accurate copy of the Imperial Troy Pound was made at the request of Dr. Moll for comparison purposes by Bate.
Moll G. On the comparison of British, French and Dutch Weights.
Journal of the Royal Institution of G.B. 1831 Vol.2. No. 4 and 5. p.64.

77. This order followed Act of 1834 requiring Magistrates to have sufficient copies of Exchequer Standards for comparison in their County. Bate made 7 of the 10 sets ordered by Middlesex at a cost of £896..19..6. Information from G.L.C. Archives Department, County Hall where the Middlesex standards are now displayed.

78. Kater op.cit. p.36-37. ref.75.

79. Science Museum London. Weights and Measures, Department of Physics contains one signed Bate, and one very similar but unsigned.
Inventory no. 1914/577 and 1914/578.

80. Bullion Office Bank of England. Illustrated London News. March 8th 1845. p.148-149. I am indebted to Mr. Keyworth, Archivist to the Bank of England for drawing my attention to this item.

81. A balance by Fiddler [sic] was presented to the Royal Society in July 1879 by Major Waterhouse on behalf of his late brother, John Waterhouse FRS of Halifax. An accompanying letter states that it "was found in an Instrument Makers shop in London, I believe by the late Wm. Gravett FRS and he was told when he bought it that the balance had a history". The balance was repaired by Cook & Son of York and was then accurate to 1/100th grain. (.0006g).
Royal Society M.C. Letter Book 1879 No's 402 and 433.

CHAPTER 4

The Chemical Balance

Summary.

Characteristics of the chemical balance.

a) hydrostatic provision

b) the case

c) beam design

d) knives, planes and arrestment systems

e) sensitivity

f) weights and riders

Balances associated with the work of Kater, Haas and Hurter, Robinson, Barrow, Bunge, Oertling, Black.

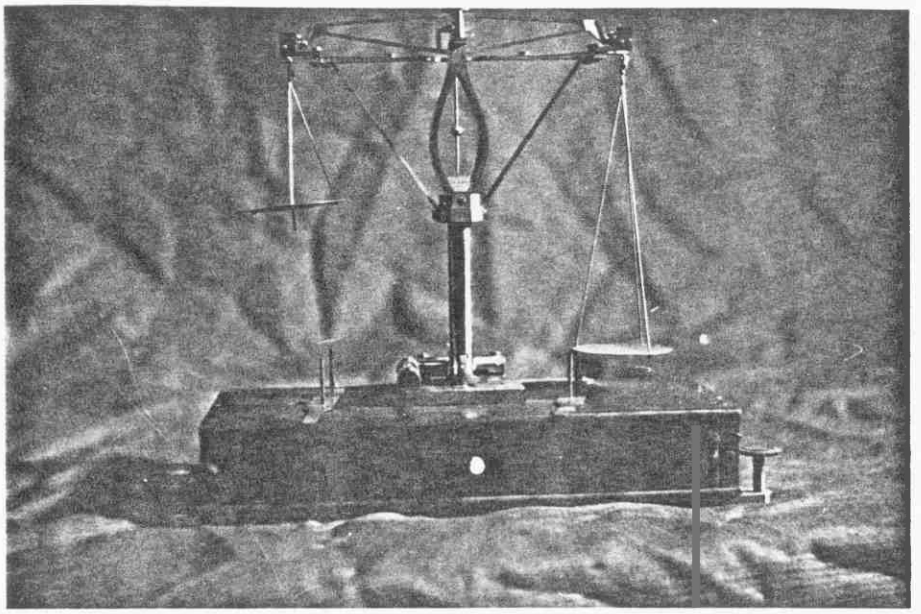


Fig. 6 Robinson

Chapter 4 The Chemical Balance

The balance that came to be used by those concerned with the study of chemistry was an instrument that developed naturally during the 19th century from available weighing instruments. No attempt was made to create the perfect chemical instrument in isolation, but there were moves to adapt and improve existing designs to accommodate new interests and new analytical techniques. As the study of chemistry itself became more diversified, a range of instruments began to appear in manufacturers catalogues, from about the middle of the century, all under the general name of Chemical Balances. Despite this diversity in design, there remained certain underlying factors, many of which had their origins in the assay and apothecaries balances, or the heavy duty balances used subsequently for the comparison of standards. The dividing line between these various types of balances became fairly clearly defined in the latter half of the 19th century, but before that time the balance used for the study of chemicals was distinguished more by the substances it was used to weigh than by any label attached to the instrument itself. The user made his choice based on the requirements of his work, and bought or commissioned a range of instruments which he considered suitable. The skill of both manufacturer and user was employed to adapt existing designs which resulted in many apparently different chemical balances proving to have much in common. In addition, all designs all share one constant aim, to achieve in weighing the greatest possible degree of accuracy. Some instruments were more successful than others in reaching this target. Some designs proved unreliable, and some operators were less skilled than others in weighing techniques, but the tradition of high standards of accuracy in weighing passed into chemical studies in the 19th century along with the basic design of the balance. These two elements provided between them an essential tool that could be used for the investigation of new substances and also created a demand for instruments which would achieve degrees of accuracy beyond those required for the quality

control of precious metals. The two elements of design and accuracy were also interdependent. Without suitable designs there could be no consistent standard of accuracy: without the traditional insistence on sensitivity sufficient for the operation in hand, design could not develop. The two together enabled chemical analysis to become a reliable tool for use in the investigation of a complex branch of science.

The most immediately obvious feature common to all chemical balances is their glass case. So much has the case become part of the accepted appearance of such instruments, that it can become a criteria on by which the balance inside the case is classified. While collecting material for this survey it was necessary to request information about weighing instruments in general from many sources. Enquiries limited to requests for details of old chemical balances sometimes resulted in items being passed over. A balance without a case was not considered to be a chemical balance and therefore could be of no interest to the enquirer. A fragile case is prone to accidental damage but the advantages to be gained from enclosing a balance ensured that the vast majority of balances used for chemical work would be fitted in this way. The harmful effect of dust and corrosive fumes as well as draughts were well understood. Only about fourteen percent of the chemical balances seen had in fact no cases.(1) There were several instances of cases with cracked or totally absent glass panes, but this damage could easily have been sustained after the balance itself passed out of constant use and into store or the sale room. Several cases were patently not the original one made for the balance, suggesting that any case however ill-fitting was considered better than none at all. The majority of those instruments without cases however were of the type already discussed, where the balance was designed to be completely portable and to pack into a fitted drawer which itself slid into a wooden cover. Unlike the majority of the otherwise similar simple lever balances encountered in dispensing work of this period, however, these chemical balances were designed to be used for hydrostatic work. Their fitted boxes contain glass counterpoises and weights in addition to the

standard beam and pans. Balances of this type were made and used over a considerable period.

An incomplete balance of the design described and illustrated by Hauksbee (2) is in the collection of the History of Science Museum in Oxford.(3) Although the centre pillar has been lost, the steel beam with swan necks, glass pear shaped bucket and counterpoise, and brass weights survive exactly as illustrated. An interesting 19th century example of a hydrostatic balance is in the same museum's collection.(4) This combines normal weighing with hydrostatic work by providing two standard pans and a lever arrestment within the centre pillar as well as the traditional glass pear and bucket and brass counterpoises. Rather more accurate results were obviously intended to be obtained from this balance as a finely divided end scale is provided. The Hauksbee type balance would have been intended to be used in the manner the designer described, mainly to demonstrate the varied specific gravities of certain pre selected substances. The other balance is 19th century and can be dated fairly closely as it bears both a trade card and the name of its owner. This fortunate combination of circumstances is unfortunately rare. The balance was made by John Newman who gives his address as No.8 Old Lisle Street, Leicester Square. This manufacturer was instrument maker to the Royal Institution for many decades until his retirement in 1866.(5) From 1826 onwards his address is given as 122 Regent Street. As the building of this new precint was subject to many delays and much disruption to trade in the area, this date is probably reasonably correct, the Lisle Street address being the premises in use by Newman in the early 1820's. This tentative date is further borne out by the owner of the balance whose name is inscribed on it.

W.Crum F.R.S. 1796-1867

It would seem reasonable to suppose that Crum bought the balance fairly early on in his career and during the early 1820's he would have been in his mid 20's. About a century separates these two particular hydrostatic balances and it seems clear that a greater degree of sensitivity had been attained by the time the later model was produced. The demand for a

facility for hydrostatic work to be available in a balance did persist throughout the century. During the latter half of the century however the two types of weighing again became separated and balances solely designed for hydrostatic work were produced particularly by Becker and of a somewhat different design. They relied on a counterpoise permanently fixed to the side of the beam thus forming a small steelyard. These instruments could often be taken to pieces and packed away, but could no longer be used for normal weighing procedures. The disadvantage of an instrument intended to cover too many eventualities and doing more of them really satisfactorily had been appreciated, and balances had become more specialised and restricted in their use.

The real disadvantage of the Newman hydrostatic balance lay in the unprotected nature of the instrument, especially when dry weighing was being carried out and the beam was liable to be affected by draughts. The obvious solution was to produce a balance with the convenience for all types of weighing as found in the Newman balance, and which was also fitted with a glass case. Within severe limitations of size which were always a problem for any instrument designed to be packed into a small drawer, a successful solution was devised by Kater. The balance he produced in 1821 was dual purpose, could be packed away into its own drawer, and also had a small but adequate glass cover. This cover had no facility for opening panels, but was merely a bottomless glass sided box which could be dropped into place over the assembled instrument. The balance had the advantage of simplicity, low cost and great accuracy. This latter point was due to its manufacture. The former points ensured its success, and all three factors contributed to the instruments many successors and great reputation. Made by Robinson, the balance gave to those studying chemistry an instrument of a size and sensitivity which had previously only been available to assayers, or in a larger size to the wealthy or members of prestigious societies. By making it dual purpose Kater extended the range of its usefulness. As an analytical technique the old established and well understood system of comparative specific gravities was very popular in the early

19th century. This factor combined with sensitivity and the convenience in use commonly only associated with highly specialised instruments made the Kater-Robinson balance a very useful new tool for those engaged in chemistry.

Kater explained that he came to design the balance due to,

> "a wish to render the hydrostatic balance less expensive without diminishing its accuracy and sensitivity."(7)

The editor of the Journal in which Kater's letter was published had remarked in the previous volume, while describing the balance in glowing terms, that

> "A good pair of scales is an essential implement to the chemist and mineralogist, but it has hitherto been scarcely attainable, except at a price far too considerable for the generality of purchasers."(8)

The success of this early model established Robinson as a balance maker of the highest quality. He produced balances in larger sizes than the 5 inch beam of Kater's design, and these larger balances had cases with doors in the end walls of the case. The entire glass case is however intended to be removed bodily and small clips were provided to anchor it in place.(9) After Robinson's death in 1842 his successor Barrow produced a balance with two glass doors on the front face of the case.(10) The doors however have been deliberately produced of unequal width. This deliberate off-setting of the central jamb was essential if the operator was to be able to sight accurately a central pointer, and this case demonstrates the problem faced by the case designer. As long as pointers fitted to the end of the beam were a popular design feature, as they were during the late 18th and early 19th centuries, the provision of doors in the case presented no problem. Certainly there must ~~of~~ have been others apart from Hassler already mentioned who felt that closing doors contributed to the disturbance of air within the case. He advocated a sliding panel, and the solution also appears in some Fortin balances.(11) On a large balance the sliding panels do became unwieldy to the point of danger, but no reason for their absence from small balances

seems immediately apparent. Once the end pointer was replaced in popularity by the central downwards pointer, which seems to have occurred in the 1820's and to have persisted throughout the century except for instruments of the very highest sensitivity, the provision of doors became a problem. It was usually overcome by inserting a central fixed pane onto which both doors closed and through which the pointer could be clearly sighted. As both the cases and the drawers beneath the balance would all have been made by skilled cabinet makers, it seems possible that they preferred to make what was in effect a miniature bureau bookcase, rather than a sash window frame. Certainly the high quality of the joinery of many cases can still be clearly seen and the provision of numerous tiny dovetail joints in the drawers allows them to be compared favourably with furniture of the same period. (12)

The provision of a glass case, which was a feature of chemical balances, and which had undoubtedly been derived from the assay balances already in use, became universal during the 19th century. In fact only in very recent years has the design of chemical balances changed sufficiently to allow any other system to be adopted. The development of a balance in which all moving parts except one scale pan are permanently enclosed and protected, has greatly changed the need for any additional case. Although balances of the highest sensitivity still demand total cover, a wide range of instruments have been produced in recent years in which this once so obvious feature has been dispensed with. The provision of one or more fitted drawers on the other hand, also a feature of so many assay balances, gradually ceased to be of importance during the 19th century, and only half the balances seen in fact were so provided. As with the assay balance, the drawer developed from the fitted receptacle for all parts of the balance into a useful storage place for weights, spare pans, scoops, brushes, and other odds and ends. Once it was accepted that the balance was never going to be dismantled and that the balance might be transportable but was no longer expected to be truly portable, the need for a long drawer in which to pack the beam disappeared. One large

drawer, a feature of all the Robinson balances, was divided into two small drawers. This had the advantage of allowing the arrestment system to develop under the floor of the balance, to become more elaborate and to incorporate pan arrestments as well as beam arrestment. This sometimes necessitated cutting sections away from the drawers to allow the connecting rods to pass, but this was done, and would not of itself have caused the phasing out of the small drawer. It is more probable that as the century progressed the conditions of use of the chemical balance changed, while those of the assay balance or dispensing balance remained much as they had always been.

With the success of experimental work in chemistry in Germany, and the popularity of the courses run by Liebig and Bunsen, moves were made to set up similar establishments in England in which students could be trained in the study of chemistry and from this arose the Royal College of Chemistry. Many such establishments were in existence by the end of the century, all requiring numerous chemical balances. These balances were the direct successors of the ranges of balances which individuals such as Lavoisier and Wollaston are known to have owned. It was not sufficient to provide good quality instruments however. It was also essential that they be put in a separate room. This had always been advocated as a desirable practice, but instruments which could be comfortably accommodated in a small alcove when used by one owner who could only use one item at a time, now demanded a large separate room to allow several people to work at once. The assay balance however continued to reign in solitary splendour. Outside the premises of the important, but numerically very few Assay Offices, and the large but not numerous bullion dealers, assay work was not undertaken in amounts that required a firm to have banks of instruments. Each assay balance had to become its own balance room within the compass of its small case, self contained, often lockable, and completely furnished. Large educational chemical balance rooms could be provided with shelves, drawers and cupboards for the use of all. The

tiny drawer under the balance became redundant. Precious weights were not left unattended. The need for this extra storage space gradually disappeared, and the drawer by the end of the century was no longer a standard feature of the chemical balance. During the early 20th century drawers tended to disappear completely.(13)

The phasing out of the drawer or drawers certainly enabled more elaborate arrestment system to be fitted. As with the assay and dispensing balances already discussed a gradual change in the type of arrestment predominately in use became apparent during the century. The lever and string system given way to the press lever which by a see saw motion forces a bar of metal up inside the central pillar to raise the plane. This in turn is superseeded by /s the turn knob, eventually sited below the case floor, which operates cams to raise and lower both pans and beam. An alternative system which seems to have been particularly favoured by German manufacturers was to reverse the above procedure and allow the beam to drop onto the plane rather than raise the plane. This system had of course been used in the double cone beams, but had experienced problems of stability and location of the knife in the plane. These problems were solved in balances made by Ruprecht in particular towards the end of the century by providing proper arm rests for the balance beam to sit on when not in use.(14) These provided stability and accurate alignment of the beam, and when in use it was these arms that dropped away sufficiently to let the beam gradually descend onto the centre plane.

The beam of the chemical balance was always the subject of experiment and investigation. Unlike the assay balance the chemical beam had to be capable of carrying quite substantial loads throughout a long working life, and these loads would vary in size across a wide and usually unknown range of weights. The assayer could predict the mass of the piece of metal left after assay fairly accurately, because he had determined the size of the original sample. Neither the original weight nor the final weight would in

practice be very large due to the value of the metal involved and the wish to avoid obvious damage to the object assayed. The chemical balance was expected to cope with a very wide range of chemicals, some of them liquids or gases in bulky containers, and many of them corrosive. These problems led to attempts being made to try unusual materials for the beam such as wood, and unusual designs such as the double cone discussed previously, but in the majority of cases, the steel beam gave way to brass, and the solid structure to the open work lattice. Within this general pattern considerable variation remained. The possibility of aluminium being used for beams was not over looked. The preparation of this very light metal in gradually increasing quantities and decreasing price after 1855 opened up considerable possibilities in the search for lightness with strength, and these were rapidly investigated.

In 1855 the French firm of Collot produced a balance for the Paris Exhibition for that year which is described as

> "Balance de precision à fléau au 1/20e de milligramme, première balance en aluminium, construite en France ayant figuré à l'Exposition de 1855 construite par Collot en 1855"(15)

The judges in 1855 who awarded Collots a 1st class medal for their display of balances were impressed.

> "M.M.Collot exposent également un fleau en aluminium; le poli des surfaces et la netteté avec laquelle sont sertis des plans et des cônes en agate font voir avec quelle facilité ce métal peut être manié; enfin l'emploi de l'aluminium pour établir de petits poids, et surtout les subdivisions du milligramme, constituent un des résultats utiles des travaux de M.H.Deville."(16)

The jury had in fact remarked upon the one serious drawback of using aluminium at this time, which was the difficulty of working it. The skill of the firm of Collots had obviously overcome what were already recognised as problems in the way of a substantial replacement of brass and other copper based alloys by the apparently far superior new metal aluminium. Makins whose influence in the design of assay

balances has already been discussed did consider the possibility of further improving on his already excellent and light brass beam by using aluminium. Accordingly he asked Oertling who had made the original beam to repeat the design in aluminium.

> "He [Makins] then had one made for his own use in aluminium, and to this Mr,Oertling applied small ruby points in place of the steel ones. But although the specific gravity of the metal used was so low, the beam yet weighed 78 grains from the impossibility of working aluminium to so delicate a frame as brass could be reduced...."(17) (18)

Although manufacturers of balances seemed disposed to investigate the possibilities of new materials and a wide range of designs for their beams, the actual lengths of the beams remained remarkably consistent throughout the century. Nearly three quarters of the chemical balances covered in this survey had beams less than a foot long: 6inches, 8inches, and 10inches were by far the most popular sizes and account for over half of those seen. These modest sizes had the advantage first of familiarity. The hand held scale was made in the same range of sizes, and when made in the traditional solid steel was strong enough to carry most loads that would require to be weighed in the course of daily life. Although in the chemical balance the beam was permanently suspended, its strength under load was still an important factor. At the same time all beam designs aimed to provide minimum dead weight of metal or wood in order to reduce the inertia of the beam. A longer beam was proportionally more prone to this problem and less popular. Nearly all chemical balances were supplied in cases, and once the convenience of a balance that could be packed away became less important than the reliability of a balance left permanently assembled there was an additional advantage in small beam size; the shorter the beam, the smaller and less cumbersome the case. There was a downward limit in size dictated by convenience. Although numerous handscales survive with beamsof 4 inches or less, this size does not occur in chemical balances until the development of the semi

micro balance during the 20th century. A very short beam necessitates very small pans in order that the loads should not foul on the centre pillar or each other. The beam must be of extreme lightness and even apparent fragility if changes in the small load it is capable of carrying are to register on the scale accurately. Such highly specialized requirements remain an important but small section of chemical work and only a very few semi micro instruments appear in collections indicating the comparatively small market for such equipment.

The extremely short beam of the semi micro balance also highlights a problem that had long been recognised in larger instruments. In order to obtain a high degree of accuracy, the pointers must move over a finely divided scale. The finer the division of the scale, the more difficult they are to read. The large Fortin balance used by Lavoisier at the end of the 18th Century was provided with a lens to make reading easier, and optical attachments occur on some precision instruments made during the latter half of the 19th century. On the semi micro balance however some optical aid is a necessity, and on one surviving example two lenses are provided,(19), one to read the position of the pointer on the graduated scale, and the other to enable the operator first to place the rider attachment on the beam and then read its position accurately.(20) The importance of good lighting conditions is illustrated by the provision of artificial light sources in a few balances where a high degree of sensitivity was required. This useful aid does not occur on balances of the 19thcentury, since it required not only the provision of a small electric light bulb, holder and transformer with each balance, but also demanded that the premises in which the balance was to be used should have had electric light installed. From this supply the balance could then be lit, by means of the extension flex provided. Good lighting could however produce as many practical problems as it solved as the following extract from the description of a micro balance in an Oertling catalogue of the 1930's will show:-

"Prismatic reflecting micro balance.(21)
Giving direct readings to 0.001 milligram. Specially constructed for the Imperial College of Science and Technology, London S.W.7. No 55/PR. .... The balance case is enclosed in a second case (not shown) and the 12 volt lamp is attached to the outer case in order to avoid any alteration of the humidity of the atmosphere in the balance case from that of the outside atmosphere....
Price £67-10-0." (22)

If balances with beams below a certain minimum length had limited popularity, the same was true at the other end of the spectrum. Fewer than a dozen of the balances seen had beams exceeding two feet in length. Most of these, for example the instruments by Bate, Ramsden and Troughton have already been mentioned. It very soon became possible for accurate balances to be produced with beams of more modest length than that designed by Ramsden, and the very long and powerful beam became increasingly used for purposes unconnected with pure chemistry where an ability to sustain great loads beacame paramount. To this end firms like De Grave, Napier and Oertling produced large bullion balances for such customers as the Mint and the Bank of England. Some of these magnificent pieces of heavy engineering have been preserved in national collections notably that in the Royal Scottish Museum. The beam is approximately 54 inches long and the instrument is proudly labelled

"'The Lord High Chancellor' Patent
James Murdoch Napier
Invenit et fecit A.D. 1884." (23)

Such massive items had by this time ceased to have any connection with the study of chemistry having become a separate and highly specialised branch of the balance industry.

Although heavy engineering as such might appear to have little connection with or influence on the small scale world of the chemical balance, there was in fact one area where the problems of the two branches of engineering and their solutions closely coincided. Every attempt made by any designer, dissatisfied customer or manufacturer to design a better balance beam was circumscribed by the need

to produce maximum rigidity with minimum material load. The plain steel bar whose fabrication into a beam Archer had clearly described in the 16th century had been the standard pattern in beam design for centuries. The move away from steel and towards brass however opened up a new range of possibilities in design. The realisation of these possibilities in the field of beam design was surprisingly slow in coming. The advantage to be gained from the use of brass in other fields were well known in the 18th century. Brass can be turned on a lathe, cast, drawn into wire, hammered into sheets and filed into shape as well as, and often much better than can iron or steel. The intricacy of the designs of the various time pieces produced by John Harrison between 1737 and 1759 illustrate this well. Brass can also be gilded, a useful additional protection from fumes of the laboratory. It has however a higher specific gravity than iron, approximately 8.4 to approximately 7.5, and would therefore only constitute advantage in weight over an iron or steel beam if less metal was used in the construction of a beam of equal length. Ramsden's device of using sheets of metal rolled into cones to replace a solid bar had obvious advantages. It also had disadvantages which have been mentioned, and in fact provided more strength than was required in the beam which only needed to have rigidity in the vertical plane. This fact seems to have been first seized on in the balance offered to Van Morum for his collection of scientific instruments in 1793.(24) The balance which has a 12 inch beam is signed Haas and Hunter, London. The beam itself could have been formed by taking Ramsden's double cone and slicing away all the metal from the front and rear faces, leaving only an elongated diamond shaped skeleton with end pointer. The two halves of the diamond spring from a central circle of metal, two spokes of which hold the central steel knife. The next datable balance with a similar approach to beam construction of which records survive would seem to be the Nater-Robinson balance of 1821 to which reference has already been made above. This gap of a quarter of a century before such a

practical idea gained wider acceptance could be blamed on the continuing disturbed state of Europe during this period. In fact the partnership of Haas and Hurter was dissolved in 1795(25) and Haas later went to Portugal, after complaining of the lack of work in London. A similar instrument signed Hurter is at Darmstadt(24) and two further instruments and protractor and a hygrometer with the same signature are mentioned in the catalogue of Cavendish's apparatus.(26) As none of these items would have been well known, or even known at all in London, it is quite possible that the innovation of this design passed unnoticed until Kater and Robinson produced between them a beam

> "....made so light as to be extremely sensible, it is at the same time rendered sufficiently strong by its form...."(27)

The illustration published in 1821 of the balance made by Robinson for Kater shows the beam to be of very simple construction(28). This design was repeated with only minor modifications in all surviving Robinson balances as well as those of other manufacturers throughout the century. A bar of metal usually but later in the century not exclusively of brass was used, of sufficient length and perhaps $\frac{1}{4}$ inch thick. The width of the bar which would eventually form the vertical plane of the beam would have been about an inch in diameter. From this plain oblong of metal as much material as possible would be removed. The widest portion of metal remained at the centre of the beam to accommodate the knife, the beam being tapered towards the ends. Just enough support was left along the length to prevent the structure from collapsing, or more seriously, warping unnoticed under load. The horizontal thickness of the metal could be further reduced away from the centre, and the final design resembled two elongated isosceles triangles joined at their bases. This structure represented all that remained of the original Ramsden double cone design.

The actual proportions of metal to space in a beam of this open work pattern depend on the use, and therefore the loading, for which the beam was designed. Robinson balances with a $10\frac{1}{2}$ inch beam were given an additional

supporting bar on either side of the central knife and little less than half way between the knife and the plane.(29) The beam makins designed for his assay balance however and to which reference has already been made had several extra braces on either side of the centre, dividing the triangle vertically but the whole beam in makins design was reduced to such narrow bands of metal that the entire structure appears to be no more than a fragile web. The same double triangle shaped beam with the addition of a stabilizing support running from each pan hanger to the central pillar could be used on a balance designed to take loads of up to 2lbs. in each pan.(30) The additional support ensured that the loaded pans did not weigh on the beam until the arrestment mechanism was carefully released thus avoiding excessive wear; in use the beam alone took the load and was accurate to 1/100 of a grain (.00005g). This same design, but with the parts manufactured in cast iron instead of brass could be used for bullion balances.(31)

It would not have been surprising if the double triangle beam pattern which had been shown by Robinson to be simple and effective over a range of popular sizes, had rapidly ousted all other designs from use. In practice this did not happen. Despite the undoubted success of the pattern and its frequent appearance in collections of instruments of the 19th century and early 20th century, only half the chemical balances covered in this survey are of this type. The whole group divides itself almost evenly into balances with lattice beams of the type just described, and those with beams that are basically plain metal bars. The persistence in popularity of the plain beam of the type known to Agricola and Ercker was only to be expected. Formerly made of steel, and during the 19th century increasingly made of brass, the plain beam had ease of manufacture, strength and familiarity to recommend it. It had a very long and successful manufacturing life. The gradual phasing out of such a venerable design might have been expected, but in common with designs of assay balances which also showed little change, satisfactory performance was

considered more important to the purchaser than novelty of design, and plain beam chemical balances continued to be offered for sale throughout the 19th century, and also well into the 20th century. A diagram attached to a specification issued in 1909 by the Royal Arsenal Woolwich shows such a balance. It was required for weighing samples of cordite for testing and had to be sensitive to ½ a milligramme.(32) A note added to the reissued specification in 1921 remarked that,

> "The particulars of balance No 000 as described in Mr.Oertling's catalogue, do not differ materially from those of the pattern."(33)

This specification was reissued at intervals, the seventh issue being in 1943 with only minor modifications. Balances of this basic design continued to be manufactured in large numbers after this date and were to be found in school laboratories for many years after the end of the last war.

The solid bar beam might have retained its popularity during the 19th century to the exclusion of all other designs had not a demand grown throughout the century for greater sensitivity in chemical balances. The desire for greater sensitivity was encouraged by the move towards the use of smaller samples of chemicals in analytical work following the work of Berzelius. The mass of a bar of metal from which a beam is formed must be deflected by a constant measurable amount when constant loads are applied to it. The greater the total mass of metal involved the more difficult it is to ensure this, particularly with very small changes in load. Kater's satisfaction with the beam made by Robinson was partly due to the fact that it achieved "accuracy and sensitivity" at a modest price, the beam being made of bell metal,

> "which combines the essential desideratum <u>lightness</u> with the requisite degree of strength."(34)

This Robinson balance was accurate to 1/100 of a grain (.0006g) and a set of adjusted weights from this size upwards to 100 grains was included in the total cost of £o.(35) By 1829 however, less than ten years after the development of the original balance, balances "made and sold by T.C.

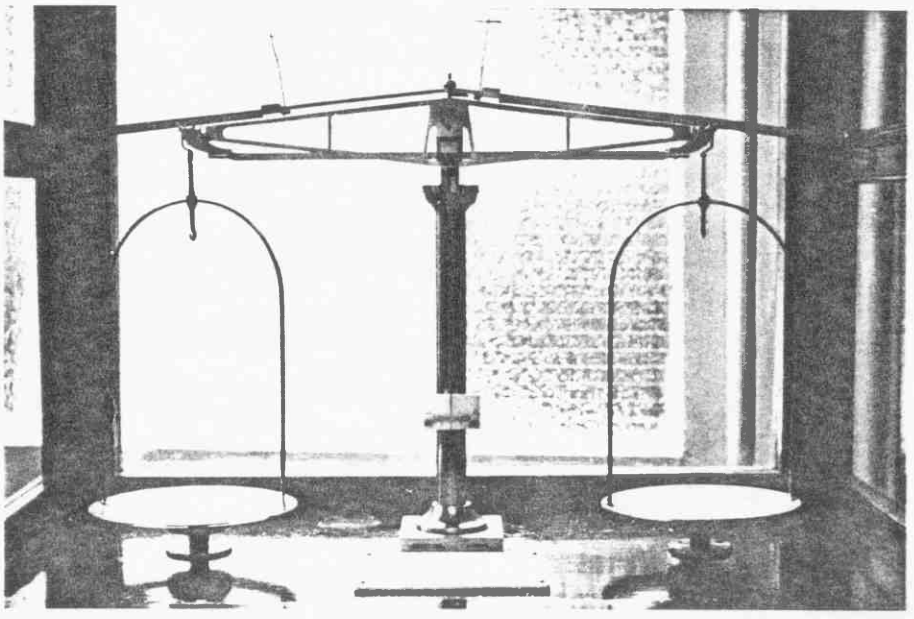


Fig. 7 Oertling

Robinson" were being advertised with a greater sensitivity than claimed in 1821.

> "They will indicate .001 of a grain with 1000grain"(36) (.00006g)

By 1851 this higher standard of sensitivity was assumed to be the norm for any good chemical balance, by the jurors inspecting the exhibits at the Great Exhibition, and the design features which Nater had failed to find readily available and which he had had incorporated in his own new pattern were by that time accepted as desirable in all balances of good quality. The catalogue for the Exhibition of 1851 lists the balances exhibited by Oertling. These included one chemical balance accurate to 1/200 grain (.0003) when loaded with 1lb., and one accurate to 1/1000, ~~for~~ when loaded with 1000gr. The comment was added,

> "The value of such balances is perceived in delicate chemical analyses, in which a fractional error has often led to important mistakes. R.E."(37)

Many variations in beam design were made by other manufacturers particularly during the latter half of the century. Lightness with strength was the constant aim, and many varieties of lattice structure were evolved, some of which were developed into distinctive patterns throughout a manufacturers range, enabling some makes of balance to be identified by their design. All beam manufacturers were faced with the same type of structural problem as beset bridge building engineers of the same period. The scale of the engineering involved was vastly different, but the problem was basically the same. The similarity between some of the lattice patterns evolved by balance makers for beams and bridge designs in the same period is striking. The increasing use of wrought iron and cast iron in bridge structure as a replacement for the traditional brick and stone had had considerable effect on bridge design producing longer spans and an open work structure; the benefits to be gained from using materials in a new manner were obvious to all. In London alone there were five such bridges constructed of wrought or cast iron sections by the end of the century.(38) By the end of the century however new developments in balances

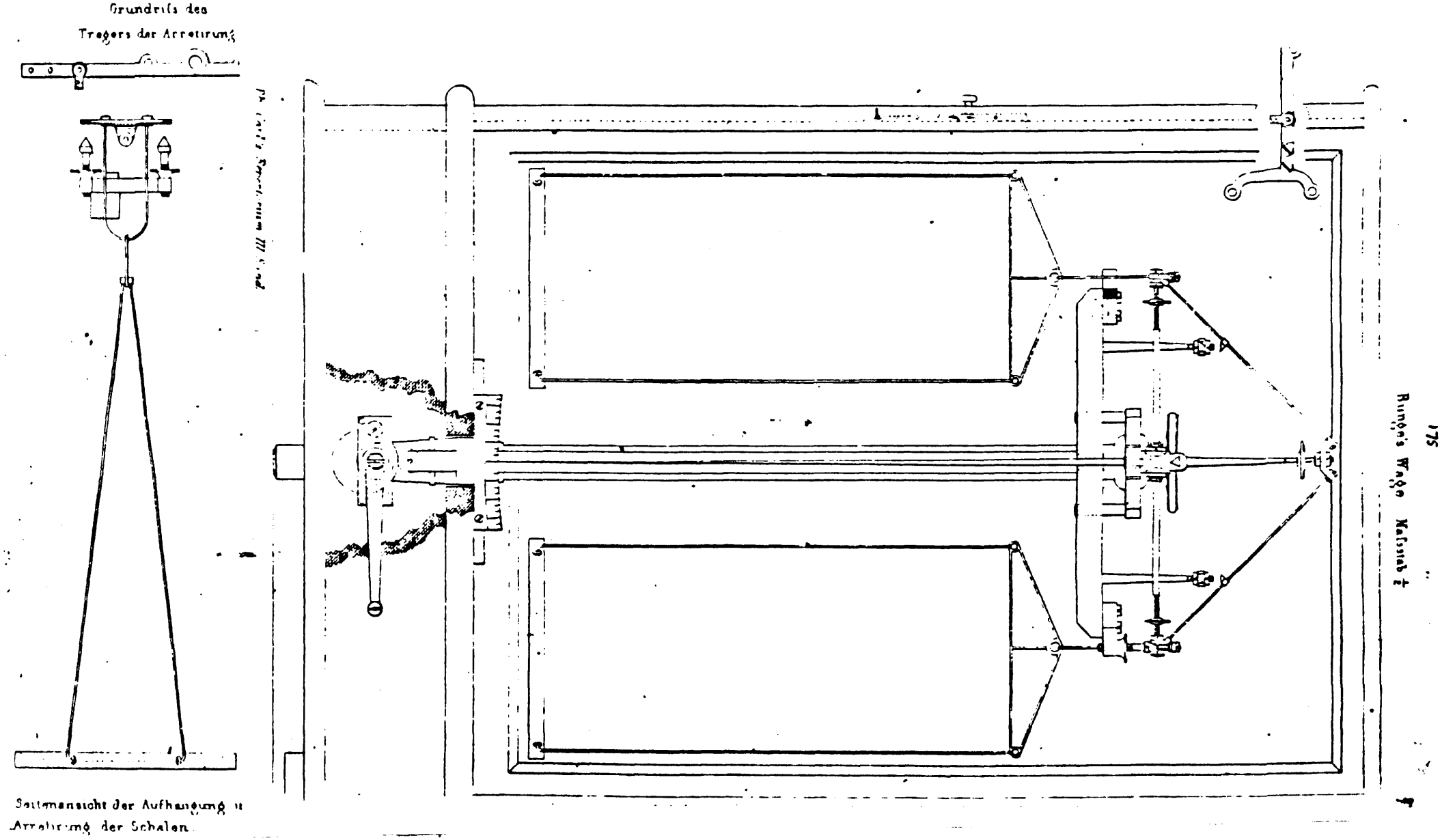

Grundriss des
Trägers der Arretirung
Seitenansicht der Aufhängung u
Arretirung der Schalen
Bunge's Wage Maßstab ½
175

Fig. 8 Bunge

design had already taken place which eventually resulted in a move away from long light openwork beams towards bars. These bars were not however plain oblongs of metal of previous centuries, but short light strips which formed the base of a triangular structure, the short beam.

The development of the short beam balance represented another attempt to produce a light weight beam that was also reliable in use. Designed by Paul Bunge in Hamburg and published in 1860(39) the beam resembled the centre section of a lattice long beam. If three quarters of such a beam were shorn away from each half leaving only the inner most triangle of the lattice, and this complete triangle, now composed of two isometric right angled triangles, was slightly enlarged to give a total base length of about 5 inches the short beam would result. Bunge claimed his design combined a high grade of sensitivity with a reduction in the time taken for the beam to come to rest. This not only saved time, but also of course wear and tear on the bearings and promoted greater reliability. In his design the pans are suspended from planes resting not on knives but on hardened pins, reminscent of assay balances already discussed.

The degree of influence on balance design achieved by the introduction of the short beam in this country does not appear in the light of surving instruments to be very great. Of the many chemical balances covered in this survey, if instruments by such manufacturers as Robinson which can be confidently dated to the early part of the century are disallowed, balances with beams of 6 inches or less are not numerous. Although short beam designs appear in the catalogues of Oertling's from about 1880 onwards, few seem to have been purchased and even when every allowance has been made for partiality of survivals, only 16% of surviving instruments can be classed as short beams and of this handful several are 20th century products. They are by such manufacturers as Kulhman, Sartorius, Stuckrath, and of course Bunge. There are only two Oertlings. It would seem that until the 1920's, fifty years after Bunge's original idea, those wishing to use a short beam purchased one of

the many excellent German designs. The majority of purchasers continued with traditional patterns. The contrasting success of the short beam in assay balances suggests that as so often happened with revolutionary designs, parts of the design were found to have valuable applications for instruments quite other than those for which they were originally made. These parts were absorbed into the general stream of design changes and development and their origins almost forgotten, until changes in patterns of balance use brought them to the fore once more.

The need for a balance to be accurate to very small units of weight produced problems which could not in the end be solved solely by developing light beams and reducing friction and inertia in all moving parts. These changes all helped, but a limit was rapidly reached beyond which the balance became hampered by the limitation of its weights. Small weights were traditionally made from lengths of fine wire. When supplies of malleable platinum began to become available in the early 19th century, platinum was used for weights by such manufacturers as Robinson.(8) This metal had considerable advantages in use. It was not prone to the problems of atmospheric corrosion which beset other metals commonly used for weights, but it was very dense and even short lengths of wire might well have a mass greater than that required. The idea of placing 'weights' directly on the beam had been used for many centuries in the steelyard. The transfer of this idea to the beam balance was not difficult and could be expected to arise when a demand for greater sensitivity made it necessary. One half of the beam was accurately divided into ten sections and the metal marked off with a small groove. Into these grooves the rider, a piece of bent wire of known mass, could be lodged. By careful manipulation differences in weight equal to 1/10 of the mass of the rider could be added to the beam.(40)

In practice the system needed some degree of care in operation. A beam balance is not a steelyard and the rider, to be effective, must be made of a short length of thin wire, not a lead weighed plumb bob. The rider is therefore not easy to manipulate manually without causing vibration in the beam itself. The beam cannot be cone shaped, and

should for preference be made not of steel but of brass which can be more easily marked off. It is also essential that the beam should have been well designed and set up before any rider be brought into use, as the system depends on the beam itself being symmetrical and the knives correctly set. Only if the facilities exist enabling necessary adjustments to be made to obtain these standards in the balance, can the addition of a rider be expected to add to its performance. The rider is an additional benefit, not a replacement for careful maintainance.

Of the surviving Robinson balances only the one at Edinburgh is provided with a divided beam and this may be a later addition. The exact date of the introduction of the rider into common use in this country cannot be stated with certainty. By 1851 however the device if not commonplace was at least not considered by the Jury reporting on the exhibits to require any special commendation for novelty of design. The only reference made to a rider on a balance is contained in their description of the prize winning exhibit from Oertling.

> "The beam is graduated and small differences of weight are determined by a small weight that can be placed upon parts of the graduated beam."(41)

No mention is made of the presence of this device in the instruments of other manufacturers. This cannot however be taken to show that no such refinement was present. The Jury Report by its very nature could only summarise some details of some selected exhibits chosen from those offered by numerous different makers, and it would be wrong to assume that this reference implies exclusivity or innovation. Ten years later however the picture was quite different. What ever the exact state of the development and introduction of the rider in 1851, by 1862 it was "well known".

> "In several of the first class instruments the well known plan is adopted for decimating the value of the smaller weights, by dividing one half of the beam into ten equal parts. On the points of division, or at any intermediate point, a small weight may be deposited, and subsequently removed, by an arm projecting

> laterally from the end of a sliding rod. This apparatus is a convenient adjunct to a good balance." (42)

This clear description high-lights the real reason for the success of the rider as an adjunct to the balance. It was not the adaptation of the steelyard weight to the delicate chemical balance which was the crucial factor, but the development of the mechanism for moving so tiny a piece of wire and placing it accurately on the beam. Balances with a divided beam but no mechanism for moving the rider were produced. One such balance with a lattice beam and swan neck ends is in the collection of the History of Science Museum in Oxford.(43) In attempting to use this balance it soon became apparent to the writer that the provision of a rider sliding mechanism, while not essential, was greatly to be desired. The need for a high degree of accuracy in marking out the beam was also evident, as the Oxford instrument does not give reliable readings for different rider positions. Its accuracy when new was no doubt considerably greater, but reasonable skill in the manufacture was obviously essential.

The provision of a rider beam as a separate entity from the mechanism for moving it was not unusual practice. The earliest surviving Oertling catalogue c 1850 (44) lists separately balances in which,

> ".. the beam is divided in 10 parts from the centre to the end;.."

and those in which,

> ".. the beam is divided; apparatus fixed in the case above the beam for moving the 'rider';.."

The latter is dearer. This distinction persists in Oertling catalogues throughout the century. The number of balances with divided beams but no mechanism soon becomes a small proportion of the ever increasing total of those with such extras, and there is the occasional footnote in the catalogue adding that this mechanism can be provided as an optional extra.

By the end of the century the division of the beam into 100 divisions enabling the rider to provide an additional fractional reading had been introduced.

Difficulties were encountered however in finely dividing a length of metal which due to the double triangle construction of the beam was inevitably sloping. Where feasible i.e. in the lightly loaded assay balance the sloping top line of the beam was straightened. In the heavier duty chemical balance rather than risk stress in an unsupported overladen beam, the rider bar was introduced. This was a strip of very light metal carefully and accurately divided and placed above and in front of the actual beam to which it was attached at each end. Inevitably with the development of the short beam balance the rider bar came more and more to dominate the design. From being a useful but optional extra, the minutely divided bar of metal became the central part of the beam. Particularly in designs by German manufacturers, notably Bunge, the provision of a metal plate to hold the knives for the central fulcrum and pans seems almost an appendage tucked under the rider bar.(45) Earlier balances by the same manufacturer had reduced the beam to a triangular group of thin rods of metal, all that was left of the original braces, which now serve to counter balance the forward drag of the all important rider bar.(46)

The success of the rider in enabling finer units of weight to be accurately added to the load further served to stress the importance of reducing all internal friction in the beam and bearings to a minimum. Small units of weight could not be expected to overcome large degrees of inertia, or more important. , to do this consistently. The gradual move away from steel knives and planes to agate or 'crystal' ones was a natural result. The gradualness of this move can be seen from the fact that the balances covered in this survey divided themselves into three groups of almost equal size; those with steel central knives resting on steel supports, those with steel knives but agate planes, and those with only agate knives and bearings. Given that balances made after 1850 tend to survive in larger numbers than those made prior to this date, the third group should dominate the survey. The fact that this does not occur suggests only a very gradual transition to all agate system occured which cannot be entirely explained on grounds of inate conservatism.

As might be expected those balances with all steel system tend to be those from the late 18th century and early 19th century. These balances are direct descendants of those used by Ercker where a steel knife is lodged in a steel loop which not only holds the two parts together, but also acts as a self locating mechanism. Several balances in the collection at Oxford are of this pattern.(47) On a grander scale the balances of Cavendish, Fidler and Fortin already referred to, use steel, but the loops of metal have been replaced by flat polished planes. The problems of accurate location that this change produced are neatly avoided in a balance said to have belonged to Davy. In this the tear drop shaped central knife rests on a slightly concave 'plane'. (48) The steel system persisted throughout the century in the massive bullion balances already mentioned, where the size of the load involved made any use of the hard but relatively brittle agate unsuitable.

The introduction of agate conferred certain advantages to the balance. The corrosion of steel was rapid in a damp atmosphere and aggravated by inadequately ventilated fumes from decomposing acidic compounds. Agate was unaffected by these problems, and although a separate room in which to place the balance away from the usual laboratory atmosphere was an agreed advantage, it cannot often have been possible to provide it in the cramped and difficult conditions in which many people worked. The contrast between the suite of rooms provided by the University of Edinburgh for Hope in 1823 and the accommodation used by Berzelius in the same period is striking. Hope had two laboratories, two apparatus rooms, and two classrooms, one of which could accommodate 530 students. His carefully planned and executed demonstration lectures commanded large audiences for many years.(49) He did not encourage practical work for students except in very small groups taken by his assistant Reid, probably from the realisation that this would require an outlay in bench space and additional apparatus which would appear out of all proportion to the number of students involved and their likely fees. Berzelius on the other hand did take students, though

very few in numbers. The description of his laboratory in the Academy building in Stockholm also in 1823 is given by Wöhler.

> "The laboratory consisted of two ordinary rooms with very simple equipment: there were neither furnaces nor a hood, no water or gas pipes. One of the rooms was furnished with two ordinary long tables of spruce; Berzelius had his seat at one of these, and I was seated at the other....In the other room stood the scales and some cupboards with instruments and apparatus and a little workshop with a lathe." (50)

In the nearby kitchen the housekeeper the redoutable Anna both cooked meals and kept the sand bath permanently heated. Under such conditions the replacement of steel bearings in the balance by agate would seem to have been highly desirable.

The balance which Ramsden made for the Royal Society in 1787 would seem to be the earliest surviving balance to incorporate agate in its construction. A few years earlier in 1781 however Magellan (51) had put forward a design for an assay balance incorporating an agate plane. The idea can be said to have been in the air towards the end of the 18th century but no certainty exists that Magellan's balance was ever constructed. Other balances no longer extant may have incorporated this idea, and this suggestion is somewhat strengthened by the fact that the description of Ramsden's balance in 1788 and the reference made to it by other contemporary observers do not imply that the plane, of "pierre fine, très-dure" was something new and remarkable. The interest expressed in the description for "une nouvelle forme" was applied to the design of the cone beam itself, which was a novel idea, rather than to the central bearing. The important thing to the author of the description of Ramsden's balance was not that the plane was made of polished stone, but that it was cut as a plane surface,

> "parce qu'il [Ramsden] a très bien observé que souvent le couteau ne tombe pas toujours dans la partie la plus basse de l'anneau, où on le place ordinairement, ce qui cause une erreur considerable." (52)

The balances made by Robinson in 1820 were

also designed to have steel knives and an agate centre plane. The knife was no longer of the tear drop shape usually adopted by previous balances but,

> "a piece of very hard steel of an equilateral triangular form, passing through the beam and bearing on agate planes; the knife edges are ground to an angle of 120°, which has been chosen thus obtuse from the liability of a more acute edge to be broken when suddenly lowered upon the agates."(8)

The list of Robinson balances offered for sale in 1829 gives steel knives and agate planes as standard but adds,

> "with crystal knife edges instead of steel each size one Guinea extra."(36)

Of the few surviving Robinson balances none in fact has "crystal" knives. This could be the effect of chance, or the reluctance of customers to spend an extra guinea for an additional benefit they considered unnecessary.

The introduction of agate into balances in any large scale seems to have been hampered in the early part of the 19th century by lack of suitable raw material. Agate was mined from the area of Idar Oberstein in the Saar region of Germany, but suitable supplies in Britain were limited to the decorative but relatively small stones found near Montrose. In 1827 however abundant supplies were located in South America in a belt of deposits extending across the Rio Grande do Sul from Porto Alegre in Brazil to Salto in Uruguay. This was the origin of the "Brazilian agate" used increasingly for knives and planes in the 19th century. Unlike the German agate, the Brazilian product was of an uninteresting dull grey colour, clearly seen in balances of the period. In addition to its abundance, the Brazilian product however was also easier to cut, and despite the problems of transport over so long a distance, the large agates enabled commercial production to expand rapidly.(53)

The use of agate for the central planes of chemical balances rapidly became wide spread. By 1850 De Graves were among the few firms who appear from surviving instruments to have retained the traditional steel pattern throughout their range. The earliest surviving Oertling catalogue c 1850 lists ten balances, other than those

specifically intended for bullion or assay work. Of these ten, the three most expensive designs are supplied with"agate planes". By 1870 the proportion had risen to five out of ten, and by 1890 of the twenty three chemical balances offered, only seven do not mention agate in their specification. (54) The contrast between that which is offered for sale to that which is purchased is of interest. Even when every allowance has been made for the chancy nature of survival among instruments, it is noticeable that of the large number of 19th century Oertling balances which survive and were not designed for assay or bullion work, only two balances signed by Oertling appear to have a steel centre plane.(55) This would appear to indicate the long working life obtained from agate and also a definite preference for agate planes by customers despite the additional cost.

This preference extended in a less marked fashion to agate knives. Two thirds of Oertling's balances offered for sale in 1890 were supplied with agate planes, but slighty less than half the group offered agate knives as well. This proportion is reflected in the surviving balances almost exactly if the instruments of all manufacturers are considered together, but it has to be admitted that Oertling's own customers showed a decided preference for all agate systems; less than a third of the surviving Oertling balances have steel knives. Mr. Oertling's customers would seem to have taken the advice of his catalogues.

> "...the three edges of the beam are made of agate, so that all the working parts of the instrument are most effectively protected against the fumes of the laboratory, or the effects of a damp climate." (c 1865)

Mr.Oertling's many customers did have a great advantage over many users of chemical balances, and this advantage they shared with those who used his assay balances. The Oertling firm, as revealed by their account books, maintained a very large and flourishing repair and maintenance section in their undertakings. Rapidly improving systems of communications enabled balances to be serviced at regular intervals and this facility was well used. The account books

show that most of the balances sent in were as might be expected of the firms own manufacture, but other makers were sometimes included. Local suppliers of laboratory equipment in other parts of the country sometimes acted as clearing houses, forwarding balances to London for specialist treatment.(56) This maintenance service though very valuable was not of course free, and was inevitably limited to the balances of those customers, who could afford both the original outlay and the service costs. Less fortunate owners has to find alternative means of maintaining their instruments in good order and the central knife edge would present both the most difficult and the most crucial area on which to do repair work. In addition to fair wear and tear, there is always the possibility of accidental damage to the knife edge and it has then to be reground. This regrinding can prove difficult.

> "The agate knife edge adds nothing to the precision of a newly made balance but it always remains clean, while a steel knife, in a chemical laboratory more especially, is apt to rust. Steel knife edges are generally ground to an angle of 60° (or 90° for very heavy charges). In agate knives, as made by Oertling, only the body of the agate prism is ground to 60°, while the edge is formed by two narrow facets, inclined to each other at a far more obtuse angle. Such an obtuse edge stands many years constant use without wearing out." (57)

Despite the undoubted long life of an agate knife, the difficulty of reproducing the original edge structure in a material with which the average repairer could hardly hope to be familiar and which was also irreplaceable, must have encouraged many to retain the familiar and easily sharpened steel knives. This compromise of steel knives and agate planes achieved the best of many worlds and occurs in many balances. The greater tensile strength of steel over agate enabled steel knives to be held in place in a beam relatively easily with small bracing screws. Agate was usually mounted in brass which was in turn held in position. The mobility of steel was made use of in some balances in which it is

found that the steel knife whether of equilateral or diamond shaped cross section is fitted with all the 'corners' ready sharpened. The only purpose for this must have been to enable the owner to turn the knife as required.(58) The provision of a spare knife among the items stored in the drawer of another instrument from Vienna suggests a reasonable supply of spare parts was used as an alternative form of maintenance.(59)

If the designs for central knives and planes were relatively uniform, the methods of attaching the pans to the ends of the beams were many and varied. The nice simple S hook which looped the top of the pan hanger on to some link or bar at the end of the beam was replaced in Robinson balances, and many of those who came after him by an equally simple J system. This was really the central knife and plane turned upside down and moved to the end of the beam. The edge of the knife, set parallel to that of the central knife now pointed upwards, and the pan hung from a loop formed by the toe of the J whose top bar was a piece of agate. This agate was usually fixed traditionally with sealing wax on to a brass mount. The system could be endlessly varied. Just as the central plane could be replaced by two small circular discs of agate across which the knife rested, so the end plane could be formed of a cylinder of agate on its side, with the underside not cut with a horizontal face but slightly hollowed forming a shallow inverted V shape. This gave some degree of centering for the knife and plane encouraging them to take up the same position each time.(60) This system made it very difficult however to judge whether all three sets of knives and planes when in use were exactly parallel. Dittmar writing in 1890 did not approve of this system, maintaining that a proper arrestment system would stabilize the swinging pans and ensure that as their weight was taken up by the beam they would come to rest fair and square on the knife beneath.

> "The general plea against the system [of knives and planes] was that flat end-bearings were subject to rotational movements;[but]... a <u>really plane</u> bearing as a matter of fact, does <u>not</u>

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rotate on a <u>really</u> <u>straight</u> knife-edge, even if the pan oscillates strongly..." (57)

To help the pans stabilize, it was necessary to hold the plane mount still between weighings. The holding device, or arrestment arm, had to disengage, preferably just slightly before the central knife and plane met. One knife and plane system replaced the U plane holder by an inverted stirrup shape. The bar of the stirrup held the agate and could be extended to carry two small glass or metal spheres. These rested in shaped holders in the top of the arrestment arm, one holder having a concave surface, the other a groove to ensure the correct angle for the loop holding the pan.(61) The loop itself could be extended to hold lower hooks, or loops at right angles to the main loop, through which yet more loops could pass forming a type of universal joint. One suspects that all these increasing elaborations could have produced more problems from inertia than they solved in flexibility. The arrestment system that incorporated two pin heads or spheres as locating devices is reminiscent of a similar system used earlier in assay balances. This transfer of design techniques from one group of balances to another is also seen in replacement of the knife edges by two steel pins which bear upon the agate,(62) and is further evidence of increasing tendency towards a partial merging of what had been two distinct lines of balance development.

The progressive move of chemical balance makers towards first the short beam, then to the semi micro instrument, moves encouraged by their users, blurred the distinction between the assay balance and the chemical balance during the early 20th century. This move was the result of a demand for ever higher degrees of sensitivity coupled with smaller units of load. Better performance in terms of speed of weighing, sensitivity, accuracy had been the aim of all design innovations in chemical, just as in assay balances. The degree of success was always uncertain, depending as it did on so many variables; the skill of the operator, the working conditions, the standard of maintenance of the

the balance, and the far from standard quality of the chemicals involved. It is also true that remarkable scientific progress was achieved by chemists whose apparatus would seem with hindsight to be totally inadequate(03) and yet was judged by them sufficient for their needs. Since the likely performance of a balance was usually expressed in terms of its sensitivity in much the same way as the power of engines might be compared, a consideration of sensitivity is necessary.

The sensitivity of an old balance is the one aspect of its structure most likely now to be at variance with/the figures originally claimed for it by either its owner or manufacturer. Most other alterations, modifications and adjustments to an instrument can be noted, and in considering a number of similar balances the variation can be allowed for. The "original" pattern may indeed no longer exist, it may have been completely overlayed by an improvement but one can make a reasonable guess at the original design and judge how far the changes were beneficial. Sensitivity falls into a different catagory. It depends on the condition of the knives, planes and bearing, the degree of rest on the steel, the lack of oil on the arrestment mechanism. Unlike the damaged hook, missing pan, broken pan hanger or frayed string it cannot be replaced. One cannot resharpen the knives, lest they end up in a better condition than the original grindstone was able to achieve. In many cases because some essential component has been lost or damaged it is not possible now to assess sensitivity at all. In some the mechanism has siezed up due to bad storage conditions, dirt, damp and general neglect. A good 2/5ths of the balances seen were in these unfortunate categories, and this situation seems more prevelent among chemical than among the very highly specialised assay balances. There one often had the feeling that the assay balance, if not actively and obviously still in use, had certainly been in use yesterday, or at the latest last week. Perhaps their highly specialised field of use made them unsuitable for any change of occupation or owner, and assay balances were kept by the firm until superseded, and then "retired" to storage. As the

quality of work required from them was the same at the end of their useful career as at the beginning, the degree of maintenance was high and sustained until the end. The chemical balance however, often had many users, and several owners; it could and did progress down the hierarchy from "best and newest" to"rough weighing only". The varying degrees of work required in a chemical laboratory ensured a long and "wearing" useful life for the chemical balance, but a decline in status could be equated with a decline in obtainable sensitivity, and only when it was no longer suitable even for the roughest work was the instrument discarded. Given all these parameters it is not surprising that it is difficult to obtain a clear idea of the original sensitivity of a group of 19th century chemical balances. What is surprising is that provided due allowance be made, some conclusions can be drawn even with a relatively small statistical sample.

Sensitivity "as found" in late 18th century and 19th century chemical balances produces results across a large scale. Some balances require as much as .1 gramme to produce any reasonable deflection in the pointer; others obviously are still capable of producing results with changes in load of .0001g or .00001g if properly adjusted.(64) What does emerge is that loads in the region of .006g (1/10 gramme) represent a minimum load sensitivity for the majority ($\frac{3}{4}$) of the balances which it was possible to check. If however the results are divided roughly between those from balances made before about 1850 and those made after, there emerges in the later period a substantial group of balances with figures far in excess of .005g. None of the earlier balances achieve these results. This may indicate nothing more than the comparative youth of the "newer" balances. It does suggest however a vast increase in original sensitivity. This improvement in quality was helped by finer workmanship, the introduction of agate bearings, the rider mechanism, and the smoother arrestment systems. All of these have enabled the post 1850 balances to retain a very high degree of accuracy, even under very difficult conditions,

and suggest that a substantial group of very accurate balances were being produced and purchased in this period, as well as the vast majority of good middle range instruments.

Any attempt to establish by how much the sensitivity has fallen off is fraught with difficulty. This change so obviously varies from balance to balance that a simple "% drop off" factor is hard to determine and no figure could be used with confidence as its reliability would be so difficult to establish. The range of sensitivities originally offered by balance makers can however be found in surviving manufacturers catalogues, and where these extend over a period of time, changes in market demands can be found. Until 1870 the pattern in fact remains remarkably consistent. The two most popular sensitivities from catalogues of Robinson, Griffin, and Oertling appear to be .001 - .0006g (1/50 - 1/100 grains approx) and .0001 - .00006g (1/500 - 1/1000gr). Robinson balances all fall into this latter group. J.J.Griffin and Sons who built up a flourishing business supplying chemical apparatus during the 19th century list balances in their catalogues.(05) Some balances in later catalogues are listed separately and are Oertling balances, but a group of balances made to Griffin's own designs are also included and the senstivities of both groups of balances follow the pattern of Oertling and Robinson products in general. In the last years of the century however a new group of balances emerges in Oertling catalogues with sensitivities in the range of .00001g (1/5000gr) and this trend continues into the 20th century.

A comparison of the sensitivities of chemical balances as found with those claimed by three manufacturers does lead to some general conclusions but it must be remembered that these are based on two sets of averages from groups by no means entirely similar in composition. Many manufacturers balances survive for which no catalogue exists, and an unknown number of balances were offered for sale, but not necessarily purchased. Within these limits it is possible to suggest that sensitivity has declined ON AVERAGE by about 10-15%. The substantial groups of balances with sensitivities

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offered in the range .00005 - .00001 g. and .001g corresponds roughly to the majority of sensitivities found, which seem to group themselves round the .0001 - .0005 g. and .005 - .01 g mark. A far more valid comparison would be obtained if it were possible to extract instruments for which original catalogues are extant and compare their performances. In practice this group of instruments would not be very large as 19th century manufacturers catalogues are not numerous particularly for the early part of the century, and are frequently lacking in illustrations. This makes it difficult to determine exactly which model from a range has in fact survived. Model numbers were known to the manufacturer, and frequently to the purchaser(66), but metal plaques bearing specification details fixed permanently to the instrument case appear to be a post First world war feature. Two examples of instances where it is possible to compare the ideal with the actual figures are available however, and illustrate the inadvisability of applying the above figures rigorously to any individual instrument.

The manufacturer Robinson offered a very limited range of balances, differing only in the length of their beams and all were sensitive to 1/1000 grain (.00006g). (67) Two of these survive in good condition.(68) Of these, one was made after Robinson's death in 1841 and is signed Robinson and Barrow, the other signed by Robinson seems likely to have been bought about 1830.(49) Both are still sensitive to 2m.g. per division of the graduated scale below the pointer. While this is a great achievement in itself, .002g represents a considerable decline from the original sensitivity of .00006g. By contrast an Oertling balance for which a catalogue reference can also be found shows a different picture. The instrument is dated 1893 (69) and appears in the Oertling catalogue of 1891 at six guineas, a "No 2". The rider slide was an optional extra not chosen by the purchaser. The balance was auctioned in 1928 and subsequently stored with the Wellcome collection after a working life of about thirty years. Despite its steel centre knife, without any adjustment it gives a sensitivity in excess of .005g + rider. The catalogue claims .001g for this model.

As direct comparisons between claimed sensitivities for designs and existing instruments are difficult to obtain, it is fortunate that some additional information is available from contemporary accounts. These also illustrate the attitude of balance users to the instruments available to them. One such writer W.Nicholson added a preface to the second English edition of Kirwan's "Essay on Phlogiston" in 1789.(70) Nicholson expresses doubts as to the accuracy of the weights of reactants claimed by the protagonists in the Phlogiston debate. His scepticism suggests that in general balances were not expected to weigh to the degree of fineness that the results he was discussing implied. He descibed the results as exhibiting,

> "An unwarrantable pretention to accuracy... [because,]
> 1. Such beams as have been used by the most accurate operators, and are spoken of as being extraordinarily good, do not in general weigh accurately beyond four places of figures....2. If we admit of the pretended accuracy of beams, which are said to have weighed to five and six places of figures; yet they could not be thus used in the ordinary course of experiments, because their motion cannot but be extremely slow; not to mention that the proportional accuracy of all beams is relative to one particular weight or load only... 3. The error of weighing any elastic fluid is at least thirty times as great, in proportion to the whole, as in common weighing. For the glass globe and apparatus made use of, must be extremely light indeed, if it be not thirty times as heavy as the included air."

In support of his argument Nicholson cites various contemporary balances whose performances had been mentioned in print. These included the balances used by Roebuck and Whitehurst and Lavoisier to which reference has already been made, and which were accurate to 1/100 grain (.0006g) 1/2000 grain (.00003g), $1/10_{\gamma}$(.006g), $1/512_{\gamma}$(.0001g) respectively. He also mentions as accurate"to six places of figures"..."The Royal Society's balance by Ramsden". From this it is clear that Nicholson's "six figures" should not be interpreted as .000001 but as one millionth part of the

maximum load of the balance. In fact the Ramsden was accurate according to Ure, to "1/100 grain 1/7,000,000 part of the [total] weight" (71) Because a primary concern in chemical investigation at the time in which Nicholson was writing was to establish ~~names~~ the identity of gases, a notoriously difficult undertaking, the capacity of a balance to take large apparatus was, as Nicholson points out, an important consideration. Once techniques of analysis no longer required this work to be undertaken with such large gas samples, maximum load could become of less importance to the user. It does emerge from Nicholson's remarks however that even the best balances of his day were not expected to achieve sensitivities much in excess of .0001g and most did not attain that. When Robinson produced his balances accurate to 1/100g (.0006g) in 1821 and later to 1/1000 gr it is easy to see why they had much immediate success and acclaim, despite their smaller capacity (1kg as opposed to Ramsden's 10lbs.).

The change in both attitude to and availability of apparatus during the 19th century is clearly seen in an article in the "Chemists + Druggists Diary" of 1875. This considers in detail the desirability and practicalities involved in the pharmacist setting up his own laboratory.

> "It is in the field of chemical investigation and analysis that the facilities and appliances of a well-appointed laboratory become most indispensible... It is to the pharmaceutical chemist, the only representative of the occult science in the majority of provincial towns, that the medical man will send urine, the farmer guano and superphospate, and the householder his well water." (72)

The balance is likely to be the most costly item of apparatus.

> "No wonder that his heart palpitates and his head swims as he pores over the terrible catalogues, and finds himself free to lay out any sum between 30 shillings and 70 guineas!"

The unnamed writer recommends for general use instruments "sensible to about 1/4 milligramme" (.0025g). This is already beyond the range of Ramsden in sensitivity, though of course the load is only 100g.

> "If, however, we contemplate exploring

> the unknown region of original research, or hope to unravel the delicate threads of ultimate organic analysis we must ensure .... the most accurate sensibility".

The instruments recommended would indicate 1/20 milligramme rider giving them a sensitivity of .00005g or better. They would also cost 17 -18 guineas, but

> "The purchase of a good balance is a treat which generally occurs but once in a lifetime..."

It is interesting to notice that the sensitivities recommended correspond with those of the two largest groups of instruments offered for sale in the second half of the century, suggesting that the catalogues, however limited in number, probably reflect accurately the requirements of all those engaged in chemistry.

The sharp rise in available sensitivity and decrease in load in balances in the 19th century should not be taken to imply that such figures were unobtainable before 1850. In a letter written in 1790 Black describes a balance he devised for his own use. The balance was made from a thin lath of fir wood a foot long and each half was divided into 10 sections which was then further divided into quarters. A small piece of sheet brass was bent round to form a flat bottomed U shape 1/5" high. Across this was rested a needle to act as a point and across that the "beam". This delicate but simple device Black claimed enabled him to,

> "learn the weight of any little mass from one grain or a little more to the 1/1200 of a grain." (73)

As 1/1200 grain is in the region of .00005g, a remarkable figure for the time, exceeding even Robinson's balances the possibility suggests itself that Black was mistaken. However, given that he had made himself a set of brass weights down to 1/30 grain, one of these placed at the division of the beam nearest the fulcrum would, given a very steady hand and ignoring any inertia in the simple machine, counterbalance a mass of 1/1200gr placed at the opposite extremity. The device was simple and effective, but with a maximum load of about 1 grain not suited to the mass of experimental work done in the period of late 18th century.

In addition to describing his balance, Black also described in detail how he made the gold and brass weights used with it, and his method is typical of that employed in the period.

> "The weights I use are one globule of gold, which weighs one grain; and two or three others which weigh one-tenth of a grain each; and also a number of small rings of brass wire made in the manner first mentioned by Mr.Lewis(74) by appending a weight to the wire, and coiling it with the tension of that weight round a thicker brass wire in a close spiral.... and applying a sharp knife which is struck with a hammer, I cut through a great number of coils at one stroke, and find them as exactly equal to one another as can be desired. Those I use happen to be 1-30th part of a grain each, or 300 of them weigh 10 grains; but I have others much lighter...."

The only limiting factor to this simple but effective system would seem to be the diameter of the wire used. This must be thin enough to produce curls of manageable length once cut, each piece weighing 1/30 grain. Assuming a length of about 12 inches was originally used, the length weighed 1 grain, and brass has a density of 8.5 grammes per cubic centimeter, wire of diameter 0.0178cms would have been required, each curl being about 4/10 inch long. The brass "former" round which it was turned would have had diameter of .1275 inch, (roughly the size of a number eleven knitting needle) (75)

The availability of wire of .0178cm must be considered, (36-37 SWG). Wire of 1/500 inch diameter (.0167cm) was used in the late 18th century for electrical instruments made by Nairn, and reference to silver wire of 1/485 inch (47 SWG) (76) and "small pieces of the very fine wire of which gold lace is made" also occur.(77) during the 18th century. Wire drawing techniques had been well understood for many centuries, but the availability of platinum wire with its resistance to corrosion greatly prolonged the useful life of wire weights. Samples of the fine wires drawn from platinum by Wollaston in early 19th century

survive, ranging in diameter from .01 inch - .003 inch (30 - 44 SWG) (78). Allowance would have to be made for the fact that platinum is approximately 2½ more dense than brass and the diameter of the wire reduced proportionally to achieve the figures Black obtained for brass weights, but the provision by Robinson of platinum weights to accompany his balances in 1821 suggests that these problems were rapidly overcome. Oertling was offering grain weights down to 1/100 grain by 1850 without specifying the material. By the late 1860's however sets of weights comprising

> "1 gramme its sub-division in 1000 parts in platinum for assaying of silver £1.10.0
> [and] ½ gramme ....
> for assaying of Gold £1.10.0"

were available in addition to the older grain weights. The anonymous writer of the Chemists and Druggists diary had no doubts which system of weights should be used.

> "No one who has had the least practical experience in analytical work will dream of meddling with the detestable grain system of weights. If such a misguided individual does exist let him eschew it at once and for all time.... The set of weights comprising a 50 gramme piece downwards to a milligramme is the most suitable for general use.." (72)

Assay weights for gold and silver continued to be made of the metals which they were designed to assay,(79) but economic forces overtook platinum weights. In 1905 Oertling's issued a memorandum:-

> "Owing to the increase in the cost of production, and also the high price of platinum, I have decided to discontinue the use of this metal in the various sets of weights I supply, unless platinum is specially asked for at the time of ordering.." (80)

During the 19th century the chemical balance as a separate entity came into existence. It was no longer necessary for those whose interests lay in the study of chemicals to make do with balances designed for trade older but different traditions. It was also no longer

necessary to have sufficient means to commission a specialised tool to ones own requirements; a fair selection of designs were available to order. Chemical balances were never cheap, but the £40 one might have to pay for a first class balance by the end of the century, accurate to .0000lg, with microscope, agate planes and knives, rider mechanism and gilt metalwork, compares favourable with the 30 guineas paid by the Royal Institution for Fidler's balance in 1802. Both represented the finest available in their period, and the differences between them were far more representative of the changes that had taken place in the study of chemistry than fundamental changes in design or materials. Both instruments were designed to achieve precision. The method of obtaining this varied over the years and total agreement was never reached on the "best" system. No sooner had chemistry developed into a separate science than it simultaneously discovered different specialisms within its self, and various and varied designs of balances were produced to cope with these different requirements.

One of the great difficulties, as with assay balances, lay in the need to combine speed with accuracy. Inevitably there had to be a compromise between the two and this was reflected in the range of prices and qualities and sensitivities available. Although sensitivity in a balance is important and is an easily measurable entity, the improvement in this achieved during the 19th century does not appear to be very great. Ramsden and Robinson both produced instruments accurate to 1/100 grain (.0006g) and although Robinson was able to produce instruments within a few years accurate to 1/1000gr (.00006) he did not fundamentaly alter his design to achieve this. The later Robinson balances are larger than that depicted in the illustration of 1821, but all the facilities for fine and careful adjustment of knife edges and beam length were already present in the smaller prototype. Not until the end of the century do balances aided by a rider emerge in quantity with sensitivities of .00001g (1/5000gr). This

comparatively small change on paper represents however a substantial improvement in performance, greater than figures themselves immediately suggest. It must be remembered that to ask a balance maker to produce an instrument which was formerly accurate to .0001, accurate now to .00001, is of the same order of magnitude and subject to the same difficulties as would be faced by someone who had run a mile in 4 minutes, and was then asked to repeat the performance in 24 seconds. It is the difference between producing an engine that will cruise comfortably down a motorway rather than one that will chug behind a man with a flag. Such advances cannot be produced overnight, and may not even be desirable. What the change in balance design in the 19th century did accomplish, which was in itself far more important, was a reputation for reliability and consistency of results. Without this built in repeatability of performance the balance could never have become the reliable tool that it did. Only by producing a tool which gave invariable results could instrument makers in any field assist the progress of their subject. In a world full of variables such as the chemical world the fundamental need was for a standard against which all other theories could be tried. Provided the standard was constant its part in the experiment became the measure of the variable commodity being investigated. For this reason precision in manufacture and use became of paramount importance, and the widespread availability of this degree of precision engendered confidence in the results obtained. On this basis could theories of chemical structure be built.

1. The usual difficulties of classification arise here as with other types of balance. There exist balances without cases which were formerly the property of Lavoisier and Wollaston. It is not possible to determine now which if any of the various instruments both men possessed were used exclusively for chemical experiments. Both were men of wide and varied interests, and the existence of free standing but unshielded balances in their collections illustrates the diversity of equipment in use c.1800, but is not significant when considering the general overall design of balances intended for chemical work.
2. John Harris. "Lexicon Technicum or an Universal English Dictionary of Arts and Sciences" 1710 under "H".
3. Inventory No. 323
4. Inventory No. 324
5. Royal Institution Minutes. Newman was succeeded at the R.I. by Ladd, a maker who will be discussed later. In 1828 Newman had received a silver medal from the R.I. for his work. He also had the unfortunate distinction of once being struck by the laboratory assistant: this resulted in the assistant's dismissal, and the vacancy thus created was that offered to Faraday in 1813. Hartley Sir H "Life of Davy". 1960 p.89
6. Hobhouse H. "A History of Regent Street" published London 1975.
7. Kater Capt. H A letter respecting the Construction of a Balance August 8th 1821 Quarterly Journal of Science Literature and the Arts 1822 Vol. 12 p.40
8. [W.T.Brande] Description of the Balance represented in Plate V fig.1 Quarterly Journal..1821 Vol.11 p.280. (The work of this maker will be discussed later)
9. Balances of this type are to be found at the Whipple Museum Cambridge Inv.No.1593 and the Royal Scottish Museum Edinburgh. Inv.No.1970 L2
10. Whipple Museum Inv.No.1371. The doors are 26 and 15.5cm respectively.
11. L.N.A.M. No.11481. No.3337 also Fortin has the front divided into 3 separate sliding panels.

12. The wood most commonly used for cases in England appears to be mahogany. There were three or four distinct varieties or species of mahogany in use in this period, as well as satin wood and tulip wood. All these were popular in furniture manufacture, and to the inexpert eye of this compiler appear identical. Reference to mahogany cases should be interpreted perhaps as "mahogany type" throughout.
13. Illustrations of chemical balances made by Oertling during this period show that for the last quarter of the 19th century about 1/3rd. of them were not provided with drawers. By the 1930's of 17 models illustrated, only two had drawers fitted. Earlier catalogues unfortunately are not illustrated and details of cases are rarely given.
14. Three balances of this type are in the collection of the Royal Institution.
15. C.N.A.M. Inv.No.16222
16. Rapport du Jury Mixte International Exposition Universelle de 1855. pub. Paris 1856 p.420
17. Makins G.H. Manual of Metallurgy London 2nd ed. 1873 p.204
18. Correspondence extant between Oertling and a customer in 1878 suggests that aluminium beams could be made to order (but it is noticeable that these were never advertised in the firm's catalogue). After describing the beam which he recommends, "its entire weight about 70 grains", Oertling adds a postscript:-

> "The beam in aluminium would be a little larger in bulk but still lighter in weight. The aluminium beam I think, would weigh about 55 grains. L.O."

The weight reduction compared to that mentioned by Makins suggests either improved techniques or more probably the introduction of the short beam.
19. Science Museum Collection. Inv.No. 1933/159
20. The importance of the rider will be discussed later.
21. The prism referred to was a device by which the

movementof the pointer tip was reflected up to a ground glass screen at the top of the case, at the eye level of the user. The divided and numbered scale was in fact attached to the tip of the pointer, and the reading was obtained by noting the position of the reflected scale against an engraved line on the ground glass screen.

22. Catalogue of Chemical Balances and Weights of L. Oertling Ltd. c. 1935

23. Royal Scottish Musuem Edinburgh. Gallery 17. It is said that it was found necessary to reinforce the floor before the balance could be assembled for display. The case is approximately 74" x 31½" deep x 60" high and this section rests on a plinth 34½" high.

24. Letter from Hurter and Haas to Van Marum of October 8th 1793 quoted in Turner G L E and T.H. Levere Martinus Van Marum life and works. ed. E.Lefebure and J.G. de Bruyn. Vol IV Van Marum's Scientific Instruments in Teyler's Museum pub. Noordhoff International Pub. Leyden 1973 Fig. 8 and p. 135. The instruments Van Marum ordered were to form the basis of a collection of apparatus designed to demonstrate basic scientific principles at public lectures.

25. Turner G L E. Auction sales of the Earl of Butes Instruments 1793 Annals of Sc Vol. 23. 1967 No.3 p.242 appendix.

26. Auction Catalogue 1810 previously cited. Cavendish papers.

27. [Brande] loc cit ref 8.

28. [W.T.Brande] "Description of a Balance..." ref 8

29. Whipple Museum Camb. No.1593

30. Oertling chemical balance "No.6" in catalogue of Oertlings Ltd c.1880.

31. Oertling catalogue Bullion balances "A" to take up to 2000 ozs.

32. "Apparatus testing gunpowder...Specification to govern manufacture and inspection". Approved 25th March 1909. Reprinted Nov. 1943. Private communication Mr.C.M. Robertson AD/E. Procurement Executive. Ministry of Defence. Royal Arsenal East. S.E.18

33. The balance No.000 first appears as a hand written amendment to balance No.00 in the copy of the 1891 Oertling Catalogue. This catalogue was used as a production handbook by the firm.
34. Kater loc. cit ref. 7
35. [Brande W.T.] "Desription of a balance" ref 6
36. Astronomische Nachrichten 7, 232 (1829) quoted by Stock J.T. Thomas Charles Robinson and his balances. Journal of Chemical Education 45 Apr. 1968 p.254
37. Offical Desriptive and Illustrated Catalogue Vol.1 Great Exhibition of the Works of Industry of all Nations 1851. Class 10 p.446
38. Albert 1873 Blackfriars 1869
Battersea 1890 Westminster 1862
Southwark Iron Bridge was rebuilt in 1922. The others remain. "Crossing the Thames in London" G.L.C. publication.
39. Bunge Paul. Neve Construction Der Wage. Reperatorium Für Physikalishe Technik 1867 p. 209
40. As Dittmar points out, in practice position 0 and 10 may not be easily accessible and by 1890 the division of the beam into 12 sections was sometime adopted, and supplying a rider of 12 milligrammes. This will enable 10mg to be read. Dittmar also attributes the idea of the rider to Berzelius. Dittmar W. Article on Balances 1890 Reprinted 4th ed. Thorpe Dic. of Appl. Chem. (1930) p.591
41. Report by the Juries. Exhibition of the works of Industry of all Nations 1851 Class X p.258
42. Report by the Juries, International Exhibition 1862 Class XIII p.20
43. Inv.No. 160 History of Science Museum Collection Oxford
44. "L.Oertling Manufacturer of Balances .... 13 Store St. Bedford Square". Oertling Archive.
45. Private Collection.B. . .
46. Royal Institution Collection. This collection of balances is of particular interest as it contains several very fine German balances of the late 19th

and early 20th centuries not represented in other collections.

47. Including No.157 "Dr.Daubany" balance, No.159 by Knight and No.324 by Newman.

48. N.W.Museum of Science and Industry Manchester Inv.No. L1971.9
In this respect as in the design of its beam and pan hangers, Davy's balance bears a strong resemblance to the design for a gold standard beam proposed by Dearborn in 1801.
B.Dearborn remarks "The construction of the common scale beam, with a description of the new Gold Standard beam invented by the author".
Memoirs of the American Academy of Arts and Sciences Vol. III part 1 p.40-49 1809

49. R.G.W.Anderson "The Playfair Collection and the Teaching of Chemistry at the University of Edinburgh 1713 - 1858.pub. Royal Scottish Museum 1978 p.5

50. J.Erik Jorpes. "Jac Berzelius His Life and Work. Stockholm 1966 Trans. B.Steele 32 -33.

51. J.Hyacinthe Magellan "Lettre..." Obs sur la physique.. XVII part 1 1781 p.43

52. Obs sur la physique XXXIII p.144 ff

53. Bauer Dr.Max "Precious Stones...." pub. 1896 Trans Spencer 1904. New edition 1908 Vol II p.515

54. Catalogues of Instruments of L.Oertling

55. One is the instrument now in the possession of Oertlings originally purchased by "Mr.Beale" in 1847. Its unusual history has already been mentioned. The other exception is an experimental model. Sc. Mus. Inventory No. 1876/127 which will be discussed later.

56. A balance of unknown make but good quality originally made in Giessen was forwarded to Oertling's in London for repair by Harrison and Parkinson scientific equipment suppliers of Bradford on behalf of an unidentified local customer in 1873. Information from Oertling account books and private communication from Harrison and Parkinson Sunbridge Road Bradford.

57. Dittmar in Thorpe's Dictionary ref 59
58. An early Oertling balance with this feature occurs in the private collection of Mr.M.Joyce
59. Science Museum Collection Inv.No. 1979/- made by Seyss.
60. N.W.Museum of Sc. and Ind. Manchester Inv.No. 1969.2.4. balance made by Liebrich in Giessen
61. Royal Institution Collection. A balance made by Paul Bunge Hamburg is typical of this design as is a balance by Sartorius c 1875 in Science Museum Collection No.1876/369.380. Another balance made by Sartorius in the Science Museum Collection No.1969/377 places another bar in parallel with the agate bar (the agate being held between them). Both bars are fitted with spheres to fit into two pairs of resters.
62. Royal Institution Collection. Balance by Paul Stückrath
63. The balance used by Dalton is a good example of this. Although the balance itself is no longer extant, surviving photographs show it to have been a pillar balance with a pull string arrestment and a box ended beam. The pillar fitted onto the top of the box in which it was packed. It had an upwards pointer and is shown set up for hydrostatic weighing with one long and one short pan. Also shown are a glass counterpoise and bucket. The whole is typical of the simple balances described in earlier chapters and used by Ercker and Hauksbee, and illustrated in the bill heading of the supplier Accum c 1810 Sc. Mus. Photo No. - 6878. Dalton's apparatus was exhibited in 1870 and is discussed by Roscoe in Proc. of Lit. & Phil Soc Vol.XV No.7 p.77 1876 and, with illustrations, by R.Farrar "Daltons Scientific Apparatus" in "John Dalton" ed. Cardwell 1908 p.168. Although Accum's catalogue for 1813 lists "Assay balance" as well as accurate balances, Dalton's balance seems unlikely to have been intended for assay work.
64. One has to remember that even a balance in good order, with all checks for beam length, pan weight, and centre of gravity and knife position completed should be

allowed to 'rest' for an hour or two to come to room temperature before being used, if it has been necessary to move the instrument to a new position. In this survey this was never possible in practice, and the results obtained are probably less then the balances in reasonable order might have been capable of producing, given sufficient time and adjustment .

65. John Joseph Griffin "Chemical Recreations" 9th ed. 1849 p.550 describes 3 useful balances one to turn at 1/20gr, one at 1/50 and one for organic research at 1/100 grain (.0006g) In their 1889 catalogue, balances & illustrations occupied 10pages.

66. As would appear from the assay balances which were 'named' after their stock number.

67. See Ref. 36 above, which refers to the balance Robinson offered for sale in 1829. It has to be assumed that the balances discussed here are the same as those covered by that early list, despite the fact that Robinson may have increased his range or altered his specifications in later years, or Barrow (his successor) may have done so after his death. Certainly Robinson did make to order a superior balance for Moll.

68. Royal Scottish Museum Edinburgh Inv.No.1970/12 on loan from Dept. of Chem. University of Edinburgh and British Museum (Natural History) mineralogy Dept. at present on loan to Sc.Mus. Inv.No. 1977/-

69. Wellcome Collection.. (26)

70. Kirwan Richard "Essay on Phlogiston and the Constitution of Acids" 1st English edition 1784, 2nd ed 1789 Reprinted 1968.

71. Ure Andrew "Dictionary of Arts...." 4th ed. p. 115

72. [ ] The Laboratory. The Chemists and Druggists Diary 1875 p. 19 - 20 . I am indebited to Dr.L.B.Hunt for drawing my attention to this article.

73. Black. Letter to James Smithson Esq. describing a very sensible balance Sept 18 1790 Annals of Philos. New Series 10 1825 p. 52-3
Later in the same letter Black adds, after describing his remarkable instruments, "We have no chemical news.." One is reminded of the French song. Obviously Smithson

did not consider the information news worthy either, until 1825 when the letter was published, suggesting a change in approaches to chemistry and the demise of the large capacity balance.

74. Wm.Lewis "Commercium Philosophicum" p.544 "The best way of procuring equal small weights is, by cutting off equal lengths of finest silver wire..."

75. I am greatly indebted to Dr.K Dawson for his assistance with this section.

76. Jurich J. "An Essay on Distinct and Indistinct Vision" 1738 (Smith's Opticks)

77. Rumford B. Count of . "An enquiry concerning the weight ascribed to heat" Phil Trans 1799 vol 89 p.179-194. He is describing experiments performed in 1787 using a balance belonging to the Elector Palatine and counter poises of fine wire p.180

78. Science Museum Inv.No.1946-228

79. 2 sets of assay weights of this type occur in the Wellcome Collection.

80. Oertling archives.

CHAPTER 5

Robinson and Oertling. Two nineteenth century Instrument makers.

CHAPTER 5

ROBINSON and OERTLING

TWO 19TH CENTURY INSTRUMENT MAKERS.

The making of precision balances in England in the 19th century was dominated by two manufacturers, T.C. Robinson and L. Oertling. The substantial improvements attained in quality and performance in balances, as exemplified by surviving instruments made during this period, has been discussed in general in the preceeding chapter. Many of the innovations which enabled this increased standard to be achieved were due to the work of two makers whose active careers spanned between them nearly the whole of the century: Robinson and Oertling.

Thomas Charles Robinson was born in St. Marylebone in 1792 and remained throughout his life at the family home in Devonshire Street, just off Portland Place. The Marylebone area of London in the late 18th century was only just becoming built up and lay on the very edge of the new developments of town houses in Portman and Cavendish Squares. By the time of Robinson's death in 1841 the building of Portland Place and Regents Park had transformed the area and provided rapid access to the fashionable shopping centre of Regents Street. Robinson's parents owned a successful haberdashery and linen shop which provided sufficient income to enable two of the sons to develop their artistic talents and exhibit at the Royal Academy and, Robinson himself, to build up an instrument making business, perhaps helped by his cousin Henry Blundell who was a clockmaker. (1)

The first recorded reference to Robinson as an instrument maker was in the account previously referred to of a balance made by him and described in the Quarterly Journal of 1821.(2) The unnamed author who may be assumed to be the editor described enthusiastically the small and inexpensive balance owned by Mr. Children (3) and gave the name and address of the manufacturer Robinson. This highly desirable free publicity does not appear to have been in any way sought by Robinson who probably knew nothing about it. The next edition of the Journal however contained a letter from Henry Kater, written in August of the same year, (4) pointing out various inaccuracies in the description and stating that the original design was his own. His intention had been:

"to render the hydrostatic balance less expensive without diminishing its accuracy and sensibility and it has, in every respect, answered my expectations". (4)

How long Kater had had his balance and exactly when he first approached Robinson is, unfortunately, never made clear. (5) By 1821 Robinson would have been nearly thirty and may well have been making instruments of other types for some years, perhaps supplying parts for the larger concerns before he was brought to the notice of Kater. No separate notice of his business appears in the Trade Directories at this stage, or for some years after, and yet the balance he produced entirely satisfied its designer and was of such quality as to be accurate to 1/100 of a grain (.0006g) the size of the smallest weight supplied with it. This brief note in the Quarterly Journal marks the first mention of Robinson in print. Throughout the next twenty years the small enterprise continued to grow in reputation, despite the fact that four years previously, in 1816, and less than half a mile away, the equally promising venture of Robert Fidler, M.I.M., which has already been mentioned, failed.

The importance to Robinson's independent career as the instrument maker of Kater's balance was very considerable. Although Robinson seems certain to have made other instruments during his working life, and was in correspondence with G.B. Airy, Astronomer Royal, at the time of his death in 1841 over a recently completed magnetometer (6) the references made to Robinson in print refer to his balances and weights, rather than to his instruments in general. He had many satisfied customers. Henry Kater's interest in instruments extended back to his service in the Indian Army where he had taken part in surveys of the subcontinent and the establishment of base line. (7) This work had ended when ill health caused his return to England in 1808 but his interest continued in the problem of exact measurement and he continued the work on standard measures begun by Sir George Shuckburgh in 1798. (8) With his background of known interests, Kater would have met and worked with all the leading contemporary instrument makers, in particular the firm of Troughton's, the quality of whose instruments was long established. (9) The choice of Robinson, then (apparently) an unknown maker, to produce the small, exact, balance Kater required may have been brought about by nothing more than Troughton's inability due to pressure of work to complete the small order. (10) A direct connection between Troughton and Robinson, though plausible, has yet to be established.

Once Robinson became known as a manufacturer of precision balances, however, his reputation was soon established. Both Wollaston (11) and W.H. Miller (12) appear to have owned Robinson balances but, where as Wollaston's balance is of the type illustrated in 1821 with a 5" beam, Miller's is a larger version of the same design with a 10" beam. This larger pattern Kater had used in his work in the new Standards in 1826. (13) He described his balance as being made by

> "Mr. Robinson, an artist who has directed much of his attention, and with great success, to the improvement of this instrument. The beam is only ten inches long and, together with the scale pans, weighs eight hundred grains. The scale pans are attached to agate planes which rest upon knife edges. The ultimate angle of the central knife edge is 120 degrees. This balance with one pound avoirdupois (7,000 grains) in each scale, it may be seen by the following details, varies immediately one division, equal to about one-tenth of an inch, on the addition of one hundreth of a grain." (.0006g).

Three years later, in 1829, Robinson was advertising balances in three sizes, both the $10\frac{1}{2}$" and $5\frac{1}{2}$", already referred to and an intermediate 8", at prices ranging from 8 - 14 guineas.(14) (15) Further improvements had been made and, for an extra guinea, "crystal" knife edges were available as well as the agate planes normally supplied.

> "Larger sizes are also made to order, their arrangement embraces several important improvements by Captain Kater, Dr. Wollaston and the Maker, all the sizes are furnished with platinum weights to 100 Grains and upwards of brass. They will indicate .001 of a Grain (.00006g) with 1000 Grain." (15)

This sensitivity is equal to one part in a million of the load, figures comparable with those obtained only from Ramsden's balance at the end of the previous century.

One of the balances of "larger sizes .. made to order" referred to above was used in 1831 by Dr. Moll of Utrecht when comparing British, French, and Dutch weights. An authentic copy of the new metre and kilogramme had been presented to each of the governments whose representatives were sent to Paris in 1799 when the Commission for the establishment of the metric system produced their new standards. Dr. Moll wished to compare the Dutch set with the British Troy pound, a copy of which had been made for him by "Mr. Bate of the Poultry", a manufacturer already discussed. To compare these substantial weights a large balance and some weights were required and Dr. Moll used:

> "..one of the well-known balances of Mr. Robinson of Devonshire Street..... The beam of the balance which I employed is about eighteen inches in length; the knife edge of the axis is about two inches and a half long; the knife-edges on which the scale pans are suspended is about one inch. When loaded with a kilogramme in each scale, 5/1000 of a grain (.0003 g) are sufficient to show a derangement in the equilibrium of the beam." (16)

This suggests a sensitivity of approximately 1/3,000,000 parts of load or somewhat higher than the balance used by Kater, a remarkable achievement being the equivalent of a sensitivity of .00003g with a more normal 100g load.

Although no example of a large Robinson balance with a beam over 10½" is known to survive, it is likely that this balance used by Moll, together with those used to re-establish the Standards after the fire in the Houses of Parliament in 1834 had destroyed one set, were all of similar design. How much of the original design was due to Kater and how far Robinson modified the pattern, in the light of technical expertise or later experience, cannot be stated with certainty. Between them, however, Kater and Robinson established the essential characteristics of a good and reliable balance and produced a design that enabled this quality to be maintained almost irrespective of load and over a very long working life for the instruments. Only five instruments signed by Robinson have so far been traced (17) but, the account books kept by Oertling in the last quarter of the century show a substantial number of Robinson balances coming in for repair and maintenance. This suggests that, during his known working life of 20 years, Robinson produced far more balances than the small number of survivals would lead one to imagine. It speaks highly for the quality of the instruments that, forty years after Robinson's death, and perhaps fifty years after the date of original manufacture, owners considered Robinson's balances worth maintaining in good working order.

Robinson's balances are of traditional design in so far as they are all provided with a fitted drawer into which beam and pans and weights can all be packed away. A removable glass cover was also provided, though this fragile item has sometimes been lost leaving only the hooks in the wooden base which originally secured it. The important aspects of the design are to be found in the beam construction and the elaborate care taken to provide for the adjustment of the beam length and exact placing of the knives and planes. As has already been mentioned, the open lattice beam pattern had been used

in a balance made for Van Mayrum by Haas & Hurter. As this partnership was dissolved in 1796 it is not possible to establish whether or not Kater saw this balance or one of similar pattern by the same firm, and incorporated the remembered design in his own ideal balance many years later. Certainly the lattice beam was a rarity before 1820. It did solve the strength without weight problem more efficiently than the cone beam or traditional bar beam had done and, had the additional advantage that adjustment mechanisms could be more easily incorporated into it than had proved possible with a more solid structure.

The essential points of adjustment, and those whose presence gave Robinson's balances their long term reliability, were for the equalisation of the two halves of the beam and the location of the three knives. The presence or absence of agate and the smoothness of the arrestment mechanism all contributed to the total quality but on the beam everything else depended. It was essential that the two halves of the beam should be both of equal length and of equal mass. As it was not possible, except presumably with a cone beam, to weigh each half beam separately, some provision for countering assumed inequality was necessary. The traditional swan neck beam could be adjusted normally to equalise length but, the Kater/Robinson design incorporated a screw on a fine thread passing inside the curve of the swan. Brute force had been replaced by finely controlled adjustment. This adjustment, as can be seen in the surviving example in the Wellcome collection, was only provided at the end of the beam, the other end remaining fixed with respect to length. This other end was, however, provided with a screw placed vertically through the swan neck which would serve to raise or lower the pan attached to the swan. This, according to the contemporary illustration, was the side for the full length pan, the other end being for the hydrostatic pan. The threads by which the pans hung would vary slightly in length with humidity.

By the time Wollaston came to buy his basically similar Robinson balance, the swan neck had been dispensed with and the bottom loop from which the pans had originally hung was replaced by an improved system, a horizontal piece of brass on which the end knife sat. The removal of the swan neck did not alter the need for some means of adjustment to beam length, and this is retained. A similar horizontal screw to that used in the early models now is used to open or

close a vertical slit in the metal at the end of the beam. The curved part of the swan has, in effect, been squashed flat and incorporated into the bulk of the beam metal. (18) It has been pointed out (19) that this device in clumsy hands weakens the beam structure by straining the metal and, certainly, the brass beam by its thickness would convey more resistance to adjustment than a piece of spring steel separately applied to the beam end, as was the case with the original swan design. However, none of the surviving balances show signs of the metal having suffered damage in this way and, no doubt, the users considered the advantage of fine adjustment facilities out-weighed the need for delicate handling. Similar small pressing screws were provided to hold the three steel knives in place and, also, to rotate them slightly horizontally, thus ensuring that all three knives were made parallel to each other and placed at right angles to the line of the beam. These two features, which controlled the beam length and the knife position, created, really for the first time in balance design, an instrument that could be tuned to a high degree of accuracy and re-tuned whenever necessary. Such delicate manoeuvres were not really suited to the expertise of the average purchaser and required both considerable time and practice. It is not known what arrangements, if any, Robinson may have made for the maintenance of his instruments but, certainly, by providing a high performance instrument, at a price suitable for purchasers who were unlikely to have skilled assistants at hand, he created a need for specialised maintenance. A balance forged out of bar metal and composed of parts held together with a metal pin leaves little room for adjustment. Robinson balances, though far more sensitive, could only produce the results claimed for them if handled with care and adjusted accurately and this shift in emphasis was to become more pronounced as the century progressed.

Writing in 1890 Dittmar said of Robinson balances:

"Robinson of London was the first to make both knives and bearings of agate."

Later, when describing the bearings more closely, he added:

"...the pans are suspended by plane bearings which a suitable extension of the arrestment keeps in their right position. Robinson's balances were justly famous in Great Britain - a few of them are still working to this day - ." (20)

The first part of his remarks bears out the offer of "crystal" knives made by Robinson at least as early as 1829 and, it would appear, that Dittmar had himself seen such instruments, though none of this type survive. Dittmar's later emphasis on Robinson's use of plane bearings for his pans, which must have been introduced before 1828, the year Wollaston died, raises the interesting question of whether the use of plane bearings for the knives, whatever material they were made from, derived originally from the balance used by Cavendish. His balance would seem to be the only late 18th century example of a balance extant in which knife and plane bearings, albeit of steel, were used throughout. This balance passed from Cavendish in 1810 via his nephew to Sir Humphry Davy and, thence, to his friend J.G. Children, in whose laboratory Davy had worked (3). Kater may have seen the balance there or, earlier, in the laboratory of the Royal Institution or at the Royal Society.

There seems no doubt that Kater himself believed that Cavendish was the originator of the knife and plane bearing. He wrote in 1831 of a 10" Robinson balance:

> "The fulcrum....rests upon an agate plane.... and the scalepans are attached to planes of agate... This method of supporting the scale pans we have reason to believe is due to Mr. Cavendish." (21)

The use by Robinson of agate in place of steel for the planes may have been inspired by Ramsden, but Kater himself by 1818 had found agate to be a better material than steel in some situations. He constructed a pendulum which incorporated knives made of Wootz steel. "Two planes of agate" were used for the knives to rest on. "Plates of hard steel were first tried but were found to have suffered penetration by the knife edge." (5) The development of agate knives may merely have been a logical development from this in the light of more generally available sources of agate in the 1820's. The suggestion that Cavendish instituted the use of agate in balances would seem to be based on a misinterpretation of the above extract, rather than on any published reference by Cavendish on this subject. (22) Cavendish did, however, discuss the use of agate in a compass bearing. If these bearings were not properly ground to a smooth concave surface:

> "...the needle will not always stand horizontal ... Mr. Nairn has since ground some himself which are perfectly free from fault." (23)

In addition to the knife and plane bearing system, mentioned above, Cavendish's balance also contains a distinctive method of pan arrestment which is also found in all Robinson's balances. Kater said of

this mechanism:

> "Dr. Wollaston has contrived the following additional apparatus which he finds particularly convenient...." (4)

The device consisted of thin flat pieces of metal fixed to the centre back of the base board of the balance, and extending slightly beyond the case edge at the front. Each length was formed from two pieces pin hinged together and could be positioned below the inside edge of a scale pan.

> "Four press pins .... of a sufficient length, project perpendicularly from the side pieces. These pins are brought into contact with the scale pans .... when the beam is elevated above its support. The knife edge being lowered upon the agate planes and the pins withdrawn, any want of equilibrium becomes instantly perceptible." (4)

This raises the question of whether Wollaston fitted these bars and pins to a Robinson balance no longer extant and purchased by him circa 1820 or whether the surviving Wollaston Robinson balance at Cambridge (11) is contemporary with Kater's account, despite its more elaborate construction. This simple but effective pan arrestment device is also present on Cavendish's own balance and may be original. It gives no sign of not being so, but could have been added with minimum disturbance to the instrument at a later date such as post 1810 and used by Wollaston at the R.I. or Royal Society. If its presence is contemporary with the rest of the balance i.e. late 18th century, it is possible that the true originator was Wollaston's father, the Reverend Francis Wollaston, F.R.S., rather than W.H. Wollaston.

After Robinson's death in 1841 balances of his design continued to be made, but show only slight variation from the basic design. This suggests that the majority of those who required instruments capable of great accuracy were quite content with the finely adjustable knife and plane mechanism with which Robinson had provided them and could see no need to alter it. The balances with their very distinctive central pillar, which half way up its length splays into a tulip shape to accommodate the short pointer attached to the beam, continued to be made and, after 1841, were signed "Robinson & Barrow". Barrow took over the name and good will of the Robinson instrument making business and continued it for some years, though at a new address in Oxendon Street.(24)

W.H. Miller working on Standards after Robinson's death used a balance supplied by Barrow which:

"In its construction it nearly resembles the balances of the late Mr. T.C. Robinson." (25)

It had end pointers and, with a load of a pound in each pan had a probable error of ".00056 grains or less than 1/12,000,000 of the weight in either pan." (25)

Although this particular balance appears not to have survived, other "Robinson & Barrow" balances are extant, in particular a magnificent example located in the Natural History museum and now on loan to the Science Museum. It was originally the property of Professor Story Maskelyne and perhaps used by him at Oxford in the 1850's. In this balance the size of the agate planes has increased substantially and they have become pieces of agate set in brass holders rather than diminutive inserts. The adjustable screw used to ensure equilibrium in the two halves of the beam has been placed within one of the triangles of the beams structure, rather than protruding from the ends, and the pans and chains are of platinum and may be an original feature. (26)(27)

Under Robinson's Will, his apprentice, Dover, received £5

"in approbation of his zeal and integrity." (1)

and later exhibited a balance of Robinson type on his own behalf at the Great Exhibition (28) where his work was highly praised.

This continuation of the Robinson design in balances, long after the death of their originator, cannot have failed to influence the work of an instrument maker who arrived in London during the early 1840's. Ludwig Oertling continued Robinson's work as a manufacturer of precision balances. That he was able to build up a substantial business without benefit of locally inherited good will suggests that he was able to fill an important gap left by Robinson's death. The instruments Robinson had begun to make almost by accident had, in his lifetime, become an essential component of chemical analysis and the need for a permanent supplier of such instruments was met after Robinson's death by Ludwig Oertling.

Ludwig Oertling was born in 1818 in the town of Schwerin (29) Capitol of the Grand Dutchy of Mecklenburg in Schwerin, fifty miles east of Hamburg. The family was large and, in common with many others at that period in Germany, as in England, they moved from the mainly agricultural region of Mecklenburg to the City, in this case south to Berlin. There the eldest son, Johann August Oertling, established a successful instrument making firm and, from there, in about 1840, Ludwig came to England. By 1846 Ludwig had learnt

English, made the decision to specialise in the making of balances, in contrast with his brother who worked in astronomical and surveying apparatus and married Caroline Rowlatt, whose modest inheritance no doubt ensured the financial stability of the business in its early days.

Oertling's earliest recorded premises as an independent manufacturer were at 3 Jewin Street just off Aldersgate Street but, by 1849, he and his wife and their first child had moved to larger premises at 13 Store Street, Bedford Square. By the time the census was taken in 1851, Oertling was employing five men and had added to his household Fredrich, a nephew from Germany, probably August's son sent over to learn the business, and a niece, the only child of Caroline's deceased sister Charlotte. The work force had risen to twelve by 1861 (30) and the family had moved to a new house in Putney. They no longer "lived over the shop". They also had new neighbours, William Simms and his family. William Simms, (1817 - 1907 F.R.A.S.) was the nephew of Wm. Simms F.R.S., who had been Troughton's partner. (31) The importance of the many members of the Simms family to the development of the very eminent firm of instrument makers of that name is well known. (32) In 1860 Wm. Simms F.R.S. died and Wm. Junior became a partner in the firm with his cousin James, William's eldest son. The possibility of the families of Oertling and Simms accidently becoming neighbours by 1861 seems remote and suggests deliberate planning and, despite the friendly rivalry that must have existed between the two firms during the preceeding twenty years, probably implies long association and friendship. It would be nice to think that the families of Wm. Simms Senior, then living in Fleet Street, and that of Wm. Junior, in Greville Street off Hatton Garden, had been instrumental in establishing the newly arrived instrument maker in their area, but this point has yet to be established. It may be significant that Oertling, in common with all the Simms family, was married and had his children christened at St. Brides, Fleet Street.

During the 1860's Oertling went into partnership with E.W. Ladd. There is a family tradition that Ladd had formerly been one of Oertling's apprentices. (33) Ladd first appears in Trade Directories in partnership with Streatfield in 1852. The pair describe themselves as "Successors to R.B. Bate", a title adopted by several firms who probably took over various aspects of the vast enterprise Bate had built up by the time of his death. The new partnership of Ladd

& Oertling moved from Ladd's premises in Old Jewry to Bishopsgate & Without and, later, to Moorgate, where the new railway station was in the course of construction. Oertling seems always to have had an interest in good communications, siting this and all subsequent premises for his firm adjacent to a railway terminus.

E.W. Ladd's father was, almost certainly, William Ladd, instrument maker from Deal. (34) Wm. Ladd's business in London appears to date from 1846 when he had premises just south of the River in Newington. He later moved to Chancery Lane and, in 1861, was appointed Instrument Maker to the Royal Institution in succession to John Newman. (35) He then moved his business to Beak Street, off Regent Street and remained there for many years, finally retiring from business, and from the Royal Institution, in 1882.(36)

The partnership between Ladd and Oertling lasted throughout the 1860's and, no doubt, the additional capital and orders that a joint enterprise could command was of benefit to both partners. Certainly by the end of the decade it became apparent to Oertling that the press of work demanded larger premises and these were purpose built in Turnmill Street opposite Farringdon Station. The floors were specially reinforced to take the weight of the massive bullion balances then being constructed, and designed to reduce external vibration. In these premises the firm continued to grow and flourish, being subsequently controlled by Ludwig's son Henry. Only the death of Henry's only son Lewis, who had joined the Royal Flying Corps. and was shot down during the First World War, prevented the firm continuing in the direct line of management. In the event it was Lewis' brother-in-law, Malcolm Dunbar, who subsequently became Managing Director of the firm, a position he held until his retirement in 1947. (29)

The balances Oertling made have already been mentioned in this survey. It is fortunate that, due to their outstanding quality and long working life, many have survived if only due to the reluctance of their owners to part with them. A number of catalogues and account books covering the second half of the 19th century have also been preserved and, between them, give an indication of the way the firm was built up over the years.

The earliest surviving catalogue, circa 1849, is a very modest affair. It describes Oertling as a Manufacturer of Balances but notes that "Every kind of philosophical apparatus made to order.

> Chemical Apparatus of German Glass and Porcelain imported direct from the Manufacturers".

No doubt August Oertling in Berlin was able to supply these items. Thirteen balances are listed, varying in size from 8" - 16" and including the assay balance

"with palladium beam 12 inches long",

and two heavy duty balances able to carry 28-lbs and ½-cwt respectively.

From the experience gained in this small scale business, Oertling was able to produce an exhibit comprising 3 balances for the Greet Exhibition. One was the ½-cwt balance noted above, with its beam now coated with platinum

> "by a peculiar process in which the electric current was employed in depositing these metals." (37)

The plating was carried out by T.H. Henry F.R.S., an early pioneer in the difficult process of plating with platinum group metals. He was also responsible for the palladium plating on a 16" chemical balance.

> "...the three knife edges, as well as the plane upon which the middle knife edge rests, and the planes from which the pans are suspended, are of agate .... The adjustments are as few as possible .... to be very permanent ... As far as the beam and knife edges are concerned a better balance has probably never been constructed." (37)

The Jury were so impressed they awarded a Council Medal to an Oertling and this became the first of many such awards at subsequent Exhibitions. (38)

It is interesting to see how Oertling had continued in his balances the basic design features which Robinson had developed, but had reduced the amount of adjustment and, therefore, of maintenance that the purchaser could undertake for himself. No doubt Oertling had already discovered that some of his customers who were engaged in many very various occupations, were unskilled in the arts of precision engineering and mechanical theory. Repairs to balances, his own and other peoples, began to figure in the early note books kept by Oertling. This not only provided a useful additional source of income but, also, encouraged a flow of customers to the workshop premises where their needs could be discussed, the merits of alternative models expounded and, most important of all, what would now be termed "market research" undertaken. The beautiful and costly balances that impressed Juries at International Exhibitions were only one side of the enterprise. The simpler, cheaper, balances such as the three guinea balance bought by"Mr. Beale" were equally important.

Between circa 1851 and circa 1861 the total number of models of balances made, other than those specifically for assay and bullion work, increased but, the average price of these balances decreased, suggesting that the lower end of the market had increased its needs and had made its needs known. A catalogue dating from the time of the Ladd & Oertling partnership in Moorgate Street, circa 1864-1868 (in addition to being embellished with reproduction of medals received at the Exhibition of 1851, 1855 (Paris) and 1861) includes the following significant note when describing a balance @ six guineas. It:

> "....is particularly recommended for the use of pupils in the laboratory, as a really good instrument, but fitted up as economically as possible."

This balance had a divided 12" beam (but no rider mechanism) steel knives and planes and was accurate to 1/100 grain (.0006g) with 1000 grains. The figures originally obtained with such satisfaction by Robinson were now available for general school use. For £8.10.0d. the same balance was provided with agate planes and accurate to 1/200 grain, (.0003g). The same catalogue proudly announces the firm to be "suppliers of balances and hydrometers to the Bank of England, the Board of Inland Revenue, the Assay Offices of the Royal Mint, the U.S. Mints and the Anglo-Mexican Mint". Such an illustrious clientele had been built up partly, no doubt, from the excellent publicity afforded by the Exhibition but, also through personnal contact.

Some indication of the vast range of customers that visited the newly established firm from about 1849 onwards, can be gathered from a surviving Day Book kept by Oertling at that period. In it he appears to have noted down every caller and the entries are dated sufficiently regularly for missing dates to be guessed at. Not all calls resulted in orders being placed, but, the diversity of interests represented by the names (some with addresses) collected even before 1851, gives an indication of the areas into which precision balances could be expected to move. A brief selection of names in approximate order of entry will be of interest:-

1849 "Dr. Blyth. Examining and repairing 3 balances...
College of Hanover Square. Repairing two balances.
Messrs. Griffin & Co. ...
Dr. Ronalds Queens College Galway ...
Dr. Andrews Queens College Belfast...pupils balance with weights.
Dr. Blyth [as above?] Queens College Cork. Large balance...
Mr. Mansfield College of Chemistry London...

Mr. Negretti... /later Negretti & Zambra, Hatton Garden?/
1850 Folly Chemical Works, Isle of Dogs....
Farrie Brothers & Co., Sugar Refiners....
Mr. Hume 108 Long Acre... /the address of "Mr. Beale"/
Mr. Birt, Surgeon, Leamington.
Messrs. Bewley Fisher & Co.....
Mr. Coffey, Bromley by Bow...
Mr. Edwards, Liverpool.
Mr. Bruce, College of Chemistry.
Messrs. Clay & Alreham...
Mr. Henry Pollack, ... St. Georges Hospital
Dr. Franklin (Dr. Playfair's Laboratory).... [Frankland]
Mr. Henfrey /lecturer in Botany at St. Georges and brother in law of T.H. Henry/
Dr. Apjohn, Trinity College, Dublin.
Dr. Evans...Birmingham....
Alhusen & So., Alkali Works, Gateshead on Tyne.
Messrs. Jackson & Townson...
Mr. Josiah P. Cooke Jnr. Prof. of Chemistry, Harvard College... /order/ to be completed by 1st July with packing case.
Mr. Field, Mexico...
Dr. Musprath, Liverpool ... [Musprath]
Messrs. Newton Theates & Co., Copper Merchants, Liverpool...
Messrs. De Grave & Co....
Mr. Rogers, School of Medicine, adjoining St. Georges Hospital....
Professor Williamson, University College...
Professor Graham, Assay balance as before.
Dr. Miller...
Mr. Anderson, Great Suffolk Street, Borough (Soap Works).
1852 Chemical Record Office, 20 Paternoster Row.
Mexican & South American Company....
Louis Cappel (German Protestant Clergyman)....
Dr. Beale, 27 Cary Street.../son of Mr. Beale of Long Acre/
John Mackenzie, Esq., c/o Messrs. Arbuthnot & Co., P. Trafalgar, Madras. The ship calls at Plymouth on the 15th....
Mr. Field, Royal Mint ... /Henry Field son of John Field/
Captain Whitmore, Museum of Geology....
General Board of Health, Whitechapel....
1853 Messrs. (Mr.?) William Major Barratt & Co., Melbourne, Australia....
Mr. Matthey ... /of Johnson & Matthay, Hatton Garden/
Mr. Foard. Best Assay Balance, Mr. Makins pattern ....
Dr. Daubeny & Mr. Maskelyne. Ashmolean Museum, Oxford.
Capt. Ward for Australian Mint ...
Colonel Browne, Medical College, Calcutta ...
1854 Mr. Napier ...
Fortuna Mining Company
Dr. Playfair ...
Sir James Melville, Secretary, East India House.
Harper & Sutton, Chemists ... Norwich.
Mr. Kruger ...
Jos. Heywood, Owen's College, Manchester.
Bell Brothers, Newcastle on Tyne.
Captain Gossett R.E. Treasurer of British Colombia ...
Assay Office Branch Mint, San Francisco, California ... Packing balance in case lined with tin, the wood case to be enclosed in hay

> covered with canvas, iron handle on top of packing case, to be marked in large letters on top."
>
> Nitro Phosphate Manure Co...
> Mr. W.G. Reynolds, Royal Military Asylum, Chelsea.
> Dr. Roscoe..." (39)

The diversity of occupations and interests represented by this extract from a longer list of names already shows the areas in which the use of the precision balance was becoming common; industry and commerce, dispensing and assaying, scientific analysis and education, all had different needs and a range of balances was produced over the years by Oertling to accommodate those needs. If a suitable instrument or type of service appeared to be lacking, this was remedied. In this way the Makins Assay Balance came into existence and became the model for all subsequent patterns, including the "12 s b a". When the newly designed short beam chemical balance made by Bunge aroused interest in the late 1860's, short beam Oertling balances were produced. The servicing and maintenance of old and valued instruments for important clients must have given valuable experience of design patterns long since discontinued to the firms' craftsmen which, in turn, could be drawn on for new ideas. During the 1860's Oertling, while in partnership with Ladd, was called upon to renovate some important balances belonging to the Standards Department. These included:

> "...a large balance originally constructed by Captain Henry Kater. This balance was supplied to the Standards Dept., by the Astronomer Royal for weighing the Standard Bushel Measure (250lb.) and the Report mentions the fact that the instrument was in the hands of "Ladd & Oertling" to be put in proper order .... Captain Kater's large balance was also entirely reconstructed by Mr. Oertling and carries 300 lbs in each pan, having a sensitivity of less than 1 grain (approx 1 part = 4,000,000). The 1867 Report also has a reference to "Barrows" balance being put into complete order by Mr. Oertling. This instrument was used by Professor W.H. Miller for all weighings in connection with the Imperial Standard Pound." (40)

Despite the difference in scale between the Makins assay balance with its load of 25-30 grains, sensitive to 1/1000 grain, and the massive balances mentioned above, the same attention to accuracy and quality was present at both extremes and, in all balances of more modest proportions.

By the turn of the century the Oertling illustrated catalogue ran to 54 pages and covered not only assay and bullion balances but also an Automatic Balance for separating light and heavy coins from

those of correct weight. The job John Field had performed by hand was now done automatically. Chemical balances included short beam designs first introduced by Bunge in 1866 and a complete range of balances for Inspectors of Weights and Measures. There were also Hydrometers and Saccharometers and Weights of every type and description. A very substantial overseas trade had been built up supplying Governments, Mints and Banks world wide. Of those balances supplied to such organisations in this country, quite a number survive either in store or on loan to Museums. Many surviving Oertling balances have no real provenance, though many can be placed and identified from the first 1875 illustrated Oertling catalogue. Before that date, accurate identification and dating becomes more difficult, a process not helped by the painstaking refurbishing carried out by the firm which often resulted in a technically perfect but visually puzzling "marriage" of parts. Some balances were specially made for and used by the great and famous. Mendeleef used an Oertling balance and it seems probable Oertling travelled to Russia to meet him in the course of the work (29). A vacuum balance was made for Miller, designed in such a way that the load and weights could be manipulated from outside the case. (41) Both Rayleigh and Ramsay had Oertling balances, as did Moseley working on atomic weights in the early 20th century. (42) Makin's assay balance has already been mentioned and is carefully preserved. One balance of an unusual pattern designed by Airy seems not to have survived. Airy wrote to Oertling in 1872:

> "I am desirous of fixing in a wall [at Royal Observatory Greenwich] for public access a balance concealed in all important parts except the scale pan, by which tradesmen can test their one pound weights (7000 grains), showing the error in grains of excess or defect, say up to ± 50 grains..." (43)

This laudible aim was never entirely realised for, although the balance was supplied and installed, Airy found it was being damaged by "boys" and, although repairs were undertaken, the project seems to have lapsed and the balance, which must have been of most unusual design, has been lost.

Another balance with a strange device was made by Oertling for the Board of Trade and said to have been designed by a Mr. Artingstall. (44) It has neither knives nor planes but, both the beam and the pans, are suspended by metal ribbon. To keep these strips taut both beam and pans have had to be made extremely heavy. The whole apparatus is cumbersome and the design, which cannot have

offered any advantages, appears never to have been repeated. It may have its origins in a comment made by the Jury at the 1851 exhibition who regretted that no manufacturer had tried out the projected design by Gauss. (45) It seems possible Gauss was attempting to avoid the use of traditional suspension mechanisms which were subject to inertia, but the knife and plane mechanisms overcame this problem.

The majority of surviving Oertling balances have no illustrious pedigree, but were merely standard items whose designs can often be traced to the relevant catalogue. Some are known to have been bought by large organisations such as the Mint, The Bank of England, Assay Offices and National Physical Laboratory. Others by commercial enterprises such as Allen & Hanbury who bought the prize winning No.3 at the Exhibition of 1862, or Johnson & Matthey who bought an assay balance in 1851. The Royal Institution used some of the money given annually by Holland for apparatus to buy a balance from Ladd & Oertling in 1862. (46) The Royal School of Mines retains, in use, a magnificent 1 Kg. long beam balance originally purchased about 1890. Many Oertling balances had far humbler owners. Oertling continued to expand a tradition begun by Robinson of producing instruments of the highest possible accuracy. He went further than Robinson, however, building up a vast range of designs to accommodate the multitude of purposes that evolved for balances as the century progressed.

Robinson & Oertling by responding to the changing needs of balance users during their working careers were able not only to advance their own reputations as suppliers of instruments of technical excellence, but also enabled their customers to develop the study of chemistry to a point undreamt of prior to the nineteenth century. In this respect they were part of a long tradition of instrument manufacturers. Of their lives and achievements some details can be gathered but their importance and influence is the greater because they were not alone but part of a large group of makers whose instruments covered all fields of measurement, and who had a common objective, precision.

1. Stock J.T. Thomas Charles Robinson and his Balances. Journal of Chemical Education Volume 45 No.4 April 1968 p. 254-256.

2. /W.T. Brande/ Quarterly Journal of Science Literature and the Arts Volume 11 1821 p. 280-281.

3. J.G. Children F.R.S. 1777-1852. Secretary to Royal Society 1826-7 and 1830-7. Had built a laboratory in his home town of Tunbridge which was often used by Davy. It was no doubt this association which resulted in Children receiving Cavendish's balance from Davy, as has already been mentioned. The date of manufacture of this Robinson balance is not given. Children had been bankrupted in 1816 and became curator at the British Museum (D.N.B.)

4. Kater H. Quarterly Journal. Volume 12 1822 p.40-41.

5. One possible date is suggested by Kater when he described in 1818 experiments performed:

> "at the home of Henry Brown F.R.S., in a part of Portland Place not liable to much disturbance from the passing of carriages".

The house would have been very near Robinson's premises in Devonshire Street. Kater H. Experiments for determining the length of the pendulum vibrating in seconds. Phil Trans 1818 p.33-94.

6. Letter quoted in Stock J.T. Precision Balances. A chapter in their history. Chemistry in Britain Volume 7 No. 9 September 1971 p.385-387.

7. Dictionary of National Biography.

8. Kater H. An account of the construction and adjustment of the new standards of weights and measures of the U.K. and Ireland. Phil Trans Volume CXVI 1826 p.1-52

9. Wm. Simms did not become a partner in the firm till 1826.

10. During the period circa 1815 Troughton would have been working on instruments for Hassler to take back to America.

11. Whipple Museum Cambridge. Inventory No. 1109

12. Whipple Museum Cambridge. Inventory No. 1593 (and perhaps also No. 1413).

13. Reference 8 page 11.

14. Only balances of the first two sizes mentioned in fact survive, and they have beams of total overall length approximately $10\frac{1}{2}$" and $5\frac{1}{2}$" as advertised. Throughout this survey, beam lengths of surviving instruments have usually been taken as the length between the knife edges, i.e., the effective useful length, rather than the total length which may or may not include adjusting screws.

15. Advertised in Astronomische Nachrichten 7 232 (1831) and 8, 48, (1831) and quoted by Stock Reference 1 above.

16. Moll Dr. G. On the comparison of British, French and Dutch weights. Journal of the Royal Institution 1831 Volume 2 No. IV and V p.64-65

17. There comprise 3 at Cambridge, see Reference 11 and 12 above. One in the Wellcome Collection now at the Science Museum and, one at the Royal Scottish Museum, Edinburgh No. 1970 L2.

18. A clear diagram illustrating this feature which is typical of all later Robinson, and Robinson derived, balances will be found in Stock J.T. & Bryden J. A Robinson Balance by Adie & Son of Edinburgh Technology & Culture Volume 13 No.1 January 1872 p.53.

19. Reference 1 p.256.

20. Thorpe Dictionary of Applied Chemistry 4th edition p.587-589 reprints article on Balance by Professor W. Dittmar L.L.D., F.R.S., of Glasgow, originally published in 1890 for the 1st edition.

21. Kater Henry and Lardner Dionysius.
"Mechanics" in "The Cabinet Cyclopaedia conducted by the Rev. D. Lardner". 1831. "The Chapter on Balances and Pendulums ...has been written by Capt. Kater". p.278 ff.

22. Thorpe E. Editor. The Scientific papers of the Honourable Henry Cavendish F.R.S. Cambridge University Press 1921 Volume 2 p.56 footnote*

23. Cavendish H. An account of the Meteorological Instruments at the Royal Society's House. Phil Trans. LXVI 1776 part I p.390.

24. An account of Barrow's life and connection with Robinson's business in its later stages will be found in J.T. Stock Precision balances - a chapter in their development. Chemistry in Britain Volume 7 No.9 September 1971 p.385-387.

25. Miller W.H. "On the construction of the New Imperial Standard Pound and the copies of platinum." 1856 III p.753-946. Phil Trans.

26. Science Museum Inv.No. 1977/-

27. Another balance signed Robinson & Barrow is at Whipple Museum Cambridge. No. 1371. Balances by other makers based very closely on Robinson's design include one signed a) J.B. Dancer and made for Joule in 1846. Now at the N.W. Museum of Science and Industry, Manchester.
See J.T. Stock "Weighed in the Balance". Analytical Chem. Volume 45 No.12 October 1973 p.979
b) one signed Adie & Sons Edinburgh, now at Royal Scottish Museum Edinburgh No.1968/25 See J.T. Stock Reference 15 above.
c) also, located by Dr. Anderson, one signed Watkins & Hill Charing Cross now at Transylvania University Lexington and another signed Puttey, Bleeker Street N.Y. at the Smithsonian No.333993.
Child E. In "The Tools of the Chemist; their ancestry and American Evolution" N.Y. 1940 suggests that Robinson balances were the first previsision balance to be used in America and these last two may be the descendants of a lost original.

28. A detailed account of Dover's life is in J.T. Stock and P.S. Laurie "John Dover, Instrument Maker 1824-1881". Technology & Culture Volume 21 (1) 1980 p.51-55

29. For much of the background detail on the Oertlings I am indebted to private communications from Ludwig Oertling's great grand-daughter Miss Dunbar.

30. Census returns, Public Record Office.

31. Obituary of Wm. Simms /Proc/ Royal Astronomical Society 87th A.G.M. Volume 67 1906-7 p.237.

32. A brief history of the firm is to be found in Taylor E.W. et al "At the sign of the Orrery" .... and Skempton A.W. and Brown J. "J. & E. Troughton". Notes and records of Royal Society Volume 27 1972-3 p.233-262.

33. If E.W. Ladd was indeed Oertling's apprentice, this must have been during the late 1840's, suggesting that Oertling was building up his business at an earlier date than the Trade Directories would seem to imply. "Apprentice" here must not be taken to imply formal apprenticeship as understood by the City Companies. There is no tradition that Oertling ever became a member of any company; indeed the location of his business premises seems always to have been chosen with the intention of siting them just outside the formal City limits in the Wards of Cripplegate Without, Bishopsgate Without etc.

34. Census returns Public Record Office

35. A microscope by Ladd dating from the Chancery Lane years is in the Wellcome Collection.

36. Managers Minutes Royal Institution.

37. Exhibition of the works of Industry of All Nations 1851. Report by the Juries. pub. Clowes p.258

38. The collection of medals awarded to the firm of Oertling have, at present, been loaned to the Science Museum by the descendants of the family.

39. Oertling archives.

40. Unpublished memoirs compiled by Malcolm Dunbar circa 1947 by kind permission of Miss Dunbar. The present location of the balances mentioned here is not known. The "Reports" referred to are the annual reports of the Board of Trade.

41. Science Museum collection.

42. Ramsay & Travers balance, Science Museum No.1957/11
Moxleys balance at N.W. Museum of Science & Industry.

43. Archives Department, Royal Greenwich Observatory R.G.O. 1325 Sect.37. I am most grateful to Miss Willmoth of the Royal Greenwich Observatory for her assistance in locating the correspondence between Airy and Oertling among the Airy papers.

44. Science Museum collection No. 1876/127
The present ribbons appear to be made of non-magnetic stainless steel, a substance unknown in 1876 and represents a repair. Private communication from Mr. Chappell of L. Oertling Ltd. It is not known of what material the original strips were comprised.

45. "There is no example of the balances constructed under the direction of Gauss & Weber, and described in the "Göttingen Transactions ... in which the beam is suspended by two watch springs, and each pan by a single watch spring."
Report of Jury Reference 37 above.

46. Professor Faraday paid L. & O. £22.0.6d. to be charged against the Holland Trust. February 3rd 1862. Royal Institution minutes p.409. Holland gave £40.00 annually from 1859 to 1873 "for the purchase or renewal of apparatus". Sir Henry Holland was Secretary 1859 and later President of the Royal Institution.
Sophie Forgan unpublished Thesis on Royal Institution 1840-1873 1976 p.164.

CHAPTER 6

Conclusion.

Conclusion

The balance plays an essential part in one of chemistry's major concerns, the identification and quantitative analysis of naturally occuring or man made substances, and it can assist in analysing and classifying them to determine their structure, mass and potential uses. In this process the balance plays an important part, but is by no means the only tool employed, nor could it alone and in the absence of other methods of analysis convincingly establish the identity of unknown substances. It is one of many useful tools, and in this respect resembles the pocket calculator. It can perform certain tasks rapidly and with a high degree of accuracy but demands the existence of a mind to programme it, to ask the questions and deduce from the answers the relevant information. Changes in the design of the balance reflect changes in the type of questions being asked in chemistry. The new design may produce answers far beyond the expectations or aspirations of the questioner and in this way set in motion further research, but without some external influence design remains static. The latter part of the 18th century was a time in which a number of influences came to the fore, setting in motion important changes in balance design and resulting in considerable increase in available information about chemical substances. During the 19th century further changes in the approach to chemistry took place which modified existing ideas and also existing designs. This study has been concerned with tracing some of the changes in instruments that took place, often imperceptibly, during this period.

The Industrial Revolution was an important though indirect influence. The development of new industries in heavy metals, sulphuric acid, alum, soda and the destructive distillation of coal produced new raw materials and sources of power but did not themselves generate a demand for chemical apparatus.(1) The massive undertakings and factories that the Revolution created however aroused public interest both in the buildings themselves and then in the raw materials the industries used. The possible

commercial exploitation of such substances encouraged surveys of land to be undertaken and those who owned land became interested in tracing mineral deposits. A vast industrial complex would not now be considered as a tourist attraction, unless its industry was safely dead and museumised but in the early 19th century a different attitude prevailed.

> "As we approached them the effect was grand and sublime beyond all description" (2)

Not the words of a Lakeland poet on seeing a spring meadow, but the Duke of Rutland visiting the Dowlais iron works in Merthyr Tydfil in 1805. This interest in a hitherto unregarded aspect of the natural world was exploited by those who gave lectures on the marvels of science. Societies such as the Royal Institution were concerned with,

> "..the application of science to the common purposes of life", (3)

and income was derived from those members who were prepared to pay for lectures on this theme.

The Royal Institution also found itself at the forefront of another influence on apparatus design, the isolation and identification of new 'pure' substances. The work carried out by Davy on the alkali metals in the early 19th century like the long running debate begun in the previous century over the existence or otherwise of phlogiston focused the attention of those interested in the detailed investigation of substances on the idea of exact composition. Although such chemists as Black Cavendish and Lavoisier were numerically very few their influence was considerable, both on those who wished to repeat their experiements if only to prove them wrong, and on those who were interested in the results and wished to know more about chemicals without ever entering into debates about the nature of fundamental particles. These two main groups of enquirers brought into being two main styles of apparatus in the early part of the 19th century. As the number of people in each group became larger and better organised, so the provision of apparatus increased in quantity and modified in design. Both groups influenced the design of balances.

The tradition of accurate weighing upheld for centuries by jewellers, apothecaries, money changers and in particular assayers had produced basic balance designs from which, with no great degree of alteration, larger and more accurate models could be produced for wealthy clients such as Cavendish and Lavoisier. Many other professional chemists however found ready made apparatus quite suitable for certain needs and the balances of Black, Dalton and Wollaston are typical examples of the apparatus which was also in daily use by traders in the late 18th and early 19th centuries. In addition to such instruments however Black and Wollaston also possessed other more accurate instruments specially made to a higher standard, and many of the innovations in balance design throughout the period can be traced directly or indirectly to the expressed wish of a customer or large institution for an additional (not replacement) instrument to be used for some specific purpose. Not every innovation proved a long term success. Some ideas such as the cone beam despite prestigious purchasers did not persist. Other quite simple ideas , such as the use of agate or the development of the rider became universal.

It is often the small innovation rather than the massive new idea that really influences future designs and reappears in other instruments of quite different style in a later period. The end pointer rather than a centre pointer, moving over a finely divided scale and viewed witha spy glass appears in Lavoisier's Fortin balance, reappears in Troughton's balance and is exemplified in late 19th century very high quality Oertling balances used for assay work, balances totally different in style and use from the massive Fortin. The influence on design of Kater and Makins has already been discussed. They, like Lavoisier or Banks who commissioned Ramsden required a balance for a specific purpose. The purpose once fulfilled for the benefit of Kater or Makins encouraged the production of a long line of balances by Robinson or Oertling. These distinctive designs were also copied

by other manufacturers during the century. There exist not only signed Fidler balances obviously inspired by Ramsden but also balances with lattice beams from work shops other than those of their originators. In the same way once the idea of a short beam balance had been accepted, balances with short beams which resembled the original Bunge beam only in length, were also produced.

If certain aspects of change in balance design can be traced to the requirements of a few select and highly influential individuals, who were themselves interested in improving the tools of their trade, for the better investigation of chemical substances and their structure, an interest encouraged by controversy over theory and fuelled by the Industrial Revolution, there was always another group of people whose interests were very similar, but whose aspirations were very different. For this group, who came from many walks of life from wealthy patrons to aspiring clerks, lectures and books, demonstrations and discussions were organised. The proliferation of learned Societies during the 19th century enabled those of similar interest to meet and exchange views and ideas. Such groups presented a large potential market for new and improved apparatus of all kinds, but until mid century this market and its reflected influence on apparatus design grew comparatively slowly.

The learned Societies many of which were founded in the first half of the 19th century, existed for the promotion of research and publication, rather than for the teaching of others. It was assumed that their members had gained a good basic education and had some knowledge of the specialist subject which the Society promoted (4). The Mechanics Institutes which were also founded in the same period and became numerous after 1820 ran into difficulties because they could not assume the same standard of basic education would be present in all the members of their audiences.(5) This difficulty was further confounded by long working hours found in many occupations which gave very little time at the end of a day for potential members of Mechanics Institutes or similar bodies to attend

any meetings. In 1830 the principal linen drapers in Tottenham Court Road appreciating this problem, agreed to close early on a weekday at 8pm (11pm on Saturday) to give

> "a generally energetic and intelligent class of man an opportunity of procuring recreation and improvement after the fatigues of the day" (6)

The traditionally long hours of the retail trade may form an extreme example but long working hours were normal during the 19th century and left little time for further education or self improvement. The uneven distribution of education in general, and the even more restricted nature of education in science, particularly in the first half of the century, further limited the number of people able to express any interest in scientific phenomena of any kind. This educational restriction persisted until late in the century particularly in the Public Schools and the universities of Oxford and Cambridge. Commissions of 1860 and 1875 pointed out the problems faced by any one seeking to improve the provision for science education offered by such organisations. These included lack of laboratories, money, apparatus, timetable space and staff. A change in attitude was a primary consideration but this was slow to develop. The Headmaster of Rugby could see no benefit to education from a study of science and maths. In his opinion,

> "Such studies do not make a man more human, but simply more intelligent".1875 (7)

Outside the world of public schools by mid century there were changes. These were encouraged by the establishment of such institutions as the Royal College of Chemistry and Owen's College. Dissenting Academies also had a somewhat different attitude to science from older foundations, and all new colleges and academies started with the great advantage of new or adaptable premises into which laboratory space could be incorporated, and a blank timetable.

The gradual change in attitude towards and availability of education in chemistry also encouraged the production of trained chemists, which in turn, with infinite slowness encouraged employment opportunities for

qualified people in industry. (8)

This brief account of the state of education in science during the 19th century which covered all attitudes from enthusiam to indifference gives some indication of the pressures felt by all the manufacturers of scientific instruments. Those whose specialisms covered apparatus for the traditional and still much needed techniques of surveying, astronomy, and navigation continued to serve an ever expanding market as the Empire demanded those same traditional skills.(9) Those whose customers were more concerned with "modern" science saw a considerable increase in their sales as the second half of the century progressed and more outlets became available for their products. This in turn encouraged more designs whether of balances or of burettes which is reflected in the ever weightier catalogues produced by even more numerous firms. E.G.R.Taylor has pointed out (10) that by 1840 the scientist was returning to his laboratory and the craftsman to his factory, and the interplay and interdepend ence between the two, so prevalent in the 18th century, was over. Certainly the "one off" production so far as balances were concerned was replaced by basic designs containing certain selected innovations and adapted to customers requirements. These diverse requirements were however met, and new designs produced as this study has sought to show. One benefit of the mass production outlook that came with a more "mass" market was undoubtedly the sheer volume of instruments produced. The more people who were able to verify, or not verify, the findings of another chemist, be he a fellow student or an eminent fellow, the more both the standard of chemistry and the standard of basic design of all apparatus was likely to be improved.

Only a few of those who used balances have left accounts of their instruments. This is understandable. The balance is only a part of a process, or an aid to discovery: it is not an end in itself, except to its maker. A similar situation may be seen in the proliferation of cookery books to be seen in any book shop. For instructions on how to use a cooker one must seek the few books intended

for children or other "apprentices". It is assumed that those purchasing recipe books have long since passed the apprenticeship stage, and the process can be taken for granted. Times and temperatures will be stated, but not how these may be arrived at.

Despite the relative lack of testimonials from satisfied users of balances, the sheer volume of surviving instruments whether designed to meet the needs of specialist research and industrial chemists or the needs of education and commerce shows the eminent place accorded to the balance by scientists. The primary concern for all users was "good" i.e. suitable design. Without this the best of experimental technique would be hampered. With it, aspects of work became possible resulting from greater accuracy or reliability then would have occured otherwise. Better instruments were undoubtedly helped in their production by the presence of better machine tools or techniques or materials, these in turn being the products of research. The process is but two aspects of the same coin. Advances in chemistry both inspired and rested on advances in balance design. The two remain inseparable. One account which does stress the importance of the instrument was made in 1829, by a visitor to Berzelius' laboratory.

> "In the second room the first object one notices is a glass case standing on a table. It is the balance. How much light this fragile simple instrument has shed on the natural sciences! How many phenomena it has explained. How many hidden truths it has revealed! Who could enumerate the discussion it has ended, the hypotheses it has destroyed. Who in former times, who would have believed that the determination of abstract truths and the development of the laws of nature would depend on the oscillation of this moving beam..." (11)

Berzelius by his work established that accurate analysis was possible and even enhanced by the use of smaller samples of material than was customary in the early 19th century. In this he encouraged a trend towards

a range of instruments of ever smaller capacity and ever greater sensitivity, a process that still continues. The determination of ever more accurate atomic weights for gases later in the century required instruments of large capacity, but also high sensitivity. A proliferation of balances for many different tasks did not overnight produce exact quantitative results for every piece of research, but did put limits on the degree of acceptable error, a trend enhanced by legislation concerned with standard weights and measures, legislation which in turn promoted the use of ever more accurate weighing devices in daily life.

There was never any such instrument as "The Chemical Balance." There was however an ever increasing range of balances suitable for use in chemistry. Some of the chief characteristics of such instruments have been described in this study, together with some suggestions as to how and perhaps why these features came into existence. The diversity of the subject of chemistry was both the instigator and the product of the diversity of the many instruments it employed, and among these instruments the balance was an essential key.

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APPENDIX A

Location and some structural details of the balances covered in this survey.

APPENDIX A

Location and some structural details of the balances covered in this survey.

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SCIENCE MUSEUM LONDON

Dept. of Chemistry

Science Museum Collection Oct.1976
Acc/Cat. No. 1900/166

Said to be used in experiments in 1789 by Royal Soc. for s.g. of spirits and water.

Case: 82cm x 60cm x 20cm deep.
4 adjustable feet, probably later.
Old photograph shows it on pillars.
Small door in each end.

Drawers: Back: Top 3 very shallow, ivory pulls.
Bottom 6 fake.
Grain 1 to rt and all inlaid.

Front: Top 6, 1 and 6 cut to pass pan arrester pillar. Left hand top one marked 13536. Contents, a few nuts and bolts.

Bottom: 2 large centre ones and 2 small ones each end.

Doors: 25x 43cm door at each end of front and centre lift out panel

Pillar: 29.5 to agate split plane, so very like the R.I. Fidler. q.v.
5 small pillars, 4 to hold beam and one stabliser.
Signed Ramsden London.

Beam: 61cm K to K. Steel K's and hooks exactly like Fidler. Has a pointer and one levelling screw. The two ends of cones are steel and not identical. Flag in brass and whole things can be turned round.
Ivory scale ÷ 0 - 45 at both ends.

Arrestment: Pan arrester handles at both ends, plus a pin to stop by internal rachet the lift at any point. Now very much needs oil. This pin would foul doors and prevent opening. Beam arrestment is a pivot from centre front which raises and lowers by seesaw, relying on wt.of beam to drop it.

Pans: Missing. Pan hangers would have been 24-27cm.

Science Museum Collection Oct.1976
~~Cat~~/Acc. No. 1925-40

Case: 55.6cm x 51cm x 33.5cm deep.
Front 42cm x 51cm, and back slides up and out. Also two doors in sides, bow fronted inside only. No marks on case.
Signed on pillar top "J. FIELD FECIT His Majesties Mint."

Arrestment: Push lever pushes twin pillars up, spring lever pushes it back. Scale also moves up as beam lifts.

Pillar: A pierced oak(?) splat holds the pillars which carry split steel plane set in brass. 25cm to plane.

Beam: Steel. Brass connectors to hold knife to beam. 29 hook to hook. Pointer 17.5 cm. Two steel V's hold beam up. Large steel K.

Pans: 4cm brass. Hangers pt. wire 24cm. Probably silk once. Redrilled. inc. steel hook.

Pan bouncers present, but never intended to move.

Can be adjusted easily and finely by the swans. .005 will move needle right across scale.

Little C of G knob on pointer has a bite out of one side. It is suggested this would act as a fine wt adjuster to level beam.

Science Museum Collection ~~Cat~~/Acc.No. 1928/1024 — Oct 6 1976

Case: Walnut + two drawers under.
47cm x 36cm x 18cm + drawers.
Drawer grain f to b 19cm x 18cm x 8.5cm deep.

Contents: Rt one unmarked and empty. Left one ÷ and fitted with s.g. pan, glass wts. etc. Three feet, 2 on left and 1 on right. Late additions. 4 holes in corners originally. 2 spirit levels. 2 side doors. Long shallow drawer across the back into which beam will fit.

Beam: 2 cones 32.5. Flag missing. Steel K's. 2 pointers. Captive hooks fit on steel knives. The two ends are not a pair. Aduster to screw out.

Pillar: 27.5 to split agate plane.
Signed W. & S. Jones London.
Column tapering.

Pan Arrester: A knob winds up two plates attached to base of pillar.

Beam Arrester: Mechanism underneath pillar. Knob winds down pushing lever on spring up, therefore raising column in column.

Grad. Scales: Fixed to side walls and can be moved in any direction to line up with pointer.
0 - 50.

Pans: 5.5 brass on bronze hooks and Fe wire chain 21.5 cm.

Sensitivity: Turns well at .005.
Not a good arrestment system. By the time the beam is wound up by rising plane the pointer no longer lines up and the scale cannot be set with beam at rest.

Science Museum Collection Oct.1976
Acc/Cat. No. 1925/41

Case: Glass 40cm x 26cm x 52cm high inc. drawer with wooden knob, ÷ to hold balance. No marks. Front on rachet with 11 spaces 37 x 44cm. 3 adjustable feet, later?. One spirit level. Perhaps another, 2 screw holes remain.
Whole balance will slide forward and out. Well used. Nice wearmarks on mahogany base.

Arrestment: Pull string. Weighed yoggy pot.
Ivory bouncers 5.5cm diam.

Pillar: 23cm to ÷ agate plane. Upwards pointer and scale 0 - 4. Arm rests 8cm each side. Flag on pointer.

Beam: Fits drawer. Length 26cm. Brass.
Steel K. Toasting fork ends cut.
Stamped F. Fe ends.

Pans: Size 1.5 on 22cm ribbon hangers. Too long.
Held by Fe hook.

Sensitivity: .005.

Signed De Grave Short & Fanner London

Science Museum Collection Oct.1976
~~Cat~~/Acc. 1898/68

See ¼ J. Chem. Soc. Vol. VI 1854 Makins

Case: 46cm x 49cm x 33cm deep inc. 2 drawers. 2 riders, 2 spirit levels, 4 feet. See Assay Office file. Very typical. Front counterbalanced.

Left drawer number 20570. Right drawer contains little pans and wts. Ag. in screw top.
Base glass over faded green.

L. Oertling Stone St. London
Later plaque says "Designed by George Hogarth Makins Carries 10g. Indicate to .001 gr"

Pillars: Twin, 20cm to agate split plane.

Beam: 25.5 pins to pins. Sloping and ÷.
Knives bright steel.
Pointer 15.5cm. Ivory scale.

Pans: 3.4. brass. Hangers 18 to "planes" = steel bars to fit over pins.
Pan arresters go up not down and beam arrester goes down to operate.

Sensitivity: .001 will turn it off scale to 10.
.001 and rider on 1 will recentre it therefore acc. to .0001.

Science Museum Collection Oct.1976
Acc.No.

"C1925 type used by R Mint and Assay Offices. 6" horiz. beam carries 2g and turns with .001mg or 10 -5"

Case: 36cm x 36cm x 20cm deep and 2 drawers. 2 riders and V finely ÷ plus very fine scale.

Left drawer 28963 34323 plus Key.
Right drawer WL 6/4/09

Manufacturer: Pillar base 10736. Oertling.
Glass floor on green. 2 spirit levels.
Flag.

Pillar: Twins. 17.5 to centre split agate circles.

Beam: 16cm horizontal.

Arrestment: Turn knob raises pan rests and beam arms.
Pins 7cm either side for end planes to rest on.

Pans: No corrosion.Steel? Plated? 1 cm. on 14cm hangers. Centred by dropping pan hook through hole in circle of beam rester. Pointer 14cm.

Science Museum Collection Oct.1976
Acc.No.1975/83

Case: Small, and balance minute. 35cm x 26cm x23cm deep. 2 side doors. A rider and spy glass plus spy on scale. Counter balanced front. 2 adjustable feet and one spike. Plumb bob. Wilh H.F KUHLMAN Hamburg.

Pillar: Centre plane is a massive agate.

Beam: No real beam, all rider bar 8cm with huge by comparison agate K. All appears to be made of stainless steel with blued adjusting screwsand agate end K's.

Arrestment: Pan rests have a centre spike which raises and lowers, and arm holders.

Pans: 3cm. Hanger 11cm. with simple simple hook. All rest in egg cups of agate.

Science Museum Collection Acc., No.1900/158 — Oct-Nov. 1976

The Royal Societies Fidler. Massive. "turns at .01grain".

Case: 95cm x 50cm x 21.5cm deep and 5 drawers under at front only, some with ivory knobs. Underneath two trap doors to cover holes below pan arresters to turn it into s.g. 4 holes below pillar to enable screw driver to reach pillar mounting.
Two little doors in ends, one off hinges. Two glass doors in face and centre panel apparently fixed. May have just warped.

Pillar: 39cm made of 5 pillars, the 4 outside ones forming a rigid top and the 5th in centre supports the beam resters front and back. Centre pillar has massive wt. at its base, appears adjustable, C of G?

Manufacturer: Signed FIDLER LONDON.

Beam: 60cm. 6.7 at centre and tapering, brass also. Flag holder. Steel K's. Flag identified in No.1 drawer plus key to adjust position. The ends are dissimilar, as R.I., with stirrup loop hooks.

Pans: 10cm brass, hanger wire 30cm. Appears to be 15 amp fuse wire. S.g. pan probably has original wire.

Pointer: Both ends, with several adjusting screws and wts knobs. At rt. a small metal scale can be fitted on pointer and intended to be read by telescope thro' glass now missing. Pointer scale suspended thro' roof and it lines up with needle only if operator stands in centre.

Sensitivity: .01 moves it 10 ÷ therefore .001g.

Arrestment: Pan arresters lower by ivory turn at bottom rt. Beam arresters by swivel knob centre front which relies on wt. of beam to drop knives.

...cont'd

Acc. No. 1900/158 ... Cont'd

Drawers:

Contents of interest as many are original:

No. 1: Top layer Sp.Gr. pan 5-6cm approx, 3 keys.
Below. 10cm diam. wheel. 4 holes could fit over top of pillar. Part of original fitments in fitted layer. Purpose unknown.
Flag, a strip of brass with square hole off centre, fits on prong of beam.
Key to move flag.
4 plates, 1 rod steel, 1 toggle handle with hole. 1 piece ivory, another scale? plus mother of pearl facer.
1 square washer.
1 wheel approx. 2 cm with square hole may fit over flag to hold it.
6 screws rusty. 1 spring. 1 cork. 1 semi-microtest tube.

No. 2: (locks) Spare hank of horsehair and packets of 1/100, 1/10 and 1gr weights.
Labelled "Mr Oertling 1868".

No.3: Metal cannister packed with cotton wool with counter balance wt. of Pb. shot packed in neck, contains s.g. bottle. Piece of chammy, a counterpoise labelled "platina dish", 1 piece of wood with 3 holes to fit over pan arrester prongs and make flat base. Did the brass one then rest on top?
2 heavy "wts".

No. 4: (locks) Wts. 2000, 3000, and 4000, grains (?)
2 stuck fast.

No. 5: Paper holding Al strip labelled for dividing spoons, and lots of collapsed pill boxes that once held Al.wts all now perished. Piece of Times of Wed. May 2 1877. Wood block hollow with lid holds Al wts made of lengths of wire. A bone lifter and 2 pairs of tweezers, one marked P.S. Stubs, glass dish, iron 'needle'. Pill boxes contained Al wts. .02gr, .01gr, .03gr, .04gr and a box "counter poises for the - centre of beam" etc.

Science Museum Collection Acc. No. 1876/227 — Nov.17 1976

"This balance was made by Troughton for Sir James South"

Case: 73.5cm x 48cm x 17.5cm inc. drawers under. Very warped and split.
Doors in both end walls, and both bowed.
Lid opens and this operates pan arresters by spring loading, therefore balance cannot be used with lid open.

Drawers: Stiff. Release operates by pushing finger through base plate to move tongue of wood. Will therefore open but not accidentally fall out.
Grain l to r.
Right - contains 2 brass 7.8cm s.g. pans on cotton strings in fitted space plus brass screw top counter balance wt, empty.
Left - contains weights from 4000 grains to 2 grains + a conversion table from their weight in grains to wts in grammes added in ink, e.g." 4000, 259.235."

Inside of drawers not stained and no markings, therefore centre space always was a stained space for the crude metal lever.
Three panes of glass make front 23.5cm x 37.5cm and do slide out but too frail to use.

Pillar: Massive hollow wood 30.5 to top. Held by 3 and previously 6 screws. Clean stain under but holes drilled twice.

Beam: Mahog 62.5 K to K 3.5 top to bottom tapering to 2cm. 1 cm thick. End K's brass on the ends + thread from brass scres. Tedious. Plimsole line to read against scale (missing) jumps off. Agate 0 centre planes. Centre K's = 2 steel pins fitted thro' brass. C of G wts. under cross piece. Flag present.

Pans: 6.9 on silk? 28.5. Too long. Once pan resters down by closing lid and beam lowered by squeezing spring, they jam.

Science Museum Collection Acc. No.1933/159 — Nov.17 1976

Small micro balance.

Case: 37cm x 34cm x 21cm deep. All glass.
2 end doors. Front slides up.
No. XVIIII stamped inside top of door.
2 riders. Dash pot, loose Lens etc.

Pillar: 18cm to agate knife.
Arrestment works on hinged arms, both ½ drop away, hinged at centre to release beam on to whole agate plane.

Beam: 8cm all very elaborate, ÷ and numbered.

Pointer: 15.cm. No. 33813 on ivory plate.

Pans: 3.5 Hangers 15 cm. Al?

J's: Held on 3 pins.

Science Museum Collection Acc. No.1923/641 — Nov.24 1976

Case: 39cm x 44cm x 20.5cm deep inc. drawers. Front 33.2 x 35cm counterbalanced. Black glass base. 1 long drawer. Chainomatic.

Drawer: Trade card, "wts and Balances of precision Christian Becker Inc 147-151 8th Street Jersey City "Signed and inspected"Pat.Feb 25 1919" stamped in drawer. Box for chain. Spare arrest knob. Space for beam,restfor s.g. and instructions, here followed.

Pillar: 25cm single.

1. 'Level balance and keep level'. 2 tiny levels in the round pillar base.
2. 'Lower arms..' hinged and held by resters 9cm overall at back of beam.

Beam:

3. 'Screw needle (19.5) to beam (18cm) getting c of g screw to front ..' 3 knives are all agate slivers set in brass.
4. 'Put beam in place and pointer should centre'. Centre plane is agate. Place stirrups in position, hook to front. 1 dot = 1. 2 dots = rt.

J's: These are crude, lumps of agate set in Al. clasps.

5. Hang bows on upper hook. Wind vernier to 0.

etc. Chain hangs from hook on beam to top of grad. pillar. As you wind it adds links and therefore wts to the rt. hand side. Pans 6cm. Hangers 20cm.

Arrestment: Beam as above. Pans by push knob which if held in,releases and lowers arms under pans (back to W & S Jones) therefore not expected to be in use very long at a time.

Sensitivity: Spot on. .001 moves pointer 1 division of grad. scale, therefore vernier and chain do 4 and 5 places.

Science Museum Collection London Dec.1
Acc No. 1976
"Ex Maclachlan No. 54 on list"

Case: 35.5cm x 39cm high x 24.5cm deep.
Front 32.5cm x 38.5cm slides up and out and also back.
2 spirit levels, glass floor, ivory pan bouncers. Rider.
Signed O.WOLTERS 55 Upp^{r} Marylebone St. London W.

Pillar: 27.5 to agate plane apparently set over wax.

Beam: 13cm K to K. K's are agate slivers set in brass. Rider bar signed O. Wolters London and ÷ 0 - 10 both sides.

Pointer: 23.5. Centre K whole, agate sliver in brass. 2 levelling screws and c of g.

Beam resters extend 6.5 either side, plus J resters which are egg cup and notch.

J's: Labelled R and L.

Pans: 7cm. Hangers 21.5 pear shaped.

Sensitivity: Levels out nicely and to at least .002 plus rider.

Also present a box of Oertling wts. No. 27004.

Science Museum Collection London Dec
Acc.No.1925/930 1976

"Presented by Chem.Soc. on behalf of Woodcock & Mellersh 1916-17"

Vacuum balance.

Case: "Gun metal tinned and enamelled". 56½cm x 45cm x 26½cm, mostly taken up with massive casing and feet, with porthole type door closing. Said to weigh 1½cwt.
Case signed C.F. Casella & Co.Ltd. No. 8941.

2 spirit levels and rider, and pillar held by 2 removal screws.

Pillar: 29cm to centre plane 'red' agate.
Rest arms extend 10cm each side.
Plinth and beam signed L.Oertling London.
No. on pillar No. 12111.

Beam: 20cm K to K - agate slivers in brass on ends and centre. Rider bar appears to be 'Silvered' brass ÷ 0 - 10 on both sides.

J's: Agate of traditional pattern.

Pointer: 21.5 Grad. Scale missing.

Pans: Flat, 10cm. Hangers 24cm. Pans shiny plate?

Pillar base plate seems to be standard fitment with 8 holes, and 4 only in case floor.

Sensitivity: -

Science Museum, London — Dec.30
Acc.No.- In Store — 1976

Case: ←
Balance on a base board 33 x 14cm intended to go in a case.

Pillar: 21cm, a tube in a tube.

Beam: 21.5 K to K. Pointer 21cm; steel knives. Beam labelled 100g. Centre "plane" is large and V shaped.

J's: Could be glass, or clouded agate.

Pans: 8.5cm. Hangers 19cm.
All brass, but has lost one of the end of beam adjusting screws, therefore not levellable.

Manufacturer: Becker's Sons Rotterdam.

Science Museum London Dec.30
Acc. No.1925/39.(In Store) 1976

Case: 50cm x 48cm x 23cm. black, with glass top missing plus one drawer under projecting. Front counter balanced 46.5cm x 48cm. 4 levelling feet, probably original.

Drawer: Contents the glass top, 1 t.t. and piece beading and a lot of numbers.

Balance held in case by two screws and will slide forward on runners, but no clearance for grad. scale under the sliding front, so probably not intended to be removed.

Pillar: Base labelled HARBAUT, Square section, 19.5cm to plane, which is two flat edges of steel with guiding V's steel.

Graduated scale ivory on brass holder above beam.

2 ivory pan plates over holes lined with paper and labelled R and L.
2 holes under but no sign of mechanism.

Arrestment: Press lever lifts the inside pillar to lift the plane up to engage on steel knife. Simple seesaw device.

Beam: 22.5 with toasting fork ends.

Pointer: 13cm.

Arm Rests: 6cm each side, with screw from underside to adjust.

Pans: Steel 1.5cm and hangers 18.5.

Will not level, suggesting this design is difficult to adjust.

Science Museum Collection Dec.30
Acc.No. 1926/534 (In store) 1976

Case: 41cm x 35cm x 27cm. Side doors. Front slides up and out. 3 adjustable feet. Plumb bob.

Pillar: C.24cm.

Beam: 13 K to K. Short. ÷ right across 0 - 9 Centreknife very large. End K's also agate each with 6 adjusting screws. Centre plane is a large agate
Beam resters are cup and V

J's: Hang from inset agate. Pans 7cm. Hangers 20cms.

Manufacturer: Baird & Tatlock

Sensitivity: At least .005. Prob. .001 plus rider.

Science Museum Collection Jan.31
Acc.No. 1975/440 (In store) 1976

Case: 37.5cm x 31cm x 25cm. Labelled
Manufacturer: Sartorius Werke A6 Gottingen
Front counterbalanced, now unthreaded.
Side doors left one totally without hinges.
Rider, magnifier.

Pillar: About 22cm, obscured by optical sighting and grating.
Milligramme turn knob. 2 possible damper cups present.

Beam: Short, 8cm, numbered 1 - 10 right acrss.

Pointer: Exceptionally wide and flat, probably A1. Agate knives and centre plane, and beam rests on agate rocket noses. All very small and finely adjustable and nonferrous. Both knife and plane at centre undivided.

Pans: 3cm. Hangers 16.5. Both J's and one pan bouncer missing. Wiring for lighting bulb for viewing seems complete.

Science Museum Collection Jan.31
Acc.No.1969/376 (In store) 1977

Case: 54cm x 49cm x 25cm inc. drawer. It has two doors in front and a centre panel. Top of case held by turn buckles, lifts off.

Drawer: 45cm x 24.5cm empty.

Pillar: Twin pillars 26.5 stamped Black,
Manufacturer: A Collot à Paris 1893. Block assay type.

Beam: Stamped C.F., Brass. Al rider bar 0 - 10 both sides. 24.5 or less K to K.Agate throughout. Centre plane a slab of agate slides out to release beam.

Pan bouncers ivory pins. Dash pot.

Pans: 7.5cm. Hangers 22. Pans steel and hooks.

J's: Agate domed railway tunnel pieces set in metal labelled G[auche] & D[roit]

Sensitivity: Better than .005 without rider.

Science Museum Collection Feb.7
Acc.No.1879/53 (In Store) 1977

Case: 33cm x 39cm x 20cm. inc. drawer. No adjustable feet. Nice clean case.

Drawer: Fitted to take beam and pans and pointer. Numbered 5287.

Pillar: Small label round it 22.12.-.
18.5 to agate split plane.

Box of weights, underneath stamped
19 1101
22.12.79

Beam: 20cm. all spotless, press lever arrestment at base of pillar. Stamped S.
Knife= agate in brass.

Pans: 7.5cm. Strings 18cm. Pointer 12cm.
Ivory scale but no beam resters.

Sensitivity: Will just about turn at .01, but not intended for fine work.

Science Museum Collection Feb.7
Acc. No. 1913/68 (In Store) 1977

"On loan from Oertling".

Case: 41cm x 53cm x 28cm inc. 2 drawers. A lock at the top of the case.

Drawers: Left signed A.W. 14.3.11.
Right contains key, 2 jays and a test tube for rider and a knob.

Glass floor, 2 ivory pan bouncers, 2 levels. Rider ÷ 0 - 10 each side.
Optics by dentist mirror at top.

Pillar: No. 11192. 29.5 to plate = whole agate.
L. Oertling London

Beam: 20cm K to K = agate slivers. Arm rests 10cm each side.

Pointer: 21.5cm.

J's: Brass L and R with agate slabs.

Science Museum Collection May 1977
Acc. No. - (In store)

Case: 41cm x 39cm x 20cm. Drawer marked 3351 and 12, as is liner.
Front slides up and out.
Now lacks a foot.

Beam: 21 K to K, ÷ for rider. Agate throughout.
(Another beam also in drawer found to fit another item)

Science Museum Collection — May 1977
Acc. No. - (In store)

Case: Badly damaged and rt. foot broken.
Balance deteriorating and in poor condition.
Case 36cm x 36cm x 24cm.
2 side doors and opens front and back.

Beam: 13.5 K to K ÷ 0 - 5 both sides.
Appears to have no number.

Manufacturer: Bunge.

Science Museum Collection — May 1977
Acc. No. - (In store)

Case: 6 sided. 42cm high and 36cm deepest section.
Electrical optics. Air damped.

Pillar: About 28cm.

Beam: 12 K to K. Agates.

J's: Missing.

Manufacturer: Baird & Tatlock (London Ltd)
14-17 St Cross St. London EC1 Eng.

Science Museum Collection — May 1977
Acc. No. - (In store)

Manufacturer: Towers Widnes. Air damped. Bal. Model 95 and 100.
Difficult to assemble.
Fraction weights done by rings.

Science Museum Collection May 1977
Acc.No.1975/442

Manufacturer: Stanton Supplied by Hospital & Lab. Supplies Ltd., 12 Charter House Sq., London EC1.

Model ADZ No.926

Air damped. 2 side doors. Electrical optics. Elaborate rings for small wts. "1 div. = 0.2 mg"

Science Museum Collection May 1977
Acc. No. 1970/469 - In store

"Presented by Glaxo"

Manufacturer: Oertling. Model 63P/PB "Greenford 14340"

A double decker Oertling. The top hinges off with case.
Beautiful.

Pillar: c17cm. 35047

Beam: c 11cm. Alas no pans or jays.
11.7.46 perhaps.

Science Museum Collection May 1977
Acc. No. - (In store)

Manufacturer: Ladd & Oertling London.
Pillar overprinted MET LAB and Cypher.
A short beam of Assay Office type.
No pillar number. Rider ÷ 0 - 9 both sides.

Beam: 20.5. Ivory bouncers.
Pans, spare small bouncers and silver bowls in Rt drawer 8887.
Left drawer 19867a 23986/A 26383
9/95 (or 9/96) 8/1901

Science Museum Collection May 1977
Acc. No. 1969/377

Manufacturer: F. Sartorius Gottingen 9450.
Short beam. Rider separate. Beam 14cm.
Complete. Nice rocking J's.

Science Museum Collection Acc. No. 1976/68 — July 6 1977

Oertling long beam.

Case: 56cm x 49.5cm x 27cm deep inc. 2 drawers, with knobs. 3 adjustable feet. Front slides up and out on counterbalance. String broken or missing. Sides do not open as rider is present, nor back. Label says 1900/158.

Drawers: Left one has label and advert. of Turnmill St showing medals of 1851 and 1856. Under drawer 2 squiggles only. Rt. drawer has 2 keys (though key still in lock at top of front). No numbers. No fittings.

Pillar: 29cm. 2 spirit levels. Glass floor. Planes agate on sealing wax. Gothic lettering "L. OERTLING London."

Beam: Signed in caps L. OERTLING LONDON. Captive unless front ½ of beam holder is removed. One rider missing. C of G. 36cm. K's agate slivers in brass. Rider ÷ 0 - 10 each side.

J's: V plain. J's pans on Pt wire approx. 21.5cm. Pans of Cu covered in Ni? size c.6cm. Now wearing off.

Pointer: 21cm. Ivory bouncers.

Arrestment gear out of sinc.: the pans go down when the beam holder drops.

Sensitivity: Does not move easily at .005. .01 better. Rider too long but not reliable.

Apart from 4 on various parts of pillar, NO NUMBERS anywhere.

Science Museum Collection Acc.No. 1876/127 — July 6 1977

"from Board of Trade"

Case: 49cm x 48cm x 20cm inc. one long shallow drawer.
Front counterbalanced slides up and out.
No rider. Back slides up.

Drawer: Space for arrest knob, which has to be removed from mechanism before drawer can be opened. 46.5cm x 9cm deep.
No markings anywhere.

Pillar: Of unusual design for Oertling and approx. 35cm to top hook.

Arrestment: Turn knob to drop arm rests, (about 8.5 each side of centre) and bouncers (ivory).

Beam: Labelled L. Oertling London, but no other marks. 30cm. No K's.

Pans: Very heavy. 19.5 rigid hangers.
13 - 8cm at narrowest. Labelled L & R.
Steel hooks.

Suspension: Everything is suspended from pieces of untarnished metal ribbon.
Replacements supplied by Oertlings.

Science Museum Collection Acc. No. 1876/369,380 — June 1977

Case: Marble base and very heavy. Rider ÷ each side 0 - 10. Steel rimmed doors at sides. Arrestment knob on left hand side. Plumb bob. Front and back slides up. Inscribed F. Sartorius Gottingen Patent.

Manufacturer:

Pillar: 26.5cm. Stamped Sc. Mus. or more likely S.K. [en] Mus. and mongram.

Beam: Short. Appears to be Al. Steel K's. Agate planes. 13.7cm or 5½".

J's: Rest on elaborate egg cups (non agate) yet pans hang on hooks.

Arrestment: Knob turns to lower beam rest arm.

Pointer: 22cm.

Pans: 9.1. on 19.5cm. hangers. s.g. hooks provided. Steel. Pans unequal.

Sensitivity: Turns at .005.

Science Museum Collection Acc.No. 1926/810 — June 1977

Case: 62cm x 52cm x 29.5cm. including drawer which juts forward. Blackish wood. Ivory key plate. 2 front doors open, knobs missing. Centre panel slides up and out. Centre front arrestment, knob, brass.
Signed at top of pillar

Manufacturer: F.W. Brethaupt & Sohn in Cassel.

Drawer: Contents: Reel of Fe wire. Round box screw lid of wts.16, 8, 4, 2, 1 grains? Brass wts. assorted 180, 960, 1920, + 3 for Pb. shot.

2 buttons. Large damaged fitted O spirit level. Fitted also for beam.
Small oblong box of wts labelled Pilgrim in Diez.
Contents 100, 50, 25, 16, 8, 4, 2, etc. Ag?

Pillar: Cylindrical.

Beam: 43cm K to K.
Ivory pointer scale to the rt.
Centre plane agate, Centre K steel.

J's: Fit over steel ? K's. Very crude.

Arrestment: Not working alas.

Science Museum London — June 1977
Acc. No. 1977/

Case: 50.5cm x 40cm x 22.5cm inc. drawer flush. 2 side doors and case lifts off. 2 front doors of 20cm. Centre panel fixed. Back also slides up, counterbalanced. 3 feet (later?)

Drawer: Beautifully fitted.
Card inside. "Balance No. 4 Originally belonged to Prof. M.H.A. Story Maskelyne and used by him in his chemical researches (probably at Oxford). On his retirement from the Keepership it was purchased in 1881 through J.R. Gregory." (Thos. Chas. Rob. 1792 - 1841 was the first maker of prec. bal). See letter from J.T. Stock 681/20 of 15.6.70. Photo in Mus Studio. "This balance is intermediate in design between Barrow's balance in the Science Museum and the later type recently found in Cambridge. S. Maskelyne was the last user of the chem. lab. in the Old Ashmolean at Oxford in 1857: he had residence there from 1851. See Gunther. Dr. Moss 3.5.72 Composition of pans and chains in Pt of s.g. 21.2 and 21.0 respectively confirmed by spec. plate 135.2. Sensitive 2mg/div. As displayed the RH pan is 14.5 mg. lighter than the LH pan which is within 0.5mg of the s.g. pan in the drawer.

S.g. pan surprisingly heavy 6.8 cm diam., 11 cm. chains with links. Ivory tipped forceps. Under drawer 8929.

Pillar: 24.5 cm to removable centre plane = agate slab.

Beam: 26.5 or 10½" K to K.
One adjuster as usual, c.of g. Steel K's and pressing screws as usual.

Arrestment: Pan stabilisers. Ivory thumb press down and to rt drops the beam holder.

J's: Agate slab in brass.
Manufacturer: Robinson & Barrow Oxendon St., London.

In beautiful condition.

On loan from British Museum (Natural History).

Science Museum Collection Acc.No. 1957/11 — Sept.21 1977

"Ramsay & Travers". An Oertling long beam with no number.

Case: Standard.
2 drawers. Front counterbalanced. 2 riders.
2 spirit levels. Keyhole. C. of G. & Flag.

Drawers: Left. Spare pan arrest knob.
Right. Space for arrest knob. Magnifier but no holder, s.g. hanger, separate s.g. pan of usual design titration tile labelled for wts? .10, 1.0 etc.
Label giving origin as Bristol Dept. of Organic Chem.
One counterpoise with Pb. shot in it.
Empty box for J's. Two watch glass holders.
Paper giving analysis of sample (present) of NAEGITE and wrapper dated 3.8.06 as
SiO_2 34.89 Nb_2O_5 4.10 Ta_2O_5 7.00
UO_2 28.27 etc. s.g. 4.3?

Pillar: 29.5 Stamped 1 on each section and engraved L. Oertling London.

Arms: 20cm each side, ending in two pins to rest the beam.

Beam: 36.5 K to K. whole agate centre plane. Whole large centre K and end K's all agate slivers in brass.

J's: Have lost agate slabs showing sealing wax beneath.

Hangers: 25 Pans 10 at longest. Appear to be Ni plated and may well not be original.

Sensitivity: Not easy to level and will only just turn at .01.
No numbers anywhere.

Rider: ÷ 1 - 9 each side in inches and then into 1/5th.

From labels in display case around the following additional information.

"Balance was for work on rare gases and weighed to .01mg".

Science Museum Collection Acc .No. - Jan.25 1978

A jelly tester.

Case: 51cm x 49cm x 20½cm. Very plain.

Pointer: 30cm. painted black and counterweighted at base.

Beam: 30cm brass.

Not really a balance, more a steelyard. Difficult to get pointer set to 0 by means of rotatable counterpoise wt.

Method of operation seems to be to put jelly sample in beaker and raise it by means of stand till "probe"rests on surface. Bucket can be filled by water from dispenser above either to force probe into jelly, though bucket seems ungraduated, or cause pointer to move to a new setting therefore putting repeatable pressure on jelly surface.

.05 will if placed above probe move pointer one division of scale, .2, 4 divisions, .5, 9 divisions, etc.

Not signed Oertling anywhere and name place missing from case. However, a plaque "The Boucher" exists.

Science Museum Collection Acc .No.- Jan.25 1978

Case: 44cm x 43cm x 20.5cm. No drawers. Well splashed. Label on base says 46008. No writing. 3 adjustable feet. Rider. Plumb bob. Side doors open. Front counterbalanced. Black glass floor. Box of non Oertling wts, poor.

Pillar: No. 19749 on top back. Centre plane split. Agate on wax.

Beam: 15.2 or 6" K to K. K's slivers of agate. Arrestment by turning front knob. Black pan bouncers. Rider separate. Signed L. Oertling London E.C.

Pointer: 23cm.

Hangers: 24 inc. hook. Pans 7cm. Arm rests extend 9cm. each side.

J's: Plain J agate slabs. Ivory scale. Could be an early INVAR beam.

Sensitivity: Does not level. Needs .02, then .005 to turn.

Science Museum Collection Acc. No. _____ Jan.25 1978

Case: Front glass lacking. Sliding front with top lock. Faded green floor. 2 drawers, one ivory pull missing. Ivory pan bouncers. Rider. ÷ 0 - 10 both sides. 2 levels.

Drawers: L. numbered 13790 and contains anonymous weights.
R. has space for arrestment knob, J's, rubber bung and box for Al.wts. empty.
JW 9/5/87.

Pillar: 2070 and L. Oertling London on pillar base and beam. 30cm.

Arrestment: Bouncers and beam move as one. Centre agate whole.

Beam: 20.5 or 8" K to K. All K's agate slivers in brass. Arms to hold beam extend 10cm each side to pin holders. K's held at ends by nice little Robinson type pressing screws.

Pointer: 21cm to ivory scale.

Pans: 9.5cm diam. badly corroded plate over copper or brass. One pan drilled, but no hole in floor or means of removing bouncers. Hooks for s.g. Drilled pan has to be put on rt. Hangers 23.

J's: Topbar with hole one end and slot at other. Post Makins.

Sensitivity: .005 moves pointer 10 divisions, plus rider.

Science Museum London — March
Acc.No.- 1978

On pediment on case top: No. 1 SEYSS & CO. ATZGERSDORF b WIEN.

Case: 49cm x 39cm x 16cm. deep plus feet. Almost entirely glass. Sides open and 2 front and 2 back doors. Centre panel front and back fixed. One now missing.

Arrestment: For pans, very crude. 2 unequal pieces brass strip, 19cm and 14cm are on pivots and pushed up from underneath by tube inside centred cylinder.

Drawers: 2 spirit levels. 5 ivory knobs on base A - E from l to r. A - decoration, B - drawer front, C - pan lifter, D - smaller micro wt., E - larger micro wt.

Beam: 32.5cm K to K. Steel K's. Steel pointer 20. Lovely agate centre plane banded. Beam of unusual design:micro weights can be added by remote control mechanism.
Science Museum Collection Jan.1980
Acc. No.

Case: Stove enamelled grey 14" x 8" x 16" high plus feet. Label on top of case A9/59/23. Label on back of Case A 03 200g. No. 2546 and no. on back of beam. OERTLING. Analytical. Centre front counter balanced. Glass sides fixed. Arrestment on left. Rider on rt. Dash pot. Black base.

Drawers: -

Pillar: Black cylindrical 25cm to whole agate plane.

Beam: 13cm plus rider. 2 agate J L and R.

Pans: 8cm on 22cm hangers.

Sensitivity: c.0001?

Made according to catalogue post 1959.

SCIENCE MUSEUM LONDON

Dept. of Physics

Science Museum Collection June 1977
Acc.No.1917/99

Case: Mahogany box and cover. 34cm x 19cm x 8.5cm. Top of box has 3 holes to take feet of pillar, not quite symetrical

Pillar: Demountable 27cm from key to screw in base. Brass.

Beam: Steel, box end, 19cm. One hook end, one ring fixed.

Pans: Strings 18cm, pans 7cm.

 knife sits in a semicircle

Drawer: Well fitted contains 1 pear, 1 bucket (glass), 1 hyrdro pan, a set of Nurhemburg or cup wts, 2oz Troy, 1 oz. Troy, 10dwts Set of grain wts 1000, 500, 300, 200, 50 [30, 20, 5, 3 lost]. Tweezers.

Pointer: 7cm upwards.

Science Museum Collection Oct.20
Acc.No. 1927/1138 In store 1977

Case: 22.5cm x 21.5cm x 10cm deep. No glass left. 2 levels. 4 adjustable feet. Drawer. Pillar on large oblong brass plate held by 6 screws. 3 more holes under the plate, but wood appears spotless. Hole through base of case, perhaps to do with arrestment, or just to help set the plate. Odd. Front slides up and out. Ivory pull.

Drawer: Fitted to take beam; and lots of weights wrapped in paper, of the playing card type. Space for 2 brass pans on perished green thread. Label says Geo.III.

Pillar: 14cm to semi-circular steel "plane" screwed to brass. Two arm holders moved by metal flange (snapped off) worked by pusher up and down through the floor. Drawer cut at back to allow passage. Most awkward.

Beam: Steel 14.5cm, swans. Steelknife with pressing screws and flag. No scale. Pointer 4.5, threaded with c.of g.

Pans: 3.5cm diam. on 10cm threads by thin steel hooks. Pans very clean. Could be gilded.

No markings but very reminiscent of Oxford No.157 but more markedly Robinson in pattern.

Science Museum Collection (In store) Oct.20
Acc.No. 1886/2 1977

F.E. Becker & Co. 34 Maiden Lane London. label upside down.

Case: Nice mahog. Centre fixed panel. 2 drawers. 41cm x 44cm x 20cm. 2 side doors, rider: back lifts. No.99 on address label on underside and 773 stamped into drawer edge. Dash pot.

Drawers: Rt pull missing: plumb bob in left.

Pillar: Cylindrical, 25.5 to flat large agate whole plane.

Beam: 20cm K to K, each held by 4 screws. Centre K whole. All steel. End planes are inverted agate V's.
End knob to adjust.

Pans: 7cm diam. on 20.5 hangers with s.g. hooks. Pan bouncers drop as do arm rests when arrestment knob turned, but as rests only poke through open beam hole, they do not hold properly and whole liable to collapse.

One rider ÷ 1/10 and other ½s. Pointer 20cm.

Sensitivity: Does not level, but seems more likely to turn at .01 than .005 plus rider.

Science Museum Collection (In store) Oct.20
Cat/Acc.No.1931/982 1977

"from Board of Trade".

Case: 60cm x 64.5cm x 31cm. Front slides up and out but glass not secure: back glass missing therefore interior very dirty. 3 nice original ball b all feet. Spirit level.

Drawer: One long shallow drawer contains two pieces of beading and a nice smell (cedar?)

Pillar: Brass 53cm.

Beam: Covered in grease. 38cm. boxed ends. Pointer moves over horn(?) backer.

Arrestment: Press lever lifts pillar inside pillar, but as there are no rest arms, merely raises pans clearer of floor. Turn button provided to hold lever down.

Pans: Cu. stamped V.R.1 13cm diam. 29 cm chains. brass.

Sensitivity: .2

Science Museum Collection (In store) Oct.20
Acc.No. 1914/578 1977

Said to be by Bate, but no signature found.

Case: -

Arrestment: By handle moved from side to side, reminiscent of Fortin. This revolves an offset wheel to form a cam.

Base: Two pieces of mahog. board.

Pillar: 43cm. to top of arm rests. Steel with brass mountings.

Beam: Slab of mahogany 51cm K to K(20"). Flag. End mounted pointer over ivory scale. Steel K's chamfered and planes.

Pans: 15cm diam. Hangers 30cm stiff brass.

Sensitivity: 1 gramme.

Science Museum Collection — Oct.20 1977
Acc. No.1933/390 (In store)

Manufacturer: De Grave & Sons 1825 with crown and portcullis.

Beam: 90cm Steel.

Pointer: 22cm. Brass c of g.
Centre knife is ▽ where hammered through the beam and turned to ○ at the extremities.

Pans: Cu 37cm. Chains brass c80cm held by semi universal joint.

No stand, but hook to hang it from.

Science Museum Collection — Oct.20 1977
Acc.No. 1977/537

Manufacturer: L. Oertling London. from the Bank of England.
Set into large lino topped table, which has been raised at some time.

Pillar: 62cm steel structure.

Beam: 76cm 2'6" pointer bent. Steel K's and centre plane.

Pans: One pan 27 on chain 30 with a plumb weight.
Other square pan 25cm.

Arrestment: Handle to wind raises and lowers whole Centre V section.
Very much a steel version of Bates.

Science Museum Collection (In store) Oct.22
Acc. No. 1886/1 1977

To one centigramme

F.E. Becker & Co. 34 Maiden Lane, London WC.

Case: Box and cover. Two drawers each containing a pan. No room for beam, yet pillar demountable.

Pillar: 57cm. large brass cylinder. On face a turn handle to raise and lower inside pillar

Beam: 46cm. No resters. Labelled F.E. Becker & Co. Steelknife and planes steel V'ed.

Hangers: 50cm. Pans brass 25cm.

Science Museum Collection Oct.20
Acc.No. 1914/577 1977

Bate London Bullion balance.

Pillar: Large steel structure with V support arm. 120 cm. to flag.

Beam: Wood, mahogany slab 119cm K to K.(48"). Steel K's and plane flat in centre, but end ones are rods Q cut to become arches and therefore self locating.

Pan: One copper shovel. One pan. C of G and flag.

Arrestment: Wind handle to raise and lower arm which just lift centre K clear.

Mechanism beautifully designed. No two holes interchangeable. Both have pins to prevent nut slipping. Bolts of varied length. Each pan has its own baize covered block to sit on.

Pointer crude.

SCIENCE MUSEUM LONDON

Instruments on permanent loan from the

Wellcome Trustees

Note:

At the time of writing this collection was being catalogued by the Science Museum.

The pharmacutical instruments referred to in the following section will form part of the Wellcome Museum of the History of Medicine at the Science Museum.

The other instruments will be placed with the Dept. of Chemistry and the Dept. of Physics.

Wellcome Collection (1) 1976

Case: Mahogany drawer and cover.
26cm x 13cm x 5½cm (10" x 5" x 2")

Drawer: Lining faded beyond recall, but may have been blue. String is. One small divided section only

Weights: Assorted grain weights.

Label: Set into lid.

S. Maw Son & Thompson
11 & 12 Aldersgate Street, London

Date: 1870-71 (Trade Directory)

Pillar: 30 cm in 2 pieces and lever mechanism and pin.

Beam: "Bronze" 18cm. Steel knives. Pointer now 4cm (broken). Boxed ends.

Pans: Very mixed. One copper, one bronze coloured, one glass. All strings badly corroded.
2 small glass also.
None of these will balance alas and lever needs repair.

Drawer also contains an agate J.

Wellcome Collection (2) 1976

Case: Mahogany Drawer in cover.
Size 23cm x 12cm x 8cm.

Drawer: 20cm x 10cm undivided: lined red plush.

Weights:

2 x 5ov. (wt.8g)	5dwt - (7.8g)	4dwt,3dwt.2dwt
1 x ½ S (wt.4.1g)	1dwt - (1.6g)	½dwt.

Label: One side.
24 grains one penny weight
New Gold Rings. Old 22 Carat Ring
Value of grain 4s. 3dwt 1½ grain
Value of 1 pennyweight. 10/-.
Silver 4/- per oz 2½ dwt.

Underside.

Frederick Sheldon

Manufacturer of Scales and Scale Beams.
No. 5 Ellis Street, Brum.
Late Inspector to Mr W.C. Day.
All orders thankfully received & punctually attended to.

Pillar: In 2 pieces with pan lifter. Brass. 14cm. and 14cm.
Key to hold beam screw threaded.

Beam: 13cm. 5cm. pointer: steel centre knife.
Boxed ends.

Pans: Captive on chains 17cm long 2 "bronze" 10cm diam. pans.
The pans will not go in the drawer therefore not original.

Sensitivity: Will turn at .1 but not .05g.

Wellcome Collection (3) 1976

Case: -
A solid slab of wood (mahogany?) size 21cm x 12.5cm. x 2.5cm, on 4 squashed ball feet.

Drawer: Runs in fast corroding non-ferrous grey metal runners. (Zinc?)

Weights: Contents: Collection of wts, scruples and drams.

Pillar: Brass, about 21 to hook with pan lifter.

Beam: -

Pans: -

Very much recycled. A piece of mahogany has been covered in brown formica and the pillar screwed through. Two more empty screw holes underneath.

Wellcome Collection (4) 1976

Case: Mahogany drawer in cover. Size 27cm x 15½cm x 5cm.

Drawer: MET LAB. 1.1.5. stamped in pillar base. Blue string and plush lining. Fitments missing.

Weights: Grain and .gramme weights.

Pillar: Upper part stamped 2. 28.5cm to pivot.

Beam: Non ferrous, also stamped under holder. Steel knives. 18.5cm knife to knife. Boxed ends. One chained dish, and one stirrup.

Pans: One glass and one brass pan. It does level.

Arrestment: String.

Sensitivity: To .5 but nothing finer.

Wellcome Collection (6) 1976

Case: Nice wood: oak? Cover.
Size 27cm x 17cm x 6cm.

Drawer: 24cm x 14cm.
Contents 2 beams! and 2 pans.

Pillar: Fixed through false back plate.
Not removable.

Beams: a) 18cm plus 7cm. pointer.
2 boxed ends, one with captive hook and one lose. Steel knives.

b) a crude swan 18cm plus 6cm pointer.

Wellcome Collection (5) 1976

Case: Mahogany drawer in cover.
Size 27½cm x 15½cm x 5½cm.

Drawer: Fitted and green lined.
Pillar fits.
Contains swan neck hand balance with 12.5 beam and 3.5 pointer.

Weights: 500 grains, 300 and 200 only.

Pillar: In 2 parts plus key. About 30cm total.

Beam: -

Pans: Have 14cm strings. Also another larger pan with decayed strings of 7cm diam. and 1 hydrostatic pan.

Arrestment: Would have been by pull string.
Standard type.

Wellcome Collection (7) 1976

Case: Crude wooden box. Cover.
Size 22cm x 12cm x 6cm.

Drawer: 19cm x 9cm x 4.2 cm.
Contains crude hand balance steel.

Pillar: Lever type but non-removable from case.
Label says Top ½ is missing.

Beam: Hand type, steel beam and knives boxed plus S hooks.

Pans: 2 glass and green string., one pan still fixed to beam.

Wellcome Collection (8) 1976

Case: Mahogany drawer in cover, with central wood knob.
Size 31cm x 16cm x 7cm.

Drawer: Red plush lined. Lose green string.
Pencilled under drawer Sam Balls.

Pillar: In 2 parts 22cm and 17cm.: fits well.

Beam: -

Pans: -

Arrestment: String to lever, stamped VANDOME LONDON

Wellcome Collection (9) 1976

Case:	Drawer in cover. Size 25.5cm x 13cm x 5.5cm.
Drawer:	Mauve lining and assorted weights.
Pillar:	30cms in 2 parts.
Beam:	Steel corroding. Boxed ends. 17.5cm knife to knife.
Pans:	2 brass.
Arrestment:	Pull string.
Sensitivity:	to .01

Wellcome Collection (10) 1976

Case:	Light wood. 23cm x 12cm x 6cm deep. Cover.
Drawer:	Mauve lined. Contains nice Dram and grain weights.
Pillar:	25cm to hook. Brass lift lever.
Beam:	Steel 13cm. No pin. Beam held by S hook.
Pointer:	5½cm.
Pans:	Glass captive.

Wellcome Collection (11) 1976

Case: 26cm x 13cm x 5.5cm. Cover.

Drawer: Lined in blue. No contents.

Pillar: Has sliding front section. Beam held by key.

Beam: 18cm. Badly corroded. Boxed ends.

Pans: Lefthand one on a stirrup.
Lifted by lever which pushes up side of pillar.

Pointer: 7cm.

Wellcome Collection (12) 1976

Case: Mahogany. Cover.
Size 25.5cm x 12cm x 6.5cm.

Drawer: 22cm x 10cm.
Contents 2 brass spoons to set in pans and lots of V.R. weights, stamped.

Column: Fixed brass and lever set offset in base to lift pans.
Stamped '5'. 15cm.

Beam: 15.5cm with captive hooks, steel knife and pointer.
Pointer back stamped '5' and also under top block.

Knives: Are circles of steel set into V.

Arrestment: Lever pushed cylinder up within pillar to raise pans.

Pans: Only one on fixed arms 13cm long.
Pan 4cm diam.

Wellcome Collection (13) 1976

Case: 25cm x 13cm x 5½cm.

Drawer: Contains: piece of chain far too long, glass dish, metal dish very light and weights.

Pillar: A pin to hold beam.

Beam: Boxed ends.

Pointer: Upwards.

Manufacturer: AVERY

Arrestment: Lever and string.

Wellcome Collection (14) 1976

Case: Drawer and cover.
Size 25cm x 12cm x 6cm.

Drawer: Very faded lining.
Contents: piece of rock, piece of metal, spatula inscribed S Maw and Son & Thomson Glass plate.

Pillar: Cylindrical. Lever and string.

Beam: 18cm. Captive key.

Pointer: 6cm.

Pans: Right hand one on stiff stirrup for glass plate.

Does not level.

Wellcome Collection (15) Feb.1976

Case: Bow fronted, walnut veneered with drawer. Wormy and smelly. 4 brass screw feet, one missing.

Pillar: 50cm. once held by wing nut inside now broken. Large base plate has remains of quite nice pattern. Brass.

Drawer: Crudely stained red. Grain ⊥ to rt.

Beam: Brass 24cm, boxed ends, steel knife at centre. Only one face of holder survives, and no indication of how, or if, it fitted to pillar.

Pans: -

Arrestment: By string back over pulley and through hollow top of case.

Wellcome Collection (16) Feb.1976

Case: None. Stands on slab of wood. Size 45cm x 23cm x 2½cm deep.

Manufacturer: S. Maw, Son & Sons, Aldersgate St., London.

Pillar: Brass cylindrical 34cm to top, 2.3cm diam.

Beam: 30cm. hook to hook, presumably brass (non ferrous). Stamped "Maw Class B to wt. 2lbs."

Pans: 2 and hangers captive, one on a stirrup. Rt. hand pan captive. Left pan 20.5cm or 8": rt. hand 13.5cm or 5½". Beam slots in from side. Steel knives. Has flag and is stamped.

Arrestment: None, but will centre with care. Ivory grad. scale.

Sensitivity: to .1g.

Wellcome Collection (17) Feb.1976

Case: Glass.
Size 46.5cm x 17cm x 18cm high.
Box with 4 removable glass panes.
Woodworm holes. Light in colour. 4 wooden feet. Unmarked. Wooden lid.

Pillar: 14cm.

Beams: 34cm each. There are two parallel beams at top and base of pillar.

Pans: Brass 17.5cm or 7".

Steel knives and circular centering devices. Unusable with the lid on, though pans fit through it and not much better with lid off. Not enough play, no pointer, and uneven distance between the bumbers on which pan supports rest.

Odd suggestions of repair, drops of solder.

Wellcome Collection (18) Feb 1976

Case: None.
Set on slab of wood.
Size 49.5cm x 22cm x 2cm deep.
One foot missing.

Pillar: 31cm to top of centering device.

Arrestment: Lever at base and ivory scale.
Unfortunately jammed in the "up" position.

Beam: 30cm (12") hook to hook. Stamped Class B to wt. 21b.s.
Steel and sits in V Slot. No plates.
Stamped 5 & C.

Pans: 2 semi captive pans, one on stirrup. Hung from steel knife by J hook at each end.
18cm and 16.5cm diam. pans.

Will not level and badly twisted.

Sensitivity: To 1 gramme.

Wellcome Collection (19) Feb.1976

Case: Mahogany 36cm x 46cm high x 21cm deep. Sliding glass front with stops. Now cracked. 44cm x 32cm.

Pillar: Brass, appears to be in one piece and cannot be unscrewed out of plate in lid of case unless the back was taken out. 32cm high. No marks on pillar, and brass plate not removable. Key plain.

Arrestment: Lever of usual Ercker type. Green cord.

Beam: Brass, boxed ends. 21.5cm centre knife.

Pointer: 7cm. Key plain. Has 0 of ivory behind to aid reading.

Pans: One captive 7cm on 3 x 15cm chains. The other a stem holder for glassplate.

Drawer: Blue lined 31cm x 16cm x 4cm. Only one ½
Contents: 1 watch glass, appears much abraided by use in one place. 7 slides and one broken, 1 stained section. Pill box 4 x $\frac{3}{8}$" screws 4 pieces coloured glass, cover slips. Pill box 4 x $\frac{1}{4}$" empty.
Paper labelled 1/10 gramme cyanine.
Platinum wire. Magnifying lens.
6 cribbage (?) pegs. Labels on wrappers and pill boxes.

a) Fine magnesium powder 12/- Fuerst Brothers 17 Philpot Lane, London EC.

b) Hinton & Co., 38 Bedford St. Covent Garden WC. Box contains blue glass.
3 labels Liquified contains 90% pure carbolic.
Phial of Palladium chloride 15gr.
Electric discharge tube 7cm by 6cm circumference.

c) A label:
[z.t.?] Norman.
Mounter of microspecimens and make all kinds of Troughs, Tanks, Cells, etc.
13 Alington Crescent, Shacklewell Lane, Kingsland,N

Manufacturers: Under drawer Manufacturers label:
C Stevens & Son
Manufacturers of all kinds of scales, weights and weighing machines, 38 Goswell Road, London EC.

Sensitivity: Better than .05.. Not .02.

Wellcome Collection (20) 1976

Case: Glass.
Size 34inches x 33inches x 21inches depth to back. Ht. includes drawer.
Glass front lifts off.

Drawer: Contents: glass pan labelled (box) S Maw Son & Sons Ltd London, 2 glass dishes and 1 chipped, 2 keys, 2 brass spoons, 1 brass pan and a lot of very assorted weights.

Pillar: 11 under both parts of pillar and under lever to lift pans clear. Height 19cms.

Beam: Steel centre knife and agate plane.
Marked "To Weight 2oz VR 2". 18.5cms.
Steel V in boxes and hooks.
Ivory graduated scale. Stamped XI on back.

Pans: 15cm. metal arms, 3cm diam. pans.
Hang from steel V shaped knives turning on dished agate planes.

Manufacturer: Oertling.

Wellcome Collection (21) 1976

Case: Black ebonite.
Size 34cm x 28cm x 14cm inc. drawer.
Heavy, glazed with sliding front and ivory lift.

Drawer: Contains 2 spatulas, light and non-ferrous.
Silvery appearance.

Pillar: Brass 17.5cm.

Beam: Large steel knives. Black non-ferrous rests for beam.

Pointer: 17cm.
Provision of altering setting of beam by screw knob.

Pans: 3cm brass on 14cm strings.
'J's missing therefore not possible to check.

Arrestment: Twist knob.

Manufacturer: Becker's Sons Rotterdam.

Wellcome Collection (22) 1976

Acc. No. 1977/159

Case: Original glass cover missing. Hooks present to hold it.

Drawer: 22.5cm x 10.5cm x 4cm. Well fitted to hold beam and probably pillar if well demounted, pans if present. 3 screw feet to level it.

Label: Circular brass plate inscribed. 5cm.diam.

Manufacturer: Robinson 38 Devonshire St., Portland Place.

This is held in place by 2 long screwed knobs, easily removable, and has a tiny screw set through the plate, presumably to further adjust pillar which is screwed in from under plate. V's not steel.

Pillar: 16.5cm. brass, with lever,(no longer quite working) to press outer casing of pillar which holds arrestment screws down, causing knife to settle on. Space for graticule,now missing.

Pointer: 7cm with screw thread all along, enabling C of G to move.

Beam: 14 cm. which has 2 adjustable swans, one out, the other up.

Pans: - probably Pt.and lost.

Stays: 2 brass fitments to steady pans, hinged leaves with holes for missing pins 3.5cm apart.

Wellcome Collection (23) 1976

Case: -
Set on a wooden block 36.5cm x 16cm with 2 levelling feet. Could well have originally slid into a glass case.

Pillar: Brass. 25cm including steel plate centering device.
Agate planes ÷ to let beam in, and one missing.

Beam: 21cm from knife to knife with extra wt. knobs for adjustment on both ends. Stamped 30 and has agate knives.

Pointer: 25cm.
Completely non-ferrous throughout.

Pans: Hang from J's set with sealing wax. Diam. 10cm. Also attached to hangers are 6cm rings with adjustable spokes.

Plumb bob and cotton.

Sensitivity: Could not be taken.

Manufacturer: Gallenkamp made in England.

Wellcome Collection (24) Feb 1976

Case: Mahogany
Size 43cm x 36cm x 19cm deep.
2 levelling feet, arrestment knob and rider mechanism. On lid "Bal 78 Didcot".
Inside painted "78".
Glass front 37½cm x 34cm. One stop button.
11 stamped into underside of base and 5 underneath pillar.

Pillar: 25cm. Rider above. Very like Gallenkamp in collection, but better made. Stamped 5.

Beam: 22.5cm knife to knife.

Pointer: 25.5 stamped 5. Graduated on rt. side.

Arrestment: Split centre plane stamped 5.

Pans: Hang by 2 J's each 10cm diam. on stirrups, 20cm. Completely non-ferrous.

Sensitivity: .005

Manufacturer: Griffin & Sons London. Made in Belgium.

Wellcome Collection (25) Feb.1976

Case: 43cm x 42cm x 25cm glazed "deal".
"78" painted on it again. (see Griffin balance)
Glass front slides up with 4 notches.
41.5cm x 42cm.

Balance does not even slide in on runners. Just pushed in, 2 levelling feet, and 1 prong which has badly scratched the base board. Suggests that a lot of those on wooden base boards may have been originally cased. No marks on base of case or board.

Base: Wooden board 39cm x 15cm x 2cm deep. Faded except under pans therefore stood in window (?) for considerable time.

Arrestment: Lift over handle.

Pillar: 26cm to agate V's set in sealing wax. Well oiled under pillar.
Plumb bob, and holding arms protrude 11cm each side of centre.

Beam: 21cm from knife to knife, agate. Graduated rt. hand $\frac{1}{2}$ and levelling knobs on ends and adjustments to raise holder arms.

Pointer: 23cm.

Pans: Held by 2 J's with agate indented planes set in sealing wax. Panhangers 23cm. Pans 10cm diam. Very shiny.

Sensitivity: .005 just. Levels well.

Manufacturer: Townson & Mercer Ltd London EC3
Trademark.

Wellcome Collection (26) Feb.1976

Case: 49.5cm x 38.5cm x 19cm deep. "Beech" Glass front lifts, but not removable, instead counter balanced with 2 strings and 2 sets pulley wheels. 46cm x 34.5cm.

Pillar: 24cm : cylindrical brass 1.8 diam. 2 arrestment arms attached each 8cm. 2 agate planes and V brass centerers. Stamped L. Oertling London 4951 stamped into back of base of pillar.

Date: On base in chalk 19908. In pencil J.B. 4.2.93.

Beam: 30.5cm hook to hook. Stamped L. Oertling London. Both sides graduated for a rider. Made of brass, also flag. Stamped 3. Steel knife. Steel end holes.

Pointer: Brass. Ivory scale.

Pans: Grey 7.5cm. diam. with tarnish. Metal? Wires not corroded. Made into links, 22cm. Steel hooks to pans. One hydrostatic pan 5cm diam. 7cm long.

Manufacturer: L. Oertling London

Sensitivity: Better than .005.

Weights: Box of grain wts. No. 9426 in brass & Pt. 600, 300, 200, 100, 60, 30, 20, 10 and 12 others approx.

Suggests that it was built to be sensitive to .01 grain = .00064 grammes.

Wellcome Collection (27) Feb.1976

Acc.No. 1977/303

Case: Crude wood box stained, perhaps with permanganate. 4 levelling feet. 22cm deep x 56cm x 42cm. No visible markings. 2 doors in front each 20cm x 33cm leaving centre fixed panel.

Pillar: 25cm. Brass, oblong in flat brass section with centre sliding pieces activated by pan arrester, but not clear what it does.

Pans: 7.5cm diam. with rt.∠ lip all round, brass coloured. Suspended by 3 brass hangers each 18.5cm to 'web' top. Extra hook for sp.gr. Top hook, unnotched steel.

Pan Arresters: 7.5cm diam. circles of brass screwed to 2.5 steel pillars. Should move up and down controlled by knob at front base. Now needs helping hand!

Beam: 37cm knife to knife. Centre knife steel and split. Pointers on each of arms.

Arrestment: Turn knob towards top of pillar to lift glass? plate. This takes beam of steel bearers. Centre steel knife rests between 2 split semi-circles of steel as centerers.

C of G and plumb bob.

Pan hooks will catch on split hooks on beams but probably originally J's of some sort. Hangers now 2cm too short.

Wellcome Collection (28) Feb.1976
Acc.No.1977/302

Case: Wooden crate, very shoddy, stained roughly; 87cm x 69cm x 40cm deep.
Stamped U.S. Customs. 2 levelling feet.
The top is held by 8 (2 lost) twists of wood.
2 glazed doors have no hinges but dowelling that "fits" into hole.
42cm x 55cm + lock (locked). Some very new looking putty.
Back has 2 glazed panels. Sides solid.
Label "Leibig Laboratory Scale".

Pillar: Wood. 33cm. 8cms diam + plumb bob.

Scale: Held up by pillar at left 41cm. tapers.

Beam: 55cm knife to knife. Brass. Steel knives A.F. rt hand has no pointer. Lt. hand one has arrow unpatterned and method of adjusting distance to knife.
Note. If all wood case is suspect, pointer could equally be at other end and thus put arrestment knob on front.

Pans: 13cm diam. circles with rt. lips. 35cm hangers. Steel braces. Shows no sign of wear.

Arrestment: Split centre knife: arrestment lifts left side of steel plate and 2 springs from rt. move it to plane centre. When in use, knife sits on agate planes.

Pan Arrestment: Elaborate. When knob at base turned it causes main lever to lever plank of wood to bear on wood pegs into tops of which pan arresters are screwed.

Wellcome Collection (21) 1976

Case: Oak? Pine stained dark? Triangular in cross section. Front lifts up. Front glazed. Back has 4 tiny port holes through which pans and needle can be seen.
Size 18½cm x 7½cm.
Mounted on part of a pillar balance drawer.

Drawer: -

Weights: -

Label: Folded card. W.Moggridge, Taylor
No. 5 Wood Street.

Pillar: An oblong of ivory, labelled F, with spike beneath for arrestment.

Beam: 13cm steel beam with tiny swan ends and 4.2cm pointer, upwards.

Pans: Tiny, silver, with holders 1.5cm.

Knives at centre appear to be brass.

Arrestment: Ivory lever when depressed would lift "pillar" from below and therefore lift beam of resters.

Wellcome Collection (30) 1976

Case:	Glass. Size 25cm x 28cm x 16cm deep. Front slides out with stop.
Drawer:	Red lined holes for weights. 64, 32, 16, 8, 4, 3, 1 and scoop. Can all be slid forward and out.
Pillar:	Has pan lifting lever with spring behind.
Beam:	Steel 13.5 with swan ends.
Pointer:	3.5cm.
Pans:	Knotted on to S hooks. Badly corroded brass, egg cup shape 3.8cm diam, 1.3cm deep.
Manufacture:	Avery

Wellcome Collection (31) Feb 1976

Case: Large mahogany base 50cm x 41cm with balance set on it.
Some glass missing. Sliding glass front slides out 43cm x 20.5cm. Whole case 48cm x 46cm x 25cm deep
'Stopping' apparently by a peg through a series of holes in side. 2 screws underneath and a hole suggest it stood on something larger (cabinet?) now lost.
No marking at all on case.

Base of Pillar: 11cm x 6cm. signed BASTICK & SON LONDON (in copperplate)

Pillar: Brass 20.5cm. 2 holder arms, one broken off and has been soldered once 8cm from centre.

Arrestment: Is another pillar within pillar. Pull string to lift. Agate planes and brass V's.

Beam: 25 cm. Plain steel:
ends not swans but definitely notched to help hooks centre. Steelknife corroded.
C of G knob above.

Pointer: 11.6cm. Arrow tip. A little bent. Runs over ivory scale on ornamental metal holder.

Pans: Top segment iron and hook. Actual hanger and pan non-ferrous.
4cm. top seg. 19.5 cm. hanger 2cm. pan,
Thin and fragile and at some time crushed, or deliberately closed up a bit. One chipped. Will not quite level.
2 little 3cm. dishes. would fit over the two O holes below pans which may have had ivory or felt covered "resters".

Sensitivity: .005 or better.

The whole so filthy that identification of metal difficult. Light in wt., grey, not much corrosion. Steel only where stated.

Wellcome Collection (32) Feb 1976

Case: Mahogany box with drop front
Size 20.5cm x 20.5cm x 7cm deep.
Front will turn under and hook back.
Glass front slides up and out. 19 x 16.5 cm.
Case lined at back with white tile.

Drawers: Are labelled L & R. L contains arrestment knob. R contains crucible and 2 pairs of tiny pans. 1 pair 2cm perhaps Ag
1 pair 1.7cm perhaps Pa?
Also 2 pieces of tile from back plate.

Manufacture & Date: O. WOLTERS LONDON 1895 on base of pillar.

Pillar: 13.5cm with striped agate planes set in sealing wax.

Beam: 14cm. Rt. hand ½ ÷ 1 - 9 for rider (Rider knob missing) Flag
Has steel centre ▽ and hooks at end of beam.

Pointer: 8.3cm. Ivory scale.

Beam resters are indented eggcup holders on arms. 'Eggs' are attached to underside of beam.
No centering mechanism.

Arrestment: Turn knob to raise internal pillar.

Sensitivity: Better than .005.

Both beam and pans can be stored behind carrying clip in walls.

Pans: 2 baise covered resters beneath.

Weights in circular screw pots. Ivory.

1 Box Assay wts. Oertling 1000 = 10 grains.9936
1 Box Gold Assay wts. Oertling 1000 = ½ gramme.
14935

Wellcome Collection (33) Feb 1976

Case:	Polished Mahogany 20cm x 21cm x 7cm deep. Front drops down and will turn under to make stable base. Glass front removable 20cm x 16cm. Beam and pans can be stored away. Lined with paper, not tile.
Drawers:	Left and Right, labelled L & R. Left contains card 48817 Right contains arrestment knob.
Pillar:	12cm including base 4cm x 2.5cm. inscribed. Holder arms extend 4.5cm from centre.
Manufacture & Date:	O. WOLTERS LONDON 1911
Arrestment:	Brass V with steel inserts at centre plane and steel vertical plate on front face to stablise beam.
Beam:	Brass with steel knife, and hooks at end. 14cm. Flag. Rt hand ½ ÷ 1-9 for rider.
Pointer:	8.3cm Ivory scale.
Pans:	Steel top section to hanger 1cm. Then light alloy hangers (10cm) and pans (1.4 diam)
Sensitivity:	to .005.. Levels nicely.

Wellcome Collection (34) Feb 1976

Case: Box with key. Contains a demountable hydrostatic balance.
34cm x 19cm x 10cm deep.

Drawer: Back and base pencilled 2. ÷ by pegs and twists of wood. 30cm x 17cm x 6.5cm.

Pillar: In less good appearance than the rest because it was not removed from lid as intended. Held by 2 screws 10cm from left edge of box top. VI punched under pillar.
13cm, x 1.5cm diam. Non-ferrous.

Arrestment: Twist knob just below beam raises pillar to bear in on 2 agate knives.

Weights: No provision for weights but rt hand beam ÷ for riders ÷ 1-9 + left hand ½ has adjustable counter balance for levelling beam.

Beam: Height from top of drawer can be adjusted for tall objects. Metal (grey) cylinder screws into base of beam holder and slides down into bottom ½ of pillar.
Beam 14.5cm.

Pointer: Upwards 8cm and ivory scale. Stamped Becker's Sons Rotterdam.

Beam: Has one J from which can be suspended the hydrometer, on a knife. Knives are agate strips set in metal.

Contents: Glass measuring cylinder 15cm x 3cm internal. This contains wooden tube marked "Displaces 5 grammes water". Inside Hg. filled hydrometer and thermometer on Pt. wire labelled Celsius Körper n Reimanu 5g verdrängend. Also 2 large and 2 small U's, tweezers and 2 boxes empty, relabelled "for Dr. Leibody. Prior & Co. LONDONDERRY".

Manufacturer: Becker's Sons Rotterdam.

Wellcome Collection *(35)* Feb 1976

Case: -
Base 34cm x 11cm. ~~Very ornate~~.

Pillar: 34cm high. Iron. Very ornate.

Arrestment: -

Beam: 27.5cm knife to knife. Steel.

Pans: Wooden blocks, one hung with heavy gut. The other prbably rewired, therefore will not centre.

Pointer: (And Scale)present. 17cm.

Manufacturer: Brevete S.C. D.C. Caiffe a Besaçon.
Non demountable!

Sensitivity: .1

MUSEUM OF THE HISTORY OF SCIENCE
OXFORD

Mus. Hist. Sc. Oxford
Cat. No. Accession No. 158

Case: Wood. Mahogany?
Size 25½cm x 26cm x 11cm deep.
Glass front 24cm x 18½cm slides out:
red"putty". Back glass had edge beading.
Base: 4 wooden feet.
Signature Dr. Daubeny.

Drawer: Label in drawer says Dr. Daubeny's balance.

Pillar: Brass 18cm long. Set into oblong plate 8.7cm x 2.6cm with 4 screws.
5cm shadow circle - 2 holes. 2 more holes under plate. Probably original position of pillar.
Pillar mend shows no tarnish under plate.

Label says "This balance Turns with 3/1000th of grain
Very sensible to _____"

Screws are brass 9mm with sawn ends.
Heads 6mm.

Beam: Steel l. 17.6cm. Cut swan necks.

Pointer: 5cm.

Pans: Brass. S hooks iron. Green string (too long).

Arrestment: Pull string.

Sensitivity: Will turn with .05g but not .02g.

Mus. Hist. Sc. Oxford

Cat. No. Accession No. 157

Case: Wood: Mahogany?
Feet: Has had at least 2 sets, all now missing.
Carrying ring set in top.
Glass front and back. Front slides up and off.
Reglazed? Putty?, painted? Indian Red.
Chips if prodded. Held by pins.
l. 25.6cm. h. 24cm. d.10cm. including drawer.

Drawer: l. 24cm. width 10cm, depth 2.3cm.
Drawer ÷ with 5 small compartments assorted.
Support for 13cm beam with notch for pointer
*suggests 5-6cm pointer. Contents: twist of lead shot and labels.

Pillar: Brass. h 15cm x 5mm x 5mm.
Set in square brassplate 15.6cm x 15.3cm
Held by 2 mushroom screws. As fitted.

Beam: Missing*

Pans: Missing

Weights: Missing

Arrestment Mechanism: Bronze fitment slides up pillar pushing 2 forks to lift beam clear of horse shoe steel brushes therefore beam had integral pins at rt⅄s.to beam to form knives.

Labels: "Small Balance of Platina by Corless c1820 (Beam melted down during Gt. War).
A drawing of the Beam by Children in Quarterly Journal of Science 1821, in which it was stated that such balances were made by Robinson Devonshire St Portland Place at £6. with platina beam".

"This is erroneous, based on a misreading of the inventory. Those were platina pans".

Mus. Hist. Sc. Oxford

Cat/Acc.No. 160

Case: Wood and glass. 38.2cm x 33cm h x 20.2cm deep. Glass front sides up on 3 stops, 37cm x 32cmh. Dirty pink putty. 4 wooden bun feet. Back glazed in 3 sections. No reason now. Carrying handle hole plugged. Centre back panel labelled "Top".

Brass plate holding pillar has 3 holes, but only 2 in use. Under plate are more holes. Conclusion, case not made for this balance. Plate 10.1cm x 7.5cm x 3mm deep.

Drawer: -

Weights: -

Pillar: Approx. 23 cm.

Beam: Brass 26cm with division markings. Held by 'arms'.

Pointer: Reads over very small card. Only 3 divisions either side covers total swing.

Pans: Size: 6cm steel on 18cm string and swan neck ends steel. Agate (or glass?) plane, steel knife in centre. No centering arrangement.

Sensitivity: To .005

Arrestment: Raise the lever. Other end drops, allowing arrestment to drop and lower beam knife on to plane.

Hist. Sc. Mus. Oxford
Cat./Acc.No. 323

Case: Oak box. 22.3cm x 7.5cm x 7.5cm.
"The Hawkesbee"
4 sections of unequal size, green lined.

Base: Heavy circular brass 5.8cm in one hole of drawer.

Pillar: Missing. Cannot have been more than 20cm unless ÷

Beam: Steel 20cm with swan necks, hardly nicked.
Integral ♀ knife steel.

Pointer: 6.6cm steel, upwards pointing. Because the box is unevenly ÷ the pointer will always drop in a space.

Contents: Glass bucket and large glass pearshaped wt = 81.66g. and small glass pear = 39.57g.
Large brass wt. 58.07, 17.15, 2.5.
These other wts to hang on or under the hanger.
A spare additional slot wt. of 12.505g.
A selection of wts marked AVERY.

Pans: With loops
Graduated scale or top marker missing.

See Harris "Lexicon Technicum" for details of probable original method of use.

Hist.Sc. Mus. Oxford

Cat./Acc.No.324

Case:	Box with opening lid.. Lid and base elaborately fitted. 37cm x 16cm x 10cm. Trade card green. Key hole, & 2 hooks to close?
Manufacturer:	John Newman. Manufacturer of Chemical and Philosophical Instruments, No. 8 Old Lisle St., Leicester Square, London. Jones S.C. No. 38 Theobalds Road (very small: printer?)
Base Plate:	Heavy brass 12cm diam. Makers name under and on top. Inscribed. W. Crum F.R.S., 1796-1867. Pres. to L Evans Coll. 1926.
Pillar:	2 brass tubes one inside the other 2.5cm diam.
Beam:	Steel 25.5cm with two integral steel knives. Brass ball on screw thread above beam for C of G. Ends are not swans, but knives with hangers built in (boxed?).
Pointer:	Is an ivory scale on detachable arm 10.5cm which fits in hole in tube at centre. This lines up behind left(?) hand hanger which has a pin attached. The two steel knives are held in with 2 screws therefore removable.
Pans:	2, each 6cm. diam. on 21cm strings.
Arrestment:	Lever at back of pillar once screwed into base, goes up to lift centre steel knives clear of resters.
Additional Contents:	1 repaired glass bucket, 1 glass pear weight. 4 wts marked Bucket Air (28.35g), Bucket Water (19.82g), Pear Air (33.725g), Pear Water (23.58g) + an ivory screwed box with tiny wire turnings, the heaviest of which weighs just under .005g. + key.
Sensitivity:	to .005 at 1gr.

Mus. Hist. Sc. Oxford

Cat./Acc. No. 159

Case:	Wooden drawer in cover. Size 27.5cm x 16cm x 6cm deep. Key + ivory lock plate △ Brass plate set in top for pillar.
Drawer: Manufacturer:	Trade plate (with engraved pictures). George Knight & Sons Ironmonger and Manufacturers of Chemical and Philosophical Apparatus, Foster Lane, Cheapside, London. Lined in green. Contents: Ball of horsehair, list of all wts.
Weights:	1, ½, ¼ oz Troy. Grains 500, 300, 200, 100, 50, 30, 20, 10, pincers. Platinum wts .5, .4, .3, .2, .1, etc. + wire.
Pillar:	In 2 parts. Total height 32cm to top + arm.
Beam:	20cm steel. Pinned to hole in pillar arm.
Pointer:	Upwards
Pans:	2 brass, one removable, + 1 with hook for hydrometry. 7.5cm.
Arrestment:	Pull string by lever.
Sensitivity:	Will detect .005g difference.

PRIVATE COLLECTION A

PRIVATE COLLECTION A March 1976

Case: Not original, but a replacement perspex dome after bomb damage.

Base: 42cm x 19cm x 4cm deep. There is a groove in each side suggesting it probably slid into its case, and therefore it had doors or a drop front. This is covered by sheet of glass, bevilled front edge, cut sides, probably replacement.
Two ivory discs screw through for pans to sit on.

Pillar: 16.2cm. Diam. 1.8cm. Brass.

Arrestment: Pull string (replaced by wire) on toggle out through front of case. 2 agate planes for beam to sit on.
Pillar within pillar lifts to raise beam by pushing up plane, steel knife on agate. Centre pillar holds plane.

Beam: 22cm. steel. Steel ♀ worn. Also brass finial and flag.
Marked F for front. No notches at ends, which are forked.

Pointer: 11cm.

Pans: Not original but of standard assay type (" 12 sba's") (Probably identical to originals)

Sensitivity: Better than .01. Not .005.

Arms: To hold beam extend 13.5 from centre.

PRIVATE COLLECTION A March 1976

Case:	Small wooden hinged box, fitted, with space for tweezers (missing). Hand balance with one surviving weight: 2.852g. No sign of tarnish.
Beam:	4" or 10cm approx. Captive ring ends.
Pans:	Held by new green strings. Engraved underneath 59. Presumably 59 grains.
Pointer:	Steel approx.4cm. Steel knife. Trimmed now with a little green tassle.

PRIVATE COLLECTION A March 1976

Case:	Box 31cm x 7cm x 5cm deep, divided to store components.
Manufacturer:	Griffin & Sons Garrick St. & Long Acre London.
Pillar:	12cm brass.
Beam:	Wooden. 30cm hook to hook (non-ferrous) Steel pin, very fine rests on pillar V. Graduated riders.
Arrestment:	-
Pans:	2 each 1.6cm., Al (alloy?) on hangers 2cm deep. Designed to rest on 2 wooden "milking stools" each 8.5cm high.
Weights:	5, 10, 20, 30 grains. 30 gr. wt. weighs 1.943 grammes. Lots of riders.
Pointer:	Fits into 3 "milking stool" for use at left L end. Stool holds 3 glass pots of weights and a wire holder.
Sensitivity:	Levels beautifully.

PRIVATE COLLECTION A — April 15 1976

Case: 45cm x 58cm x 26cm deep. Glass front 42cm x 48cm slides up and out on 6 stops. Mahogany and shows no sign whatever of repair or marking. No adjustable feet, just flat domes.

Pillar: Brass showing signs of corrosion. A very good pedestal balance. Set in base. 37cm to top.

Arrestment: None as such, but front lever pushes oblong section bar on front of pillar which lifts beam and pans.

Beam: Held by removable pin in trad.manner. 25cm from knife to knife. Engraved De Grave & Co. Ltd. Makers London
Capacity 11b.
Not easily removable. Centre knife presumed to be steel. End knives are.

J's: Steel

Pointer: Upwards into a roundel, backed by ivory plate for ease of reading.

Pans: 12cm diam. 24cm drop. Very shiny.

Manufacturer: Ivory plaque set into floor De Grave Short & Co. therefore post 1845. Perhaps a later inset and the beam label is the more correct?

Drawer: Contains almost complete set of weights. Troy cup wts., ounze wts. from 11b. down, and grain (?) 3000, 2000, 1000, 500, 300, 200, 100, etc.

Pans found to be non.mag. stainless steel replacements.

PRIVATE COLLECTION B

PRIVATE COLLECTION B.

23.3.76

Manufacturer: Paul Bunge Fabrik. Wissenschaftl Waagen. Hamburg.

Case: Glazed 36.5cm x 36cm x 25cm deep.
2 glass side doors hinged. 27.5cm x 20cm.
Black base. 7 stops.
2 adjustable feet marked 10 (l) and 9 (r).
Front slides out 32cm x 35cm.

Pillar: Plumb bob. Ivory graticule 2.4cm x 1.7cm
No. ID 5132. 25cm x 1.7cm diam. pillar.
Central agate plane
Left, centre and right pan holders = 3 pairs of agates, the front set being egg cup shapes and the back set cones and all set on adjustable brass tubes.

Pan Arrestment: 2 felt covered bouncers linked to the pillar 4.5cm x .7cm diam. removable tubes.

Beam: Rider ÷ both sides of centre 0 → 1(0)
Stamped Paul Bunge Hamburg
13.7cm ($5\frac{1}{2}$") 3 knives ▲ ▽ ▲ all held by adjustable screws. Those screws holing the end knives are steel, but the rest nonferrous.
To align under the pointer holder are 2 glass drips.

Pointer: 26cm. C. of G. knobs at centre back.

Pans: Labelled IV and IV also left and right in German and rt. one labelled Chelsea. 7cm diam. 14cm max. diam. hoops, 21cm long. Sp. gr. hooks, one missing. Top hook steel. Pans plated, Chrome?

J's: "Glass" plane ▽ and 2 glass drips. No knotch in hook. Steel screws.

Weights: 50, 20, 10, 1. 5 22 1 500 dg. etc., tweezers. All corroded.

Sensitivity: .005 not finer. Does not level. Needs .27.

23.3.76

PRIVATE COLLECTION B

Case: 41cm x 39cm x 22cm deep.
Labelled Scientific Supplies Hatton Gdn.
Front slides up and out. 39.5cm x 38cm.
2 adjustable feet. This has been used to house a hydrostatic balance.

Pillar: 13cm tall, 1cm diam. set on a base, 0,6cm, diam. screwed through into bottom of case and not easily removable.

Tube brass inside the pillar adjustable for height, holds top on which beam sits on 2 agate V's.

Beam: Labelled Baird & Tatlock (London) Ltd.
14.-17 Cross Street, Hatton Garden, London E.C.1.
Steel hook and a steel knife. Counter weighted and ÷ 1-9.

Hydrometer: Celsius Korper n Reimann 5 gr. Verdrangend

Weights: A set of hooked U's, about 10.

Very similar to the one by Becker's in the Wellcome Collection, but no top pointer. This one relies on a spike on the beam lining up with one on top bar, therefore no fine graduations. It is either level or not.

Box of weights made by Wm. H. Kuhlmann of Hamburg in a mahogany box marked 22 under the small tray. Decimal weights are flat spirals of metal (Pt?)

PRIVATE COLLECTION C

PRIVATE COLLECTION C

20.4.76

Case: Beautifully finished rounded edges, etc. Front counter balanced and 2 side doors. 39cm x 22cm deep x 38cm.
Black highly polished floor
Rider mechanism.
2 adjustable feet and one fixed spike.

Pillar: Cylindrical and ebonised. Diam. about 1.8cm Plumb bob at back.
2 felt covered bouncers for the pans.

Beam: Only removable if arrestment lowered. 12cm Knife to knife. Knives very long and thin. Graduated 0 - 10 on both left and right. Adjustment by screwed knobs at both ends.

Beam Holder Arms: 7 cm each side of centre.

All these prongs (4 left and 3 right) are adjustable and fit into underside of beam. Centre plane very large and oval ends.

Pointer: 19cm. C. of G. slides on here. The only 'crude' part.

Pans: 7cm on 20cm hangers.

J's: have planes set into underside of bar of J.

Sensitivity: .005 or better.

Manufacturer: Baird & Tatlock (London) Ltd. 14-17 Cross St., London EC1. 1908
On ivory graticule below pointer on pillar.

All non-ferrous except for double hooks on base of J's. Chromed?

PRIVATE COLLECTION C 20.4.76

Case: 35cm x 28cm x 34.5cm. Much plainer in appearance. Rider mechanism present and 2 side doors. Front counter balanced. Small disc slots in front to hold weights.

Pillar: Pan resters present. All details similar to previous balance by Baird & Tatlock.

Beam: Appears to be aluminium; all other fitments are brass. Suggests a later date when price of Al had dropped somewhat.

Beam Holder Arms: As before.

Pointer: "

Pans: 6.5.cm diam on 18cm hangers.

Sensitivity: .005 or better.

Manufacturer: Baird & Tatlock 14-15 Cross Street, Hatton Garden, London E.C.1.

Weights that could be accommodated .5, .2, .1, .1, .05, .02, .01, .01.

PRIVATE COLLECTION C — April 20 1976

Case: 36cm x 43cm x 27cm deep.
Case marked A. Gallenkamp & Co., Ltd., 19 & 21 Sun St., Finsbury, London E.C.
Front slides and rider present.

Pillar:

Beam: Graduated 0 - 10 on both ½s.
14cm knife to knife.
Beam of triangular construction, all parts being adjustable and two lots of C of G and centering adjustment.

Rider: On a separate bar screwed to the front of the beam and parallel with it.

Pointer: 26cm.

Pans: 7.5cm diam.

Manufacturer: F. Sartorius Gottingen No. 24320 on ivory plaque.

PRIVATE COLLECTION C 20.4.76

Case: Marked A. Gallenkamp, 19-21 Sun St., Finsbury, London E.C.

Pillar:

Beam: Stamped Paul Bunge (Fabrick Wissenschaftl Waagen Hamburg) No. 5245. 14cm ▲ to ▲ Has a very large centre knife and construction of beam appears to be of stainless steel rod bolted together.

Rider: 1 - 10 all across and not in $2\frac{1}{2}$'s. There is a rider bar and very elaborate C of G.

Pans: Steel top hook. Noticeably none of the elaborate hanging mechanism despite the extreme accuracy of the instrument. Diam. 6cm on 21.5 hangers.

Telescope: This fits through the glass of front of case and has hair set in. It focuses on the higher of the two ivory graticules.

Sensitivity: "1 ÷ on beam - .001005"
No reason to doubt that this could be obtained. A beautiful instrument.

Manufacturer: Paul Bunge

ROYAL INSTITUTION COLLECTION

9 Albemarle Street, London

COLLECTION OF SCIENTIFIC INSTRUMENTS

Note:

The balances in this collection, some of which are on display, have been allocated numbers by the writer solely for ease of reference.

Royal Institution Collection — June 15
Albemarle St., No.1 — 1976

Case: 44cm x 42cm x 30cm deep. 2 side doors.
2 adjustable front feet. Rider mechanism.
Glass front slides up and out on 16 stops, 40cm x 41cm.
Case has glass floor, cracked.
2 felt covered pan rests.
Rider ÷ 0 - 10 both sides.

Pillar: 32cm to centre knife. Plumb bob at back
Arrestment knob on left side of case.
Ivory graticule at base of pillar.
Label says 'Rider 5mg each ÷ - .05mg'
Beam holders extend 7cm each side of centre. Split "glass" plain at centre.

Beam: Signed Paul Bunge Hamburg. 16cm K to K.
Manufacturer: Rider bar separate and parallel to beam.
Very large centre agate ▽ to which is attached both rider bar and beam. Brass and corroding.
End knives of unusual shape. ◊ ◊
Very small screws, steel.

C of G is attached to bracer bar.

Pointer: 31.5, bent at end (when dropped?)

J's: Large, rest on two pillars, one flat top and one "M".
Glass? plains.

Pans: 9cm on 27cm hangers.

Does not level too well: needs .05 to level it. S not taken.

Royal Institution Collection
Albemarle St., No. 2 15.6.76

Case: 36cm x 30cm x 17cm deep.
Front is lockable and counter balanced.
Rider mechanism present.

Pillar: 18cm. Untarnished steel knives. Ivory scale.

Beam: ÷ 0 - 10 each side, 18cm.

Pointer: Could be Al. 15cm. C of G. spiral on pointer. Pointer bent.

Pans: 2 cm pans on holders on 14cm hangers.

J's: Top bar solid "glass".

Manufacturer: Pillar base signed A. Ruprecht, Wien.

One pan arrest (left) has been removed leaving hole in floor. Other side mechanism has been weighed with bolts to operate independently. A hook wt. .32g has been soldered to underside of pan to enable hydrostatic wts. to be done through floor.

Sensitivity: to .005.

Royal Institution Collection
Albemarle St., No. 3 June 16 1976

Case: -
Base board 37.5cm x 17.5cm.

Pillar: 26cm to knife.

Beam: 22.5cm K to K. Steel knives.
Hangers present but no pans.
Plumb bob.
Whole thing rather sad.

Manufacturer: Townson & Mercer London

Royal Institution Collection
Albemarle St., No.4

June 15
1976

Case: 40 l x 34 h x 20 deep including large drawer. One cracked glass. Rider present. 2 adjustable feet.
Front counter balanced (broken end).

Drawer: Contents: 2 tiny glass phials.

Manufacturer: Trade card of H.L. Becker's Son & Co.
Brussels, Hague, Rotterdam.
With instructions, and beware of imitations!
3 round plain turned wooden boxes of grain wts. and 1 purpose made (unmarked) mahogany box of V.G. grain wts.
Brass 1000, 500, 200, 200, 100, 50, 20, 20.
Al? 10, 5, 2, 2, 1, .5 etc.
Forceps present but do not fit.

Pillar: 18.5 Ivory scale labelled H.L. Becker & Son & Co., Brussels.
Pan arms 5.5.

Beam: 19.5 cm. K to K. Steel knives.
Rt. hand ½ ÷ 1 - 11 and engraved with a bird?
Centre plain could be glass from its appearance. Agate probably.

Pans: Black (brass under) 6.5 on 16cm hangers.

Sensitivity: .01.

Royal Institution Collection
Albemarle St., No. 5 June 1976

Case: 48cm x 40cm x 25cm d. light wood. Front slides out.
Balance free standing in its case, on wood base 38cm x 16cm.
A hole has been cut in the floor on left side for hydrostatics.
2 levelling feet.

Pillar: 25cm to plane. Probably "glass" plane.
Arm rests 11.5 cm either side of centre.
Plumb bob.

Beam: Stamped 6. knife made of "glass" and the end knives 2 C of G screws on ends of beam.
22.5 cm K to K.
Notches fore and aft of plane cut in beam attachment to centre it.

J's: Standard with domed insets of "glass."

Pans: 10cm diam: hangers 23cm.

Pointer: 37cm. Non ferrous.

Manufacturer: Philip Harris & Co. Birmingham on ivory scale. Made in Belgium.

Sensitivity: Needs .1 to level. Then to .01.

Royal Institution Collection June 1976
Albemarle St., No. 6

Drawer in cover.
Drawer 46cm x 11cm x 24cm.
Contents: assorted Avery wts., lb., Troy, Gramme, etc.

Pillar: Brass. 50cm to pin. Should presumably be unscrewed and packed in drawer when not in use.

Beam: 30cm. Boxed ends.

Pans: 16cm diam. on 34cm chains.

Press lever and beam stamped
W. & T. Avery Ltd. Makers Birmingham.
To wt. 20 oz.

Royal Institution Collection June 1976
Albemarle St., No. 7

Case: 37cm x 37cm x 25cm deep.
2 levelling feet. Rider present ÷ 0 - 10 all across.
Arrestment knob on left side.
Front 35cm x 32cm slides up and out on 13 notches.
Side doors. Floor of black glass.

Arrestment: Sadly pan arrestment works but not beam one.
Spring under probably needs oil, and probably left "up".
Plumb knob.

Pillar: 27cm to plane. Interesting mirror attachment at base behind ivory scale, curved.

Beam: Stamped W I L H. H. F. K U H L M A N N
Manufacturer: Hamburg.
There is a large centre knife held by screws.
Beam 13cm.
End knives also nicely held and adjustable.

Pointer: Could be Al. 24cm. 'Point' is a frame of wire.

J's: Basically wire loops.
Pan 7cm. Hangers 21.

All very corroded and so badly bent that pans jam and whole unusable at present.

Royal Institution Collection
Albemarle St., No. 8 June 1976

Case: 36cm x 30cm x 18cm. Wood - Oak?
Front counter balanced.

Pillar: 21cm. Ivory scale attached. Split plane.

Beam: Stamped 9. 20.5cm. Adjusting screws on ends.
All knives badly damaged agate.

Pans: Pan hangers captive on J's. Pans 9.5cm.
Hangers 18cm.
All brass.

Sensitivity: Levels. To .01.

Manufacturer: Baird& Tatlock London and Glasgow.

Royal Institution Collection June 1976
Albemarle St., No. 9

Case: A quality job. Lockable sliding front 34cm x 34cm x 24cm deep. 2 adjustable feet.
Counter balanced. Stiff intended for semi-micro.
2 side doors and 2 gimbal mounted pincers, one either side equipped with lazy susan.

Arrestment: Pan arms drop away separately from centre beam.
Dash pot in case and 2 pan bouncers.

Pillar: Brass 15cm to planes which are two circular pillar tops of agate.

Beam: 14cm to 2 pin steel knives. Beam aluminium.

Pointer: 16cm. The whole could be stainless steel.
Centre ▽ consists of 2 steel pins.

Pans: 2.5cm. Holders 15cm steel.
NO centering device therefore tricky to operate.

Manufacturer: Paul STUCKRATH FRIEDENAU - BERLIN.

Sensitivity: Much better than .005.

Royal Institution Collection
Albemarle St., No. 10 June 1976

Case: Basically identical to No. 7 q.v.

Numbered in black ink DRP No. 81019.

Rider 0 - 10 all across.

Arrestment: Pan arrestment works, beam arrestment does not.

WIL H.H.F. KUHLMANN

Royal Institution Collection June 1976
Albemarle St., No. 11

Case: 46cm x 41cm x 24cm. deep.
Black case with remains of gilt trim.
Fronter counter balanced. Case contains rider ÷ 1 - 10 each side and a thermometer.
Also side doors and the back slides up.
Most elaborate.

Manufacturer: A. RUPRECHT WIEN

A patent device seems to clamp the pointer, and work separately from the beam and pan arrestment. It resembles a large pierced bulldog clip activated from rear column.

Another added extra is a remote handling device for wts below 1g. Push buttons on front of case at bottom rt. corner depress rods on which spiral wts are hung, so resting them on rt hand 'pan'.

Pillar: 29cm to centre K. The knife looks like steel but is non. mag. Agate planes.

Beam: 20cm K to K. Beam arm holders extend 10cm each side.

Pans: 7.2 cm. diam. Hangers 20cm.
Beam arrestment seized up therefore sensitivity not taken.
Label says "Oct 16 1944 Rider x $\frac{100}{99}$ etc."

Balance has been adapted for hydrostatics.

Royal Institution Collection
Albemarle St., No. 12 June 1976

Basically as No. 11. q.v.

Counter balance string broken.

Pan arrestment present.

Spirit level present.

Mirrors at top.

Patent pointer holder appears to release with jaws up .

Very stiff but working and after levelling produced sensitivity of .005.

RUPRECT

Royal Institution Collection June 1976
Albemarle St., No. 13

Basically the same as No. 11 and No. 12.

As patent pointer holder and weight loaders were missing it was possible to remove the beam.

Knives found to be untarnishedsteel, and held by blued steel grub screws.
6 per K.

In good order.

All these three RUPRECHT balances are exceptionally heavy.

Royal Institution Collection
Faraday Museum, Albemarle St., No. 14 July 29 1976

R.I. Minutes June 7 1802 quote price at 36guineas.

Case: 60cm x 42cm x 20cm deep. and 5 drawers under. 2 side doors. left one jambed and in need of ivory knob as do 4 of the drawers. 4 levelling feet fixed to stand 70cm high.

Drawers: 10.5cm x 12.5 deep where pan arresters are in the way. Other 10.5cm x 17.0cm. 4 holes have been drilled through floor under centre drawer to allow access for screw driver to pillar base plate screws.
Large holes for pan arrester tubes. Drawers not numbered, but "2" and "4" are elaborately ÷. "5" contains slivers of beading which needs reglueing to cabinet and spare wire. Grain E → W.

Pan Arrester: Worked by ivory handle on bottom rt side, very stiff.

Pillar: Is 4 brass tubes 31cm to K and one centre tube, which is movable pillar.

Beam Arrestment: Front centre lever swing thro' 180° and pushes a lever under down therefore forcing other end of pillar up. The 4 pillars support a square frame of brass and to it are attached a N and S aligned rest arm to arrest and centre pins of beam. No other arms. Steel planes set in.

Beam: 2 cones of brass. Internal structure uncertain. Ends removable in theory. 44cm K to K. Steel V (and pins) to fit arrester V. 2 ends dissimilar. One wt. bob missing. Steel end caps held by 4 steel screws. Grade scale at rt. only. 2 pointers, both bent.

J's: Steel knifesits inside hollowed out top section to centre it. No notch for hook.

Pans: 8cm. Hangers 22cm wires. Bronze hooks.

Sensitivity: .05 just.

Manufacturer: FIDLER LONDON

Royal Institution Collection July 29 1976
Faraday Museum, . Albemarle St. No.15

Provenance: Said to have been passed from Cavendish to his nephew Ld. G. Cavendish, to Davy, to J.G. Children, to Alex.Garden by 1830, to R.I. 1868.

Case: Large, on stand with eight small doors in face. 74cm x 88cm x 30cm deep.
Sides glazed. Back solid.

All have stoppers and turn buttons of wood.
Lined with "white" paper or perhaps plaster.

Manufacturer: Harrison, according to documentary evidence.

Pillar: None as such, but a big square wooden pillar. Just above base are the sticking out handles of the pan arresters. which are designed like Robinson's 'Wollaston' ones.

2 pans rests also present. The left one has a hole for S.G. above hole (corked) thro' case floors.

Pans: 10cm on 42cm wire hangers which are too short to "sit" therefore either pan arrester mechanism faulty or replacement wires.
5cm gap. Arrester knob just above base.
2 spirit levels (out of true).

Arrestment: Knob raises or lowers pan bouncers, and end K arresters and finally center is raised clear. Two tubes within tubes run up back wall, raised by cam and gears.

Beam: Hollow, top welded on, iron, 23.6 each ½ and 2 cm wide. Steel centre and end K.
No centering.

Pointer: At rt. Wt. knob at left and C of G under beam towards rt.Steel centre plane split.

J's: Universal joints, elaborate.

Sensitivity: Levels with .59 Then about .005.

Royal Institution Collection
Albemarle St. No 16 6.4.78

Case: $23\frac{1}{2}$ x $20\frac{1}{2}$ and 12cm. Mahogany, plus 4 adjustable feet, inc. 2 drawers. Front slides up in 2 side sections. Hole in centre panel for microscope. 2 riders. Lockable doors. 2 levels. Nothing underneath.
Signed on pillar base Ladd & Oertling London
Plaque inside says "Holland apparatus No. 8."

Drawers: Left: Box of Baird & Tatlock rider weights. Microscope. A hollow prism. A glass object part mercury filled (a permanent counter poise?) Chalked under 1774 and L3.

Right: 15cm x 5cm deep approx. x 25cm long. Ivory pull. A lot of counterpoises assorted, an angled mirror on stand. Papers about "hydrophane" for Min. Mag V1II p.181 Shelsley, Kew Gardens. A rider and a spare pan hanger.

Pillar: Cylindrical, 28cm. approx. inc. whole agate plane. Arm rests extend 20cm. each side. Thick glass base over green. Ivory pan bouncers.

Beam: 33cm K to K. Agate slivers in brass ÷ for rider both sides, the left one being nicked. Centre K Massive, set in brass..

Arrestment: Raising arm rests lifts beam clear of plane. Pan bouncers work simultaneously.

Pointer: 21cm inc. v. fine scale on the end for reading through microscope. Had C of G and sliding bob as well.

J's: Labelled L & R. With hole and groove to fit over arm rests.

Hangers: 23.5 cms. inc. hooks, x 10cm wide at base. Pans loose 9.4.

Sensitivity: .005 will take needle of scale, plus rider, plus micro scale. This last perhaps was added later?

MUSEE DU CONSERVATOIRE NATIONAL DES ARTS ET METIERS, PARIS

Note:

The balances used by Lavoisier which form a unique part of this collection had been removed for cleaning following accidental damage before this survey was made and are not included in these notes. However, a detailed description of them will be found in M. Daumas "Lavoisier théoricien et expérimentateur". pub. 1955.

PARIS. Musée du Conservatoire National des Arts et Metiérs. No. 3337 — July 7 1976

Label: 3337 Balance de précision par Fortin.
Force 1 kg.
Accusant 1 mg. entrée 1848.

Case: Large glass case. Front slides up in 3 sections.

Pillar: 51cm, brass.

Beam: 66cm, steel, with steel end knives.
Centre one not visible.
Signed Fortin à Paris. an 8 therefore post Sept. 1799.
[Rev. cal. 22/9/1792 - 1/1/1806]

Right hand pointer viewed by magnifier.

Beam rest extends 21cm each side.

Pans: 11cm diam., not a pair, plus one for s.g. on hangers 44cm.

Original arrestment knob missing but a substitute enabled balance to be levelled with 1.5 on left and lg. on rt.

Sensitivity: It would just turn at 1mg.

Notes mention a pulley arrangement whose purpose I could not see.

Paris C.N.A.M.
Cat/Acc.No. 12691. July 7 1976

Label: Balance d'essai a double chape de la portée de 500g construite per GONDOLFI entrée 1895.

Case: Presumably. (not mentioned in notes.)

Pillar: 34cm to the knife. Brass square sectioned.

Beam: 44cm steel, shows no sign of corrosion.

Arm rests 14cm either side.

End knives not notched, but no mention of design or how arrestment works. Presumably they just hooked on.

Top pointer present. No size given.

Pans about 12cm on elaborate hangers 22cm with adjustable thread.

Sensitivity: .005

C.N.A.M. Paris
Cat/Acc.No. 16266 July 8 1976

Label: Balance de Précision du laboratoire particulaire de J.B. Dumas. Don de Mme Herré-Mangon née J.B. Dumas, et du General Dumas. entrée 1922.

Case: 77.5cm x 55cm x 27cm deep, + 2 drawers under. Looks like an Oertling long beam. 4 feet.

Pillar: On square base signed LECOMTE A PARIS. C.36cm to top knife. A tube of brass + ivory scale.

Beam: 45cm. No end knives, just O to hang the pans on. Not notched and not signed.

Pointer: 25cm. Rest arms 10cm.

Centre plane split and non-ferrous.

Pans: 6.5cm. Could be tin plate. Spare s.g. pan. Wires could be Pt, + steel hooks notched.

Sensitivity: .05. A lot of friction. Perhaps better once.

C.N.A.M. Paris
Cat/Acc.No. 16222 July 8 1976

Label: Balance de précision à fléau au 1/20e, de mg première balance en Aluminium, construite en France ayant figuré a l'Exposition de 1855 construite par Collot en 1855. Don de M.M. Collot c Longue et Cie. Entrée en 1920.

Case: Black ebonised, 4 side doors, front slides up. 2 rider bars. Plumb bob.

Pillar: 25cm. Tapers slightly. Unsplit agate plane.

Rest Arms: 14cm split. 2 prongs.to hold the beam.

Beam: Signed Collot Frères Exposition 1855. Lattice. Agate knives. Each ½ of beam ÷ 1 - 10 for rider.

Pans: Hung from J's. C.2-3cm.

Sensitivity: .005 or better.

In good order, of Al throughout.

C.N.A.M. Paris
Cat/Acc. No. 16773 July 8 1976

Label: Balance de précision construite par M BERTIN en 1902. Don de Mme Bertin. Entrée en 1933. pour peser l'or.

Case: c.35cm x 30cm x 24cm deep. Mahogany, + 2 drawers under. 3 adjustable feet.

Pillar: c. 20cm. Base has 2 dash pots and signed.
E. BERTIN LONDON
Rider beam ÷ 1 - 10 each side. 2 side doors.

Beam: C. 20 and signed. End knives appear to be triangular.

Pan arrestment working, but not beam, therefore no sensitivity.

C.N.A.M. Paris
Cat/Acc. No. 10513 July 8 1976

Label: Balance construite par Abraham BREGUET pour peser les masses de balanciers de chronomèteres (avant 1823). Don de M. BONIS. Entrée en 1885.

Case: No feet. Front slides up and out. Mahogany 26cm x 22cm x 18.5cm deep.

Pillar: Brass base. 15cm.

Beam: 20cm. Pointers at both ends, and of unusual design. No knives. Centre is two crossed steel needles which are braced on each other.

Pan Holders: Separate arrestment of these seems designed to push them out to jamb against the J's from the floor.

Pans: 3cm diam. on 14cm hangers.

Very unusual. Now too stiff to use.

C.N.A.M. Paris July 8 1976
Cat/Acc. No. 8646

Label: Balance de précision pour 1 Kg. par M. SCHICKERT entrée en 1873.

Case: Large mahogany. 2 feet and 2 riders. C 84cm x 43cm x 30cm deep.

Pillar: Cylindrical. 30cm to large agate plane.

Beam: ÷ 1 - 10 each side. 25.5cm. each side. Huge s.steel knife.

Ivory scale signed Hugo Schickert in Dresden.

Pan Holders: Massive 30cm + braces. Pans 10cm.

J's: Agate. Hooks below not notched. No centering, but it centres.

Sensitivity: .01.

C.N.A.M. Paris
Cat/Acc. No. 5111 July 8 1976

Label: Balance d'essai pour 1 Kg accusant 1/10 de milligramme par ÷, par M BIANCHI entrée en 1852.

Case: Large mahogany case and 2 drawers + 4 feet. C 54cm x 60cm x 30cm deep. Drawers empty.

Pillar: Square section on a large square base signed B BIANCHI Rue de la Sorbonne 9A Paris.
34cm to knife, all brass.
Ivory scale ÷ 0 - 20 each side. No rider, but a shelf at the back.
Centre plane is a ÷ agate.

Beam: 44cm K to K. Steel with stainless steel knives. ⇧ with nicely cut tops. Guiders for beam on arms are blued steel.

Pointer: 29.5cm. Pb flag at back and C of G on top.

Pans: 9.5cm x 14cm (?) Hangers 30 + cms. Agate planes to pan hangers.

Pan arrestment a bit stiff. Beam arrestment seized up solid.
Very heavy.

C.N.A.M. Paris
Cat/Acc. No. 8865 July 8 1976

Label: Balance de précision pour 250g sensible a 1/10e de milligramme par M. RÜPRECHT de Vienne. Don de M. COLLOT entrée en 1878.

Case: Black case. Two side doors. Counter balance broken.
2 riders and beam ÷ 0 - 10 both sides.
Two front doors and fixed centre panel.
C 50cm x 40cm x 22cm deep.

Pillar: Base signed A RÜPRECHT WIEN
c30 cm. Split agate centre plane held in a dome with blued steel screws.

Beam arms c 14cm each side + stays.
Already the cup and saucer holders present reminiscent of other BUNGE's q.v.

Beam: 29cm K to K. "Stainless" steel knife and blued screws. Long centre K to which pointer is screwed on front ½.

Pointer: 28cm and C. of G.

J's: with holders 28cm. Pans 7.5cm.

Arrestment (inc. pan arresters) stiff but working.
Sensitivity .01

C.N.A.M. Paris
Cat/Acc.No. 12485 July 8 1976

Label: Don de M. Armand Collet. Entrée en 1893.

A. Collot et Fils à Paris on stays.

Case: Very large mahogany. C80cm x 55cm x 30cm deep. 2 Riders and a rider bar separate from the beam and set above it, ÷ 0 - 10 each side.
Large magnifying glass to read pointer by.

Pillar: A pair of pillars.

Beam: Captive by massive centre agate planes (reminiscent of Liebig)

A very elaborate system of braces, and an elongated triangular design. Perhaps 60cm long.

J's: Stamped G (gauche) D (droit)

Sensivity: Difficult. The magnifier works but difficult to read below eye level. Perhaps .01.

C.N.A.M. Paris
Cat./Acc. No. 11481 July 8 1976

Label: Balance de précision constuite par FORTIN et ayant faite partie due lab. de CHEVREUL à la manu national des Gobelins. Don de la famille Chevreul. Entrée en 1889.

Case: Massive, but in a state of collapse. With great difficulty the front was slid out and details of construction are sparse.

Pillar: Brass.

Beam: Steel and solid: no attempt at open work. Beam signed "Cette balance appartenu a M. Chevreul Fortin à Paris."

Sensitivity: .01 or better.

C.N.A.M. Paris
Cat/Acc. No. 8084 July 9 1976

Label: Balance d'essai construite vers la fin du XVIIIe siecle, elle porte une inscription en Grec. Don de M. Collot frères, entrée an 1866.

Maintenant, Hermes ne faconne pas follement l'or mais, plus sensé il se content de l'eprouver.

Case: Has a pitched roof. Counter balance broken. 2 drawers.

Pillar: Figure of Hermes in bronze with patina and inscription as stated. 19cm high.

Beam: 20.5cm Gold colour, very bright and clean. Au. too soft. Pinchbeck? Steel centre knife.

Pointer: 10cm steel, upwards.

Pans on steel loops to swans.

C.N.A.M. Paris July 9 1976
Cat/Acc. No. 3336

Label: Balance de précision pour le Kilogramme, accusant 1mg par GAMBEY. Entrée en 1848.

Case: 53cm x 45cm x 18cm deep. 3 adjustable feet. At rt hand end a spy glass to see pointer on mirror outside at left, as well as pointer inside at right.

Pillar: c 32cm beautifully fluted like a column.

Beam: 20.5cm each half.

Huge arm rests solid full length signed Gambey à Paris.

Arrestment: Centre plane uncorroded steel and solid. Pan hangers 20.5cm stiff brass, pans 9cm.
No j's but a rocking plane in steel.

Sensitivity: About .005.

C.N.A.M. Paris — July 9 1976
Cat/Acc. No. 12690
No. 12802 identical

Label: Balance de précision de la portée de 1 Kg, construite par Fortin (An VII) en ayant fait partie du laboratoire de Chevreul au Musée d'histoire naturelle.
Don du lab de M le Prof. Arnaud au Musée d'histoire naturelle. Entrée en 1895.

Case: Massive and heavy (oak)? . Front slides up, but not enough space available.

It is two balances one on the front of the other, and both are of the pull string Ercker type but fine quality.

Pillar: C 40cm to centre pivot of simple type.

1st Beam: About 46cm all told. Plumb bob.

Pans: Hang from chains.

2nd Beam: About 24cm.

Two pointers, two scales.

Manufacturer: Signed Fortin à Paris an 7me

Arrestment: Pull string attached to weighed cups.

C.N.A.M. Paris
Cat/Acc.No. 11579 July 9 1976

Label: Balance de précision à courts fleaux construite par M. Collot don de M. Collot. Entrée en 1889.

Case: Mahogany with adjustable feet. c 37cm x 42cmh x 24cm deep, on two levels. This opens to give access to knives and rider and beam separate from the rest. Rider mechanism at bottom left and right on elaborate rachets.

Pillar: A glass cylinder about 26cm below + about 8 more above "ceiling" to K.

Pointer: Inside the cylinder with its scale.

Manufacturer: Signed A. Collot et fils à Paris 1889.

Beam: 13.5cm K to K. Appears to be non.mag.Al? also perhaps rider bar.
Agate planes.
Beam not removed.
Holders equal size.to the beam length.

J's: Egg cup and saucer rests. Agate planes.

Pans: 8cm at narrowest. Hangers 24cm. Pan arresters working, but too short. Replacements?

Sensitivity: Too stiff to take.

C.N.A.M. Paris
Cat/Acc. No. 4586 July 9 1976

Label: Balance de précision pour la livre accusant ½ mill Don de L'Intendance de Poids et Mesure des Etats-Unis d'Amerique par les soins de M.VATTEMARE. Entrée en 1850.

Case: Large mahogany and contents all shiny brass. Spirit level and 4 feet. Difficult to open. Pulley on roof for no apparent reason. Not obviously counter weight. Pulley to lift door externally?

Pillar: Tubular.

Beam: Solid, flat about 30cm. Neat centerers of circles of steel. Pointers at both ends of beam of blued steel.

3 brass knives. Eagle stamped on.

It seems unlikely that they were brass, which would be subject to much wear and tear on a large balance but it is possible.

C.N.A.M. Paris July 9 1976
Cat/Acc. No. 5401

Label: Balance de Dumas pour la densité des gaz par Deleuil. Don de l'Institute Agronomique de Versailles. Entrée en 1852.

Pillar: 50cm to central agate plane.

Beam: 27cm each ½. Stamped DL and Crown.

Sensitivity: .1.

C.N.A.M. Paris
Cat/Acc. No. 3339 July 9 1976

Label: Gambey Balance d'essai entrée en 1848.

Case: c 30cm x 30cm x 12cm.

Pillar: 17cm. Uncorroded steel centre plane.

Beam: c 20cm. Pointer at both ends. Steel beam. Non-ferrous. scale graticule. Blued steel hanger.

Pans: 3cm. Hangers 16cm.

A neat and straight forward balance, but not signed. Notches in the toasting fork ends to hold the hooks. There is a pin on the articulated pan hanger to centre it.

Sensitivity: .05 just.

Cat/Acc. No. 761 July 9 1976

Label: Balance armée d'une cremaillère pour elever le fleau.

Case: Size not given. Perhaps about 40cm x 30cm x 20cm. Made of black wood. Two drawers under.

Pillar: A huge wooden bell.

Beam: Steel with swan necks. 29cm.

Pans and downward pointer present, but no scale. Despite a certain amount of dismantling if bell ever did raise the beam it doesn't now, or ever.

C.N.A.M. Paris
Cat/Acc. No. 12803 July 9 1976

Label: Balance d'essai par GONDOLFI. Pret du Mobilier National Entrée en 1896.

Case: Black wood. Drawer under contains key to drawer and hidden switch to hold front.

Pillar: 17.5cm to K + a piece on top.

Beam: 20.5 cm Two split steel centre knives hold standard ▭ centre plane.

Pointer: 10cm.

Signed Gondolfi à Paris

Sensitivity: .005

Cat/Acc. No. 7443 July 9 1976

Label: Balance de précision pour 1 Kg accusant 1 mg par M. Hempel entrée 1866.

Case: Very large

Pillar: 52cm.

Beam: 27cm each ½

Signed O. Hempel à Paris 55 Quai des Grands Augustins Paris.

ASSAY OFFICE, LONDON

Assay Office, Gutter Lane
Mr Daladay's Office — July 15 1976

Hand balance in case.

Case: 28cm x 12.5cm x 2cm deep, red lined. Mahogany with lid hinged unmarked.

Card inside lid "De Grave Short & Fanner late M. de Grave & Son 59 St Martins' le Grand. Scale makers to Her Majestic Exchequer ... and the Assay Office Goldsmiths Hall."

Beam: 26cm steel. 2 swans.

Pointer: 11cm, tip broken.

Pans: 3.8cm silver. Green strings perished.

Top Section: Nicely finished. Steel.

Box carefully cut to take balance, unlike any other fitted box I have seen, also is slightly too small for the pointer had it not been broken off short.

Box contains letter dated Apr. 1 1956 from De Grave Short & Co. Ltd, est. 1670 Cray Valley Rd and 23 Charterhouse St. "The old De Grave scale ... believed to be before 1825 and probably pre 1800."

Assay Office, Gutter Lane
Silver Foreign Drawing Dept.

July 15
1976

A sloping beam Oertling.

Case: 54cm x 41cm x 25.5cm + 2 drawers under, now lost.
Lead counter balances now broken.
2 rider bars and beam present ÷ but not numbered.
Pan and beam arrestment. Glass floor.

Pillars: Twin 21cm to centre plane. 2 spirit levels. 2 pan bouncers ivory.

Manufacturer: L. Oertling London
8624
In old script on bottom of pillar base.

Beam: 25.5cm K to K. Knife at centre agate in brass, also end K's. These split for no apparent reason.

Arm rests: 12.5 cm.

Pointer: 16cm steel, broken and resoldered. Rest non-ferrous.

Pans: 1.2 designed to take plates or bowls.

Hanger: 17 Non-ferrous agate planes. Grad. scale numbered 0 - 10 both sides.

Sensitivity: Better than .005.

Assay Office, Gutter Lane — July 15
Gold Foreign Drawing Dept. — 1976

Case:	52cm x 41cm x 24cm. Labelled 12.s.b.a. 2 riders. Black glass base. Pan bouncers as before.
Pillar:	19cm to K. Centre plane = 2 circles of pink agate.
Rest Arms:	8cm either side of centre. Ivory grad. scale not numbered.
Manufacturer:	L. Oertling in square script. 36882
Beam:	15cm with split end K. No flag but twiddlers.
Pointer:	12 cm.
Centerer:	Neat opened circle round each end knife. All brass.
Pan Holder:	14cm, wire dishes.
J's:	Planes of flat plates of agate with one pin hole. No metal.
Sensitivity:	Better than .005.

Assay Office, Gutter Lane — July 15
English Gold Drawing Dept. — 1976

Case:	54cm x 44cm x 25cm + 2 drawers now missing. Rider bar now removed. 2 spirit levels.
Pillar:	Twin, 22cm to knife. Centre plane = 2 split agates.
Beam:	Sloping and as previously described and flag.
Arm rests:	12.5cm each side. End knives are agate slivers set in brass. Centre knife also, and not split.
Pointer:	Steel 16cm. Ivory scale numbered.
Panhanger:	17cm on J piece of roof truss design on agate planes.
Pans:	1cm.
Sensitivity:	Better than .005.
Manufacturer:	L. Oertling London in old script. 9995

Assay Office, Gutter Lane — July 15
English Silver Drawing Room — 1976

Case: 52cm x 41cm x 24.5cm + 2 riders.
2 drawers. + magnifier. Marked 12 s.b.a.
2 spirit levels.

Pillar: 20cm.

Beam: Straight, 15cm, ÷ and numbered 0 - 10.
Very similar to Gold foreign drawing room one.
No flag but 2 adjustable screws.
C of G ball attached to pointer 12 cm.

Arrestment: Circles to hold steady agate end planes.
End knives are split agate in brass.

Panhangers: 14cm.

Sensitivity: Better than .005.

Manufacturer: Oertling
36855

Assay Office, Gutter Lane — July 15
Gold Reporting Room — 1976

Case: 35cm x 35cm x 19cm + 2 drawers. 2 spirit levels.
Magnifier.
Under left drawer is 18417 26657 27656 (93)

Pillar: Twin. 15cm to K. Stamped 4659 Oertling in old script.

Beam: 15 cm. 2 agate end bars in circular holders. Arrestment is by push down knob.

Sensitivity: Better than .001.

Assay Office, Gutter Lane — Platinum Room — July 15 1976

Case: Small. 2 drawers. Riders ÷ 0 - 10. 2 spirit levels. Pan arresters.

Pillar: 18cm to K.

Beam: Level, 21cm.

Manufacturers: Oertling in square script. 35091.

Hangers: 15cms. Pans can be plates or bowls. Graticule not numbered.

Sensitivity: .005 just.

Assay Office, Gutter Lane — Stores — July 22 1976

Case: Pearwood and mahogany. 50cm x 50cm x 25cm. 2 drawers under. Right hand one for spare sp.gr. pan?
Glass base over green. Ivory bouncers.
Left hand one numbered 13111 28232.
2 riders, 2 spirit levels, Flag.

Pillar: 22cm. Not numbered. Rider.

Beam: 25.5cm. Split agate centre knife set in brass. End knife of agate in brass, with deep notch, therefore nearly split.

Pointer: 16cm.

Sensitivity: Better than .005.

Manufacturer: Oertling

Assay Office, Gutter Lane — July 22 1976
Stores

Very similar to previous one.

Back also opens and locks.

Number 10755 on pillar base. 25026 on drawer base.

Oertling

Assay Office, Gutter Lane — July 15 1976
Property of Mr Dalladay

Pillar balance in slide drawer.
Floor of box marked 1918.

Pillar: 24cm in 2 ½'s.

Beam: 15cm. Boxed ends.

Pans: On chains 15cm, pans 8.5 diam.
Standard Ercker type with usual base.
Also assorted weights.

WHIPPLE MUSEUM OF HISTORY OF SCIENCE
CAMBRIDGE

Whipple Hist. of Sc.Mus. Cambridge Cat/Acc. No. 1109 — July 26 1976

Provenance. Collection. Balance in glass case by Robinson in Wollaston Camb. Univ. Reporter May 1876 p.497

Case: Drawer in cover mahogany. Drawer 21cm x 10cm x 2.5cm.

Contents: spare pan 4.5 on 7cm strings. Steel S hook, Steel J, Tweezers copper.

3 adjustable feet. Hooks to hold case on, and 3 alining pins under case to sit into base. '5' under drawer. Case has 2 side doors. 23cm x 20.5cm x 10cm. Glass front and back and had a hanging ring.

Arrestment: Pan and beam arrestment can all be worked from outside. Pan arrestment is like Wellcomes. By pushing lever down at front, the other end being fixed behind the pillar, the outer case of pillar tube is forced down over inner and beam is lowered onto plane.

Manufacturer: Signed Robinson 38 Devonshire St. Portland Place, and plate held in by 2 blued steel screws. 3rd screw (see Wellcome) holds lifter.

Pillar: 16cm to split agate centre plane. Attached to outer pillar case are 2 arms and resters for beam with notched holders for J's. 7cm either side of centre. Grad. scale is in place. Pointer 6.5.

Beam: 5.5"K to K. Brass. Steel knife. C of G in centre. Steel end K held by 3 screws.

Sensitivity: Will turn with .005 but a lot of friction. K very much worn.

Whipple Hist. of Sc.Mus. Cambridge Cat/Acc. No. 1413 — July 26 1976

Provenance from Min. & Pet., supposedly Prof. Miller

Case:	Glazed front and back, same size as previous one. 2 side doors. Hooks on the side to hold top. Drawer only blue lined in places. Very small ivory knob. 2 spirit levels built in to square centre held with 3 blued screws.
Manufacturer:	ROBINSON 38 Devonshire St., Portland Place, London.
Pillar:	15.5 to K.
Beam:	15cm K to K as before with steel knives.
Pan arms:	8 either side.
Arrestment:	Basically the same but instead of poking pointer of 5.5cm down hole between split centre plane, this one has a pierced beam and whole agate plane held by 2 screws.
J's:	Agate of trad pattern. J type.
Pans:	4.5 cm. It has been adapted for sp gr. work by boring hole right through left side floor including drawer case.
Sensitivity:	Needs .025 to level then turns at .005.

Whipple Hist. of Sc. Mus. Cambridge — July 26 1976
Cat/Acc. No. 1593

Provenance. Reputedly used by W.H. Miller for standard 1lb. from Min. & Pet. Dept.

Case: 42cm x 32cm x 19cm deep.
2 side doors. 3 adjustable feet.
Drawer unmarked 17 x 39 x 4. Some blue lining.

Pillar: Set in square plaque and spirit levels.
23.5cm.

Arrestment: As before, but larger
Centre plain solid agate, not split.

Manufacturer: Signed Robinson 38 Devonshire St. Portland Place, London 517

Beam: 26.5cm K to K
3 steel K's, middle one massive.

Pointer: 9cm and ball.
Pan arresters and J's missing.

Pans: 7.5 cm.

Whipple Hist. of Sc.Mus. Cambridge
Cat/Acc No.1371

July 26
1976

Provenance. Stokes collection via Cavendish Lab.

Case: 2 front doors of unequal size so you can see the pointer when they are closed. One ivory knob. 2 spirit levels. 3 adjustable feet.

Manufacturer: Robinson & Barrow 26 Oxenden St. London.

Pillar: 25cm to K.

Beam: 26.5cm and much as before but with extra adjusting knob. Silvered scale.

Drawer: Contains key to push down extra stay catches on inside of case, and spare pan. Also wts 1000, 400, 300, 200, 100gr.

Pans: 7cms. Steel hooks, agate planes, steel K.

Sensitivity: Needs .03 to level, then .005 just. Adjustment has improved this. In best order of the 4.

Whipple Hist. of Sc. Mus. Cambridge Cat/Acc. No. 2232 — Oct.29 1976

Case: 76cm x 73cm x 26cm deep on a thick base and 2 adjustable feet with castors and 1 spike.
S.g. hole under rt. pan.
Only the front is glazed and slides up. helped hopefully by 3 pairs of pegs. Cannot be operated from the outside.

Signed Fortin et herrmann gendre à Paris.

Pillar: Base 9cm square. Scale cut into brass ledge.54cm to steel ÷ plane let into top of brass.
Arrestment moves arm rests up and down. All brass. Arm rest has a locator screw on left and bars to hold beam in place which join tops of toasting fork ends of the rests. 17cm each side.

Beam: 51cm solid steel. Steel knife, also toothed steel inserts to rest on arm holders, steel shielded. Knife driven through and c. of g and flag. No plumb bob.

Pointer: 52cm Hollow with brass wire inside steel which has decayed.

Pans: Flat 18.2. 44cm.stiff hangers. Steel top hook. Brass hook below for s.g.

Pillar held in case by wooden and steel turn knob, therefore intended to be removed. Very heavy. 4.2.diam.pans.

J's: Hooks of brass, massive and double and brass hooks. Steel set into top to take wear.

Sensitivity: About .1 but not .05.

Whipple Hist. of Sc. Museum Cambridge
Cat/Acc. No.

Oct.29
1976

Case: -

Pillar: 4.8cm diam. on 3 legs each splayed 20cm from centre and adjustable. Plumb bob from top of pillar semi enclosed at end over an upwards pointer attached to pillar.

Arrestment: Knob slides to lift centre pillar, which has 2 lumps of Fe inset in top.
Arms which hold pointers 22.5 from centre.

Beam: Steel bar 56cm ♀, steel + brass c. of g. attached by 4 blued steel screws.
Needle pointers on beam.

J's: Steel S hooks notched to hang from well notched steel end knives centred by brass plates and apparently removable.

Pans: 15cm saucers, on 42cm hangers. Steel hooks. All appear much too short for convenient use.

Manufacturer: Signed Fortin place de Sorbonne Paris 1790.

Pans signed Chemin à Paris.

No means of levelling beam if it is out of true.

Sensitivity: Needs .2. Turns at .02 = less than 1 grain.

Whipple History of Sc.Mus.Cambridge Cat/Acc.No. 1446 — March 4 1977

Provenance "Wollaston" See No. 1109

Case: Drawer and cover. Base 36cm x 17cm Black lined. Unmarked. Pull missing. Held by 2 hooks.

Pillar: 34cm brass, 2 slotted sections.

Arrestment: Spring loaded lever lifts centre pillar and pans.

Beam: 26cm, steel with usual swans.

Pans: 5cm on 16cm strings. Platinum?
Design reminiscent of De Grave balance at Assay Office q.v.

Sensitivity: .01.

Whipple History of Sc.Mus.Cambridge Cat./Acc.No. 1890 — March 4 1977

Provenance. From Dept. of Engineering May 1974, Lab. of Prof. Beck.

Case: Polished mahogany. 4 feet. 2 drawers. Sliding doors l and r + front centre panel which lifts out.
6 60 x 71·3 x 31·5
One drawer dated 26.3.88.

Pillar: Cylindrical on a square base + 2 spirit levels. Stamped at rear 2396.

Beam: 40.8cm, agate knives + ag. centre.
Long beam. Rider 1 - 9.
Agate centre plane and end.
J wires to stirrup pans.
Signed L. Oertling London in gothic.

Also a 12" Oertling long beam Acc. No. 1879.

THE ROYAL MINT
TOWER HILL, LONDON

The Royal Mint, Tower Hill
by door of Deputy Masters Office. Aug.4. 1976

"Balance invented and made for His Majesty's Mint by John Field Stamper of Weights 1826."

Case:	67cm x 52cm x 34cm deep + 2 small drawers under with ivory knobs, one containing 2 spare J's in neat fitting. Glazed front and back. Elaborate pitched roof and sliding drawer at back.
Pillars:	Twin pillars of brass. Inside the pillars are other cylinders that drop with the arms.
Beam:	Steel about 40cm and c 2cm high. Centre K has 2 V centerers, and appears to be steel. Centre plane may be steel.
J's:	End knives appear to be ♁ on which split steel plane on J's sit. Labelled R & L.
Pointer:	c 20cm to ivory scale ÷ 0 - 20 both sides.
Pan Arms:	to end knives.
Hangers:	Brass chain links about 25cm. Pans brass c.10cm.
Pan Resters:	Nicely chased brass.
	C of G knob and flag.

The Royal Mint, Tower Hill
In Stores

Nov.1
1976

Case: 86cm x 61cm x 45cm magnificently ornate. Has a lock hidden behind the plinth under a plate that must be released first. Front slides up. Glazed all round with bevelled glass. and also glazed roof. VERY HEAVY.
Rider bars inserted later through glass sides which are in fact doors that open. 24 227 now inscribed on side.

2 drawers with grain front and back. Rt. one has paper sticker 27772 in corner, added by Oertlings when they adapted it?

Front counter balanced and weights slide down inside front pillars.

Underneath, a large hole in floor 32 x 15. A false floor 5cm higher. Assuming the old floor was reused, the "original" pan bouncers were 26cm apart therefore 30cm beam quite possible. Hole was covered by plate 4 screw holes round the edge +
Could it have been reused twice?

Contents now standard L. Oertling 9648
2 graticules therefore designed to be read from back.

Pillars: 18cm. 2 spirit levels.

Beam: Level design 15.5 with C end and pins to hold knives.
K's are brass on 20 of agate and end
J's are agate strips. One pan hanger missing. Drawer contains 5 Sov. wt.

The Royal Mint, Tower Hill
In Stores

Feb 18
1977

Case: Light wood. Front slides up.

Pillar: Cylinder c.25 cm.

Beam: c 25cm. Knife at centre but hooks at ends.

Pans: On rigid hangers. 9 cm.

Manufacturer: L. Oertling London 11743 on top of pillar.
In very good condition. Pointer present.

TRADING STANDARDS OFFICE
BROMLEY, KENT

Trading Standards Office, Bromley — Aug.26 1976

"Model 3 Long beam chemical balance.
Awarded Gold Medal London Exhib 1862.
Purchased Allen & Hanbury Ltd 1863.
Presented to L. Oertling Ltd at time of expansion of Allen & Hanbury's Labs."

Case: 46cm x 47cm x 23cm deep (33 incl. drawers). 2 drawers and knobs. Rt. one locks. Case locks at top.
No. 1806 on plate on side of case rt, probably inventory number.
3 adjustable feet.

2 rider arms 1 - 9 each side and flag.

Drawers: Left 19 x 19 contains a 4gr and 6gr wt. Signed "This balance was shown in 1862 Exhib"
9700/39214
Front counterbalanced 43.5 x 40cm.

Arrestment: Knob pushes pan bouncers and arms up to lift beam clear.

Pillar: 21cm to split agate centre plane chipped. Base signed OERTLING. Arm rests 13cm each side. Straight bar with offset holder.

Beam: 25.5 K to K (removable if arrestment ½ up)
3 steel K's and steel pointer.
Split centre K with large V on arm holder to centre the K.

Pan: 10cm. 16cm hangers, agate planes labelled l and r. all set in brass. Non ferrous pans.

Bouncers no longer quite 'up' enough. It is suggested some refurbishing has taken place.

Turns at .005, but needs .001 to level it.
5 ÷ of the ivory scale covered by .01 rider set on 2.
2 ÷ of the ivory scale covered by .01 rider set on 1.

COLLECTION OF MR. M. JOYCE
HAMPSTEAD

Collection of Mr.M. Joyce
13 Well Road, Hampstead

Oct 27
1976

Case: 48cm x 35cm x 19cm deep + 1 drawer.
3 feet. Front slides up and out.
1 rider bar. Separate spirit level.
No side doors. Back slides up and out.

Drawer: Fitted to take s.g. pan and beam which fits, + arrest knob.

Pillar: 27cm from square base to split agate plane.

Beam: ÷ on both sides, though only one rider bar and rider holder. 30 cm. K to K + flag. End knives steel and adjustable. Centre K sq.sec.therefore can be turned to clean edge. Very rusty.

Pointer: 19.5 cm.

Pans: On pt. wires 22.5. Pans 7cm. J's very traditional.

No pan bouncers, no numbers, no signature on case, etc. Does not level. Needs .1.

Manufacturer: Oertling.

Collection of Mr. M.Joyce
13 Well Road, Hampstead

Oct.27
1976

Case: Front and back slide up and both lock.
2 drawers under. Left one marked 35275.
Rider bar right across ÷ 0 - 10 each side.
2 spirit levels. Ivory pan bouncers.

Manufacturer: Signed L. Oertling London.

Pillar: 32cm 14068.

Beam: 16cm. Black frame drops leaving beam to swing. K are agate slivers set in brass.
Centre plane ÷
A Massive short beam. End K's rest on pins.

Pans: On stiff wires.

Collection of Mr. M. Joyce
13 Well Road, Hampstead

Oct.27
1976

OTHER BALANCES IN THIS COLLECTION.

1. Griffin & George

2. "Praecision."

3. George & Becker Birmingham & London. Beam NIVOC.

4. Oertling short beam
+ rider. Balances well. No. 12791.
Pan hangers rigid. Agate planes set
in sealing wax.

5. Griffin

6. L. Oertling Ltd.

7. Becker & Fils.

8. George & Becker

9. Stanton

10. W.A. Webb Ltd. London

MESSRS. OERTLING LTD
ST. MARY CRAY, KENT.

Oertling Ltd. St Mary Cray — May 27
Mr. Hough's Office — 1977

Case: 46cm x 48cm x 32cm. deep. Key hole in top. Case mahogany. Front slides up. Counter balanced. Glass over pale green floor. 2 riders.

Drawers: Left 21023 Right 6295 5/3/97 L.F. Teale (?)
32385 Ruswith (?)
December 5 1903.

Manufacturer: L.Oertling London A.12 S.B.A.

Pillar: Twins 22cm. Magnifying glass screwed over name. One base of pillar 6295.

Beam: ÷ 0 - 10 both sides. 20cm.
Level beam. Split centre agate plane.
Split centre K = agate set in brass.

J's: Pieces of agate. Silver pans.

Sealing wax, "best Bank of England" used to hold agate pre 1951.

Oertling Ltd. St. Mary Cary — May 27
Managing Director's Office — 1977

"The earliest known Oertling balance manufactured 1847".

Case: -

Drawer and cover 29cm x 4cm x 15½cm, fitted to take beam, pans and pillar, lined in blue.

Pillar: 17.5cm, cylindrical.

Arrestment: Press lever, which also lifts grad.scale.

Beam: 20.5 beam K to K. Steel knives and steel plane. Not notched. Steel ends to beam to take hooks.

Pans: Held by strings now, but s.g. pan has fine chain (Pt?)

See receipt.

Manufacturer: Signed on beam L. Oertling.

ROYAL SCOTTISH MUSEUM
EDINBURGH

Royal Scottish Museum, Edinburgh — Aug.1977
Acc. No. 1970L2

Manufacturer:	Robinson, 38 Devonshire St., Portland Place.
Case:	Removable cover 41cm x 32cm x 16cm deep. 2 side doors, flag, 2 levels. Rider present on one side only. Need not be original.
Drawer:	Divided but no hole for s.g. pan. Label - "wire for 1/1000 gramme wts." No marks on wts. box.
Pillar:	25.5cm to plane. Wollaston type arrester. s.g. bob. Plane in agate slab on brass, removable to remove beam.
Beam:	26cm or 10½" K to K. Steel K's.
Arrestment:	Press lever down to the right. This drops beam resters which extend 13cm each side, and are attached to pillar.
Pointer:	8.6 cm.
Pans:	5.5 diam., hangers about 21, recorded by Stock and subsequently.
J's:	Pressing screws. J's are centered by two V's in ends of resters.
Sensitivity:	.005 = 2 ÷ of the scale.

Royal Scottish Museum, Edinburgh Aug.1977
Acc. No. 1968/25

Adie & Sons Edinburgh
/M.P.I. to the Queen, 50 Princes St/

Case: Everything slides up and out.
A magnifier is set into front glass.
2 levels.
Wollaston arresters reduced to ½, therefore less manoeuverable.

Drawer: Divided and contains label with address.

Beam: 25.5cm. No. c of g. lost. No flag. Steel K's. Plane agate on brass.
One s.g. pan.

J's: J.

Arrestment: Mechanism differs somewhat from Robinson q.v.

Sensitivity: Needs .005 to level and somewhat stiff.

Royal Scottish Museum, Edinburgh Aug.1977
Acc. No. 1902/53/3

De Grave London

Drawer: Contains glass bucket, bob, etc., etc.

Pillar: Flat sectioned, slide mechanism, on tripod which stands on box top, (similar to Physics one at S. Mus. q.v. 1917/99).
Stand labelled.
32cm to the pin.

Beam: Steel, 19.5 K to K, box ends.

Pointer: 7cm.

Pan: 7.5cm. strings 17.5. 3 pans, one for s.g.

Receipt extant to Mr. Bethune London July 8 1843 from M. De G & Son, successors, etc. ... £5.15.0.

Royal Scottish Museum, Edinburgh Aug.1977
~~Cat~~/Acc. No. 1928/187

No signature.

Case: 39cm x 36cm x 12.5cm. inc. drawer.
2 riders and ÷ 1 - 9 both sides.
2 adjustable feet and one prong.
Front and back both remove.

Drawer: Nicely fitted. 32cm x 11cm x 4cm deep.
No markings.

Pillar: Cylindrical 22cm to plane. Plumb bob c. of g.

Beam: 27.5. cm. Steel. split centre plane.
Beam removable only if pointer is removed and beam dropped.

Pointer: 16cm.

Pans: Brass, 5.8 on cotton from steel hooks 20.5. No pan bouncers.

Contents: Spare pan A1 (?) on link chain.
Spare set of A1. wts. Tweezers.

Sensitivity: Levels with .025 on left. Turns with .005 right across the scale, plus the rider.

Royal Scottish Museum, Edinburgh Aug.1977
~~Cat~~/Acc. No.

Oertling. One short beam A1. pillar balance No.15747.

Royal Scottish Museum, Edinburgh Aug.1977
Acc. No. -

The Johnson Matthey Oertling.

Case: 45.5cm x 47cm inc. 2 drawers x 23cm deep. Label says "The First Assay Balance made by Mr. L. Oertling 1851 and used by Mr. B. Staples for about 14 years afterwards". 3 adjustable feet. Spirit levels under the green glass with the green paint rubbed away just enough. Two riders ÷ 1 - 9 on the front and 1 - 4½ on the back. Front counterbalanced with weights. Top of case now lifts off, but was pegged and glue has dried.

Drawers: Left drawer under 21507 28998 Drawers 24cm x 19cm x 6cm deep with locks and ivory pulls.

Pillar: Cylindrical 18.5. cm.

Beam: 20.5 or 8" plus flag.

Arrestment: Lifts ivory bouncer and arms (arm rests 10cm each side) to lift beam. Centre plane ÷ agate.

Pointer: 11.7cm, slides through hole over scale ÷ 5 - 0 - 5 + 1111 divisions.

Manufacturer: L. Oertling London in fancy script.

J's: Split agate.

Pans: Silver on non.mag. hangers (later?) c.18cm.

Royal Scottish Museum Edinburgh — Aug. 1977
Acc. No.
Gallery 17

"The Lord High Chancellor Patent
James Murdoch Napier
Invenit et fecit. A.D. 1884"

Case: Top section only, in inches. 74 x 31½ deep x approx. 60 high plus plinth 34½" length.

Crane gear behind guillotine.

Beam: Length approx. 54".

Royal Scottish Museum, Edinburgh — Aug.1977
Acc. No.

Oertling in Berlin 1487 on top face of brass holder of graticule.

Case: 52cm x 36cm x 14cm deep.
Front and back both slide up and out.
Front has 18 rachets.
An extra piece of case is built into the lefthand end, 8cm x 23cm x 10cm. This unhooks and hinges back. Rt end has opening door. Rider mechanism present on the rt, but beam ÷ 1 - 10 in inches on both ½'s of beam.

Pillar: Cylindrical. 26.5cm to whole agate plane.
Plumb bob.

Beam: Steel K's. 42cm K to K. Centre K ▽ whole.
2 c of g and flag above.

Pointer: 15cm.

Arrestment: Works by pressing. A very simple mechanism underneath of tyre levers, brass. Seesaw effect for pan bouncers.

Pans: Almost certainly new. Do not quite fit.
Agate V's. inverted to form top of J's.

Sensitivity: .001.

Royal Scottish Museum, Edinburgh Aug.1977
Acc. No.

Ladd & Oertling London on pillar. Assay.
L. Oertling London on beam.

Case: 46cm x 46cm x 23cm deep inc. 2 sticking out drawers. 2 riders.

Drawers: Rt. Key and spare counter pose for case front.
Left is covered in repair numbers.

"

4357		8/06
13228		9/09
14927		
18825		Make as new
21914	May 98	New beam centre
25055		Red horn pieces.
27065		
29166		
32931		

Further repairs very doubtful /better/ showpiece."

Pillar: Single, 18.5 centre plane split red 'horn'? c of g. No flag.

Beam: 8" or 20.3cm.

K's: Red horn? in brass.

Pans: Hangers 15cm.

Sensitivity: .001 plus rider.

Royal Scottish Museum, Edinburgh Aug.1977
~~Cat~~/Acc. No.

Semi micro Oertling. Twin pillar. Very small.
No drawers. Marble floor. 40237.

ASSAY OFFICE
QUEEN ST., EDINBURGH

Assay Office, Queen Street, Edinburgh. Aug. 1977
Board Room.
Moved here in 1921 from S.Bridge St., formerly St. Giles Sq.

Case: Mahogany? Oak? 42.5cm x 55cm x 30cm deep, including drawers.

Drawer: Pull missing. No marks.
Contents:- Tweezers Fe, spoon Cu., box of assorted weights.
Under box a faded label
2 Sov wts 1842
1 x ½ .. .. Assorted grain weights.

Beam: Standard swan 26.5cm.

Pointer: 10.5cm.

Arrestment: Pull attached to well used sleeping dog wt goes up to roof of case and raises beam through crude square tube in a tube.
Probably all much later than the early beam.

Pans: Now held by stirrups, but holes for strings survive.

Sensitivity: Turns with .005.

Carved on floor D.S.C.
(Cardwell? Many of this family worked there)

Assay Office, Queen Street, Edinburgh Aug.1977
Basement Lab.

W. & T. Avery Ltd. Brum on pillar base.

Case: Mahogany. 46cm x 48cm x 24cm inc. 2 drawers. No rider. No. c of g. 2 spirit levels. Counterbalanced.

Drawers: Left, cut for mechanism, with parts for Stanton, a box of gold assay wts Oertling and key and spare lens, and carat wts in box wood case.

Pillar: 20cm to split centre agate plane. Reading lens. Single pillar.

Arm Rests: 10cm either side of centre.

Beam: 20.5cm stamped W. & T. Avery Ltd. Makers Brum. Flag.

Pointer: 11.5. cm.
K's ∓ agate slivers with pressing screws.

Sensitivity: .005 +

36433 B.O.T. No. 4356. CERT. NO. 1291 1931.

ANALYTICAL CHEMISTRY DEPT., ROYAL SCHOOL OF MINES
IMPERIAL COLLEGE, LONDON

Balance Room, Research Lab. Analytical Chem. Dept. R.S.M. — June14 1978

L. Oertling Ltd. London E.C. on beam. Met.Lab. 93 on pillar.

"Oertling 1 Kg" but no signature on pillar.

Case: 68.8cm x 57cm x 29cm deep. incl. drawers that also protrude. On 4 adjustable feet in rubber. Beam ÷ 1 - 9½ each side. 2 spirit levels. Rider bar.

Drawers: Left. 1 x 200g. wt, 2 metal dishes. Ivory pulls.

Under. 9/90	9/95. Opposite corner
	8887
	13546
	16264b
Right.8887	19867d
13546	42545
	44002

2 fronts slide up and out. Only one at back on left, said to be able to accommodate bullion bars.
Centre panel fixed front and back.
Lockable.
No numbers apparent on cylindrical pillar,
Extra brace at back of pillar and plinth.

Pillar: Approx. 37 cm. to K.

Beam: Approx. 41 (or 16") K to K.

J's: Whole agate and centre plane.
Large c of g and 2 adjust. screws at centre.

Dr. Pantony's Office, R.S.M. June 14 1978

Platner type balance "Kit balance".

No case. Base board. light colour. 28.2cm x 15.3cm. 2 adjustable feet and 1 spike. No inscription. Piece of metal sticks out in front with no apparent use, unless to jamb the wound 'pull' lever to which rust coloured thread is attached.

Pillar: 23cm has alittle camel hair brush attached to base pointing upwards and adjustable as a c of g blob steadier. Suspension of beam was originally adjustable for heigh but now set solid. String enables beam to be lifted, passing over top and bottom pulleys. All non-ferrous. Suspension piece and massive c of g blob hang from universal joint below piece of metal pulled by thread.

Beam: 19cm brass plus steel pointer 8.2 and steel K. Boxed ends. Centre K sits in agate split and concave planes. Ivory scale. This section 15cm. Steel pins through beam become notched steel K's tiny.

Pans: Brass on original threads on steel hooks 3.2cm. 14.5 string inc. hooks. Left pan has been reknotted higher therefore lighter and does not level quite.

Sensitivity: Will level with .005 and .005 will take needle across scale.

Stamped Met. Lab 179.

ASSAY OFFICE
NEWHALL ST., BIRMINGHAM

Assay Office, Newhall St., Birmingham — July 19 1979

Case: 34cm x 34cm x 21cm. Labelled Birmingham Assay Office 1 on ivory.

Manufacturer: 12 s b a of unusual pattern L. Oertling London. 2 drawers, riders, 2 magnifiers, 2 levels and box wts. Counter balanced front. Glass floor over green. Rider ÷ 1 ⊢ 10 and sub ÷ . 3 feet adjustable.

Drawers: Left. 19003 JW 12/3/94
Right. Key and space for knob.

Pillar: Single. No. 4245. 15cm. to K.
Split agate plane.

Beam: c 24cm, level, including end pointers. Centre K agate in brass.

J's: Agate pieces on 2 brass pins for plane. Hangers. 12cm pans minute, 1cm. Ivory bouncers with agate centres.

Arrestment: Turn knob.

Wts: 1000 - 10 (grains?) No. 10295 in ivory tray.

Used solely by assay master to check weights in use against standard set.
Will be retained by Birmingham.

Assay Office, Newhall St., Birmingham — July 19 1979

Case: 35cm x 44cm to floor inc. drawers x 19 not inc. jutting drawer. 3 feet.
1 very large magnifier over rider. 1 rider.
÷ all across top 1 - 10 both sides.
Counterbalanced front.

Drawers: Ivory pulls. Left. Fitted to take beam and sliding cover 31274 JW16/1/12.
Rt. Key. hole for knob. Partly fitted.
Also signed JW 16/1//19712.

Pillar: Twin. Typical 12 s b a. Signed L. Oertling London. About 18cm. to K. Centre plane 2 circular agates flat. 11553.

Beam: About 11cm. K - agate in brass. End K's as previous balance. Downwards pointer has magnifier for itself. Ivory bouncers. Black glass. Small Pans.

Sensitivity: .005 +, +.

Assay Office, Newhall St., Birmingham July 19 1979

Case: 36cm x 46cm to floor x 20cm not inc. drawers. Rider. Green under glass floor.

Drawers: Left. Minus ivory pull. 20119.
Right. space for knob. Key missing.
S.(?) B. 6.4.95.

Pillars: Twin. 2 riders. 2 levels. 19cm to K. 5086 Centre plane 0 of ag.

Beam: Sloping. Flag. 13cm to brass pins. K = ag. in brass.

J's: As before end planes are pieces of agate and drop through brass broken circle holder resting on ag in brass K. Holders are 2 brass pins.

Pans: Small 15½ hangers.
Manufacturer: Downwards pointer. L. Oertling London.

Very similar to the above. Ivory label on case Repaired and readjusted by S. Garcia. 780 Seven Sisters Road, N.15.

Case: 40cm x 50cm x 27cm.
2 drawers. 2 levels, 2 rider bars.
Sloping beams.

Drawers: Left. J.W. 27/10/94 19193 21718 28938 47408.
Right. Knob space and label Date of balance received after being repaired May 10/09 G.H. Chance.

Pillars: Twin. about 19cm.

Manufacturer: L. Oertling London.

Beam: About 14cm. Other details as above.

Assay Office, Newhall St., Birmingham July 19 1979

Wm. Ainsworth & Sons Denver Colo. U.S.A. on ivory label.

Case: 46cm x 52cm x 19cm not inc. drawers. Ivory pulls. 2 riders. 2 built in levels.

Drawers: Held shut by nails to prevent opening when case locked.

Pillar: Single. About 20 to K. Split ag. centre plane.

Beam: 16 cm. Level. K ag. in brass.

J's: Agate set in tarnished (Ni?) metal. End K ag. in brass. Out of level and scruffy.

Assay Office, Newhall St., Birmingham July 19 1979

Case: 40cm x 52cm x 28cm. 2 levels. Rider. Lockable.

Drawers: Rt. JW 2/7/92. No repair numbers.

Pillar: 30 brass. Single.

Beam: 20. Pan hangers 24. Flat pans about 9. cm. Rider bar separate.

Nice box of wts in ivory screw top box.

Manufacturer: L. Oertling London 4406

AVERY HISTORICAL MUSEUM, W. & T. AVERY LTD.
WARLEY, WEST MIDLANDS

Avery Museum — July 19 1979
Foundry Lane, Smethwick "01.02.17"

Double cone. Bought Nottingham 1944 for £6.00!

Case: 48cm x 40cm high x 20½cm deep. mahogany. Two V's small side doors. Front slides up and out. 2 levels.

Drawers: Left. Very nice and nearly complete set of weights set on their edges. Ivory pulls.
Right. ÷ to take some part of balances. Also a drawer at base of back for beam.

Beam: 32cm. End pointer. Centre K steel. Loops for J's like Fidler. Adjustable.

Pillar: 24cm. Turn knob raises pillar in pillar. 2 O of agate at centre.

Pointer: Holder for ivory scale attached to centre mechanism therefore goes up and down too.

Pans: (4cm. Stainless steel replacements on 22cm green thread)
Said to be by Troughton but no proof.
Railway arch centre to pillar top.

Sensitivity: Better than .005.

Avery Museum "Assay 1907" — July 19 1979

Case: 46cm x 53cm to base x 23cm not inc. 2 drawers. 2 levels. 1 rider.

Drawer: Left fitted and contains spare beam, etc. 27678.
Right. 15.7.07 BW

Pillar: Single 19cm. 9539.

Arrestment: Turn knob on top face of drawer.

Beam: Solid not lattice 20cm. Steel Centre K.

J's: Rest on pins. Upwards pointer. An old design for so late a date.

Manufacturer: L. Oertling London.

Avery Museum July 19 1979

Case:	42cm x 54cm x 27cm. Front slides up and out on ratchet.
Drawer:	1. Nicely fitted. No Markings.
Pillar:	Single. Agate centre.
Arrestment:	Pull heavy yoggy pot.
Beam:	25cm (10") Steel. Toasting fork ends. Steel centre K.
J's:	Rest on steel O (?). Arm rests formed from ornamental metal scrolls.
Pans:	Small
Sensitivity:	Just about .005.
Manufacturer:	De Grave Short & Fanner London

Also an old Avery's Boxed Beam. Could not see signature.

Upwards pointer over ivory. Case 39cm x 50cm x 26cm.

Beam 25cm. Pull string.

BRITISH MUSEUM (NATURAL HISTORY)
MINERALOGY DEPT.

British Museum (Natural History) Mineralogy Dept. 'No. 5' — Feb. 1980

Bought second hand 1859.
"Tubular beam by Thos. Jones 1775-1852 21 Oxendon St. Haymarket'pupil of late Mr Ramsdens' see R.T. Gunther ... p.187. with add. beam marked Thos Jones & Son 62 Charing X Road and marked direct in s.g. (See method described by A.F. Rogers. Science N.Y. 34 (1911) 59)"
"This method of indicating s.g. was probably in existence before 1911. The original balance might have been bought second hand from W.G. Lettson in 1859. Report 10th Dec. 1859. Photo in Mus. Studio 1970".

Case:	47cm x 44cm x 24cm deep inc. drawer. Drawer at back fitted to hold beam. 2 large spirit levels and stand for s.g. at rt.
Drawers:	As mentioned. Nice trade label for Oxendon St. and 2, 4cm pans. Strings 22cm repaired. Beam 37cm. No marks on drawer. 2 drawers 14cm x 21.8cm. Label indicates object renovated cleaned and lacquered 1972. Set of weights 1024, 512, 256, 128, 64 "8 grain wt. missing".
Case Cut:	Centre glass fixed. 2 doors + 2 side doors + small door top left, purpose? and top lifts. 4 adjustable feet. Brass plaque Brit.Mus.Nat. Hist. Min. Dept. 5.ER.
Pillar:	25cm approx. and 3.5 diam. Name on top section.
Beams:	One 37cm, pointer at rt. double cone. Centre steel K only sharp at centre of each ½ i.e. where it will ride on plane. Oxenden St. s.g. beam is strip of brass 36.5cm. Charing X. 2 cylindrical agate planes.
Arrestment:	Turn knob lifts agates on centre centre pillar.

British Museum (Natural History) Mineralogy Dept. "No.1" — Feb. 1980

Case:	59cm x 56cm x 30cm deep. inc. 2 drawers. 4 feet. Plaque. E.R. Brit. Mus. Nat. Hist. Min. Dept. No. 1. Top removable (?) and locking. Both front and back slide up counter-balanced. Purchased 1860 8th Feb for £20.00.
Manufacturer:	Signed L. Oertling London. Glass floor over green. Pan bouncers.
Drawers:	2. Under left one 24648. Ivory pulls. Rt. drawer blank.
Pillar:	No visible numbers.
Beam:	2 riders. Beam 36cm. Agate K and Planes throughout.
Pans:	Could be Pt? on pt chains. c.5cm diam. on agate J's. Excellent condition,

British Museum (Natural History) Feb.1980
Mineralogy Dept. "No.2"

Case:	Mahogany. 55cm x 48cm x 25cm. deep inc. 2 drawers. Lockable. Counter balanced front. Green floor.
Drawers:	Rt. drawer J.W. 10/1/87 + spare for arrest knob. Set of standard type. gramme wts. No. 7341. Left drawer 13463.
Manufacturer:	L. Oertling long beam purchased 23/2/1887. for £21.00.
Beam:	Removable if slid forward gently. Stamped S + 6. 36cm. K's agate slivers in brass onto agate plane. Beam ÷ both sides.
Pillar:	No. 1991 at base. 2 spirit levels, 2 riders. 30cm to K approx. s.g. knob and flag.
Pans:	L & R. 11cm x 4½cm on hangers 22cm. Pans badly corroded.
J's:	Egg cup and slot under J.
Pointer:	22cm over grad. scale.
Arrestment:	Turn knob turns cam. Lowers pan rests and beam rests. Still used for s.g. and weighing gem stones.

Set of carat wts. L. Oertling 12 Store St., Bedford Square 128, 64, 32, 16, 8, 4, 3, 2, 1, ½, ¼, ⅛, 1/16, 1/32, 1/64, 1/64.

Oertling microbalance Model No. 147. No. 43127.

N.W. MUSEUM OF SCIENCE AND INDUSTRY
MANCHESTER

N.W. Museum of Sc. & Ind. Manchester (Acc No. 1969.2.4. — Mar.26 1980

Case: 2 doors and fixed centre panel. Sides open and back slides up. Glazed. Hollow from front to back and wood much like the Seyss q.v. in appearance.

Drawers: 2 drawers under held shut with pins (original) dropped through holes inside locking case. Arrestment knob removable and hole centre covered with metal plate. Ivory pulls missing and only rt drwaer could be opened, cut to take pan arrestment. Odds and ends inside.

Beam: 33.5cm K to K of design very similar indeed to that in "The Laboratory" 1932 and one seen by Dr. A in Giessen. Rider mech. present one side. Beam ÷ both sides.

C of g. Brass beam. Bright steel K's. End K's set in Fe piece screwed on. 2 centre circular agate planes. Plumb bob.

J's: Cylinder of agate cut from underside.to form arches.

Pointer: Steel 21cm. ÷ ivory scale.

Pans: 8cm. pan hangers a la Oertling.

Pillar: Cylinder.

Signed: F.L.C. LIEBRICH in GIESSEN.

N.W. Mus. of Sc.and Ind. - Not accessioned Mar.26
Still at Joules House in Salford in 1971 1980

[J.B.] Dancer Manchester. Joule Collection 1818-1889.
Received it Feb. 1846.

A typical Robinson. No case and badly corroded but working just.
See Stocks excellent description, Anal.Chem. Vol.45 No. 12 Oct 73, p.979.

Pointer broken off at base and ivory scale missing.
Pt (?) links to pans badly damaged but could be put in order. Just like Edinburgh one.

Joule also had a German Silver rule from J.B. Dancer.

Joule Collection. 1969.5

Press lever balance, box and cover. Trade card Thomas Williams 71 Cannon St. (& No. 4 Abchurch Yd) London.
At one time used by J.P. Joule. Broken.

N.W. Museum of Sc. & Ind. Mar.26 1980

"c1910-13 presented by the Chem. Dept... used by H. Moseley."

L. Oertling London 9501.

Case:	Exceptionally large. approx. 50cm front to back with 2 large side doors. Front slides up and out, counterbalance stiff. 2 levels.
Drawers:	2, left one signed J.W. 20/6/6 and repair number 26932.
Pillar:	30cm with V struts.
Beam:	17cm K to K ÷ 0 - 10 both sides. Unusual design. See Mint. c of g. etc.
J's:	Labelled L & R. 9cm pans on ivory bouncers over green base and glass. Centre split agate.
Sensitivity:	High. Oertling service cards for 1954 in drawer.

N.W. Museum of Sc. & Ind. Mar.26
Cat/Acc. No.1972.18 1980

Minute balance by Oertling, presented by Courtaulds.

Case: Drawers under protrude to make work surface.
Case lockable.
Front lifts.

Drawers: Left & Right both signed JW 9/6/13.
Left one also fitted and large enough to take components of balance. Also drawer has a sliding top to shut it like a pencil box. Black glass floor.
2 riders.

Pillar: Twin. 11952. 8cm approx.
Additional fitment for ? microscope?

Beam: 11cm approx.

Pans: 1cm assay type.

Pointer: Upwards
Could have used lid of left drawer as placement for wts. All marked out in squares and numbered.

Manufacturer: L. Oertling London

N.W. Museum of Sc. & Ind. Acc. No. L.1971.9 — Mar.26 1980

"Davys Balance" lent by Dept. of Pharmacy of Univ. of Manchester. Via. Prof. Elworthy. Thought to have come from Chem. Dept., perhaps "Owens College Manchester Chemical Museum."

Case: A tramcar. On 4 adjustable feet, drawer under. Oval ends to accommodate pans. 53cm x 63cm ht. inc. feet and "roof" x 30cm deep. all approx.

Drawer: No markings. An unidentified object, length of brass about 12cm with knife afixed under.

Case ~~Out~~ cont.: Semi circular doors on ends open for pan and more important pan arrestment access. Drop front and spare section to fit over the top just as in Sc.Mus. photo.

Beam: 44cm approx. steel, solid, upwards prongs at ends.

Pointer: 24cm steel over graduated brass scale. c. of g. blob on pointer.

Pans: Brass but filthy. 14cm. on 35cm strings. Could be original being blue and brown twisted (silk?) cord.

Pillar: See photo. Elaborate brass perched (not fixed) on elaborate mahogany fretwork. Steel centre ♀ on steel.

Sensitivity: .5 at best, but probably quite good once.

Pan Arrestment: No beam arrest, but by using both hands to push down springs pan can be lowered and reading taken.

APPENDIX B

John Fields evidence to the Select Committee on the Royal Mint May 4th 1837

Jovis, 4° die Maii, 1837.

MEMBERS PRESENT.

Right Hon. Henry Labouchere.	Sir C. Lemon, Bart.
Mr. Clay.	Earl of Lincoln.
Mr. Herries.	Lord Lowther.
Mr. Hume.	Mr. Parker.
Sir Thomas Fremantle, Bart.	Mr. Baring Wall.

THE RIGHT HON. HENRY LABOUCHERE, ESQ., IN THE CHAIR.

Mr. *John Field*, called in; and Examined.

Mr. John Field. 4 May 1837.

977. *Chairman.*] WHAT situations do you hold in the Royal Mint?—The situations of weigher and teller, and stamper of weights.

978. How long have you filled those situations?—Twenty-two years the situation of weigher and teller, 16 years stamper of weights.

978 *. What are your duties?—To attend the summons of the warden, master and comptroller, and to have the duplicate weights in his possession compared with the standard weights at the office, at least once a year. Second, To adjust the duplicate weights by the said standard weights, that all weights for weighing gold and silver money may be regulated by the said duplicates. Third, To stamp the weights made use of in weighing the money, receiving a fee of one penny on every 12 weights stamped or marked, pursuant to Act 15 Geo. iii. cap. 30. Fourth, No other weights but those stamped by the stamper of weights to be accepted by law for determining the weight of the coins; and persons counterfeiting the stamps or altering weights so stamped, to be fined and imprisoned. Fifth, Not to interfere with the rights of the Founders' Company, if they have their weights sized and marked as above. Sixth, To receive the salary allowed to his office, from the warden or his deputy.

979. What is the salary attached to your offices?—As weigher and teller, 200*l.* per annum; and, on my appointment in 1815, the full understanding that as the salary was put upon the lowest possible scale, at the expiration of 10 years' service I was to receive an additional sum as shown in the scale established in 1815; but which has unintentionally been allowed to lapse. As stamper of weights I receive a salary of 120*l.*, which includes 20*l.* for an office; but this sum of 120*l.* was granted only in 1834, though appointed in 1821, and should then have been attached to the office of weigher and teller, which I will explain, as it refers to the question of fees and emoluments. In 1815 I received an allowance for the care of adjusting and examining the balances, &c., which arose from my having for some years applied myself to mechanics, as an amusement, and the Master of the Mint considered it would be a greater public advantage that the scales and weights should be adjusted and cleaned by some one attached to the department, rather than by a scale-maker out of the Mint, who might not be always at home to render the immediate assistance often necessary, and therefore requested me to undertake it, which I did, at the reduced charge of 10*s.* each importation and delivery of bullion and coin, instead of 18*s.*, the sum charged by the scale-maker; but during 1820 and 1821, owing to a coinage for private individuals;—it being necessary to see the beams and weights put to point between each importation and delivery, whether for one ingot or 100, the amount of my bill exceeded what the late comptroller considered necessary for the duty performed, as the newly-invented beams did not require quite so much attention and adjusting as the old ones, and therefore suggested to the Board that the charge for such examination should be proposed to the Master to be commuted, which was done in 1834, by nominally giving a salary of 120*l.* per annum to the office of stamper of weights, but which I believe is virtually considered as added to that of weigher and teller, for doing away the above charges.—In my office of stamper of weights, I am still entitled to receive a fee of 1*d.* per dozen from individuals bringing correct weights to be stamped, but this sum could never be expected to remunerate any one for his trouble; it could only have been ordered to have been paid by Act of Parliament when there was a regular salary paid to the officer holding the situation; my predecessor received 250*l.* per annum, and a

Mr. John Field.

4 May 1837.

gratuity of 25*l.* per annum, and 30*l.* for an office; but at that time the office was considered a sinecure, the Bank being restricted from cash payments, and after the then existing interest the salary was abolished; subsequently the Bank having resumed cash payments, necessarily a great demand arose for money weights, and the office being refused by other resident officers, was offered to me, which I accepted, with the hope that a salary might be obtained, as the office was now anything but a sinecure; but none was allowed for 13 years, when 120*l.* was given, being the sum now paid instead of the charge for care of adjusting and examining the beams, as before stated, and which therefore properly belongs to the weigher and teller for the loss of that emolument.

980. What is the annual amount of Fees which you have received for stamping money weights?—I cannot tell; it is very trifling, it is hardly worth a name.

981. Is it 10*l.* or 20*l.* a year?—No, it cannot be that.

982. Mr. *Hume.*] By what authority do you exercise the office of stamping weights?—By Act of Parliament; there was an Act of Parliament granted for it.

983. What Act?—The 15 Geo. 3, c. 30.

984. *Chairman.*] Have you a residence in the Mint?—Yes.

985. You have introduced several improvements in your department, will you have the goodness to state what they are?—The first was in the year 1818, a beam on a new principle, which, by actual experiment shows a saving of one-third of the time formerly required, and, by being more accurate, avoids disputes in the re-weighings, as they always agree with the original weight, which was never the case with the old beams, they always varied considerably, from five pennyweights to ten pennyweights in a draft.

986. What has been the effect of this improved balance?—A saving of considerable time, at least one-third, both to the public and to the Mint officers, and an actual saving of precious metal, by its accuracy, compared with the Bank scales, making an average difference of from one pennyweight to 25 in the draft; which with the difference partly of the Bank not weighing so close formerly as they do now, a large sum has accrued to the public; I allude to the double weighing, which I proposed in order that this surplus weight be brought to the public account, and which in six years gained 1,000*l.* to the advantage of the public, and is still going on.

987. Mr. *Hume.*] How does that surplus weight and profit arise?—The Bank when they purchase silver or bullion do not weigh so close as we do, and therefore I proposed re-weighing it, in order that the surplus might go to the public; it is an additional duty that I have no business to do, but I thought that it was such an advantage to the public that I ought to do it.

988. Does not the Bank send in the ingots according to the Paper delivered in by Mr. Bingley?—That is as regards the fineness, but this is with regard to the weight they bring in; now they weigh much closer than they did formerly; that is, for any weight under 10 pennyweights they made no charge, but now if it weighs five pennyweights they do.

989. Is it not your duty to give the full weight to the importer?—I give the weight according to the usage of the Mint, making a draft of about three pennyweights.

990. Then that draft above three pennyweights you have made as a profit to the Mint, not of the importer?—No, not of the importer, the Bank had no more for it, though they weighed five pennyweights, or from 5 to 25 pennyweights; but it went to the Mint, and thus by this second re-weighing it went to the public.

991. Mr. *Herries.*] In point of fact, the Bank received from the Mint credit for the weight at which they had purchased?—Yes.

992. So that the Bank lost nothing, though the public gained something?—Exactly.

993. Mr. *Hume.*] Do you make a report to the Board of that surplus regularly?—The board officers take it down.

994. What board officers?—The deputy-master or his clerk, the comptroller and the King's clerk take it down from my report.

995. Do you apply the surplusage to gold as well as silver?—No; the Bank brought the gold ingots and I weighed them, and they took it from my weight, which was very near to their own.

996. Then your observations apply to silver alone?—They do.

997. Mr. *Hume* (to Mr. *Barton.*)] Are you aware of that surplusage in weighing silver which Mr. Field has stated, and can you state whether a record

is kept of the quantity, and to what account it is brought?—Formerly, I think, there was a record kept, but at present we enter the full weight of the ingot in the journal at the time that the draft is made, but the difference is exhibited between the bill which is rendered from the Bank of England, which gives the purchase or Bank weight of the ingot and the Mint weight; we debit the Master of the Mint with the weight declared by the Mint weigher and teller, the gain by which, as Mr. Field states, owing to the Bank weighing much closer than they did formerly, amounts to very little in comparison with what it was then; it is recorded in that manner. It is involved in the difference between what we call the purchase standard of the ingot and the Mint standard; it is exhibited in that account.

998. Mr. *Herries.*] Then it appears in the account of the Master of the Mint?—Certainly; it does not appear as a distinct item, it is involved in the mass.

999. Mr. *Hume.*] Are the Board aware, by your report, of that surplusage for the public benefit?—The weigher and teller is bound to declare the actual weight of the ingot, and therefore there is no necessity for a record of the surplusage; if the Bank weigh with an imperfect balance, and sell by that scale—if their beam is so imperfect as to charge you one ounce less than the actual weight of the ingot, that is their affair, they are satisfied; they buy and sell by their own scale, but our scales being so much finer we gain that.

1000. If the Bank were to send in an account of 90 lbs. 10 oz., and there were only 89 lbs., would you take the Bank's account, or call upon them to correct it?—No, we should not take short weight.

1001. Are the Committee to understand that you take the advantage of surplusage, but refuse to make up the short weight?—Certainly, that is the case. I do not mean to say that we should take an extreme advantage, but it is the difference in the practice.

1002. To whatever amount it is, that has been the practice?—Certainly.

1003. You have stated in your written report that by the direction of the Board the importer is to have the full value as to fineness; is there any order of the Board directing them to have the full value as to the quantity?—None whatever; the case has never arisen. We are speaking of silver now, and since the King is the importer of silver he gets the full value, and importers of gold bullion get the actual value as well; therefore as gold bullion is weighed by a scale equally fine as the silver beam, the importer gets the full value.—The Bank have gained very considerably in gold, I believe, in this way.

1004. But not in silver?—Not in silver; the Bank, in weighing gold, never put in a less weight than 12 grains into the scale; but we weigh to two grains, therefore they frequently must gain.

1005. (To Mr. *Field.*) From what period was this improved balance introduced?—The year 1818.

1006. Then, before that time, was the same rule observed with regard to surplusage, or were you unable to discover any?—No, there was no notice taken of the surplusage, if any, the beams weighing so irregularly.

1007. Then the surplusage you speak of has taken place only since the introduction of your finer beam?—Exactly; 1820 was the first time it was noticed.

1008. *Chairman.*] Have you made any other improvements in machinery connected with your department?—When the money is brought into the pyx-room to be pyxed, the usual way used to be, to count, as the Bank does, so many sovereigns or pieces, instead of which I invented a box by which you can count them in the twentieth part of the time, and with only one assistant, and there used to be five or six counting, when small money was pyxed, but now we count in no time at all; you may say, we can do 100 journeys in the course of 20 minutes, and we could not do it formerly under an hour, or an hour and a half, and then there was frequently inaccuracy by miscounting, and were obliged to count it over again; now there can be nothing of the kind, for the machine separates the pound weight whatever coin it may be; they fall into small holes.

1009. Have you ever received any extra remuneration for those inventions?—None at all; neither for the beam or the counting machine, though I expended a great deal of money in both, and making a full sized model of the beam, and money to workmen to expedite its completion.

1010. Do your official duties require continual attendance at the office?—In ordinary times from ten o'clock to four o'clock in the afternoon, but during the

Mr. *John Field.*

4 May 1837.

pressure of business in the re-coinage it was from six o'clock in the morning till late in the evening, four or five or six or eight o'clock at night; and from the bad construction of the office, being exposed to a draft of air, caused me that lameness which I now experience from chronic rheumatism, which I have suffered from, for 15 years.

1011. Do you receive any additional remuneration for extra attendance?—No, none at all; for a little while we worked all Sunday; I remember the Bank was much pressed for coin.

1012. How long did your extra attendance at the period of the re-coinage last?—Nine months.

1013. Why were you employed to make and repair the assay balances and weights used at the Mint?—The person who used to do them died nearly at the time that I came into the establishment; his name was Coventry; not knowing to whom to apply, they requested me to undertake them, which duty has remained with me ever since, and is one requiring much skill and care, and consequent anxiety.

1014. Do you perform this duty yourself?—Myself.

1015. Do you do this at the Mint?—Yes.

1016. Have you a workshop or office of any description?—The office that I stamp the money weights in serves for that office.

1017. Have you any other duties besides those you have mentioned?—Yes, to weigh the copper, now coined in the Mint, which was not formerly done; it has been introduced since I have been in the Mint; it was never mentioned to me; the receiving copper in, and weighing it out in money, is an additional duty that was never proposed to me, and a very unpleasant service.

1018. Mr. *Hume.*] When was that introduced?—In 1822.

1019. *Chairman.*] Have you any clerk or assistant under you?—None.

1020. Are you allowed the assistance of any labourer?—One to attend the scales in the office, to raise the scale beams up and down, and to shift the weights.

1021. Are you allowed the assistance of any one in making and repairing the assay balances?—No, not any.

Mr. *John Buckham*, called in; and Examined.

Mr. *John Buckham.*

1022. *Chairman.*] WHAT situation do you hold in the Mint?—That of surveyor of meltings.

1023. How long have you held that situation?—I have only held that situation since the year 1832, but I have been in office in the Mint since the beginning of 1820.

1024. In what capacity were you before you held your present situation?—Second clerk and probationer melter.

1025. What is the amount of the salary attached to the office you now hold?—£. 200 a year; and I conceive myself entitled to the gratuities which Mr. Field mentioned, but which I have not received, from some misunderstanding.

1026. What gratuities do you mean?—For length of service; the salaries in our establishment were put upon the lowest scale by Mr. Wellesley Pole, with the understanding that after 10 years' service there should be a gradual increase in the pay allowed to the officers. That appears in the indenture of the Mint, which was drawn up in Mr. Wellesley Pole's time, now Lord Maryborough.

1027. Do you mean, that the plan suggested by Mr. Wellesley Pole when he was Master of the Mint, for the gradual increase of the salaries of persons connected with the Mint, was never sanctioned by the Treasury?—It was sanctioned by the Treasury, and it was carried into effect in two or three instances; but by some misunderstanding, and the interference of the Treasury, it was allowed to lapse; I cannot well explain it: the Treasury interfered, and some letters were written on the subject, from misapprehension of which letters the gratuities were withheld.

1028. Sir *T. Fremantle.*] Did you ever make a distinct application that your salary should be increased in conformity with the indenture?—Never.

1029. Mr. *Wall.*] Do you know in what year that correspondence was with the Treasury?—No, I do not; but some superior officer can state that.

1030. *Chairman.*] Have you a house?—I have apartments in which I reside; [illegible] but [illegible] other respect

APPENDIX C

Electroplating the Platinum metals.
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Electroplating the Platinum Metals

AN HISTORICAL REVIEW OF THE EARLY RESEARCHES

By Peta D. Buchanan
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The successful development of gold and silver plating in 1840 led to a number of scientists turning their attention to the electrodeposition of platinum and palladium, but before commercially satisfactory processes could be established they met with considerable difficulties because of the insolubility of the anodes and of the complex nature of the chemical compounds of these metals.

The introduction of gold and silver plating in the 1840s naturally prompted the study of the electroplating of platinum and palladium. It was at first assumed that platinum, having so many similar properties to those of gold, would be equally amenable to electrodeposition, but unfortunately its insolubility as an anode and the complex chemistry of its salts presented severe technical problems. These were nevertheless tackled with enthusiasm by a number of scientists in England, France, Germany and Russia and attempts to develop a reliable process continued throughout most of the nineteenth century until satisfactory standards of quality were achieved—a veritable triumph of hope over experience.



John Frederick Daniell
1790–1845

The very early attempts at electroplating were gravely handicapped by the lack of a satisfactory battery until Professor J. F. Daniell of King's College, London, devised his self-polarising cell which enabled thin but uniform coatings to be deposited. In this reproduction of an early Daguerrotype in the possession of the Royal Institution he is seen, on the left, demonstrating his new battery to Faraday, to whom he had described it in 1836 as "a voltaic combination which I trust you will think worthy of the name of the CONSTANT BATTERY"

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Interest in electroplating began in the late 1830s, but at this time a reliable source of continuous current was lacking: large and powerful voltaic piles were built in the early years of the century but these were quite unsuitable for an electroplating process which required a low voltage applied at a steady rate over a considerable period. Due to local action the voltaic cell rapidly declined in strength. These early researches, particularly on the electroplating of gold, have been reviewed by Hunt (1), who refers to the major steps forward taken in 1836 when Professor J. F. Daniell of King's College, London, described the first self-polarising cell or constant battery which enabled thin but uniform coatings to be deposited (2).

The Pioneer Work of Alfred Smee

It was one of Daniell's students in the chemistry department at King's College who took up the study of electroplating and who made a major contribution to the subject. Alfred Smee entered King's in 1834, gaining a silver medal for chemistry. Both his grandfather and his father had been employed at the Bank of England, the father becoming Chief Accountant in 1831 (3). At that time the Chief Accountant lived with his family in an official residence in the Bank, the necessary security confining them at home in the evening hours. On leaving college young Alfred therefore set up a laboratory in a room leading out of the family drawing room and next to the ledger office and here, working alone with elementary equipment, some lent by Daniell, he carried out a remarkable series of experiments in electrochemistry (4).

His first self-imposed task was to devise a battery more suitable for work in electrodeposition, and on February 28th, 1840 he was able to read a paper to the Royal Society, "On the Galvanic Properties of the Metallic Elementary Bodies with a description of a new Chemico-Mechanical Battery" (5). Shortly before this another type of battery had been introduced by W. R. Grove (6), and Smee considered this to be an improvement on the Daniell Cell, but in discussing those two he wrote:

> "I found that although the batteries of Daniell and Grove were admirably contrived instruments, yet it is very desirable to possess one that could be set in action at a moment's notice, and with comparatively little trouble. The platinised silver battery is peculiarly suitable for the operator, for when it is in action it completely talks to its possessor. If the current is very feeble a faint murmur is heard; if a moderate current is passing it hisses; but if a violent one it roars. At this present moment I have nineteen batteries at work in the same room where I am writing and they are each telling me the work they are performing" (7)

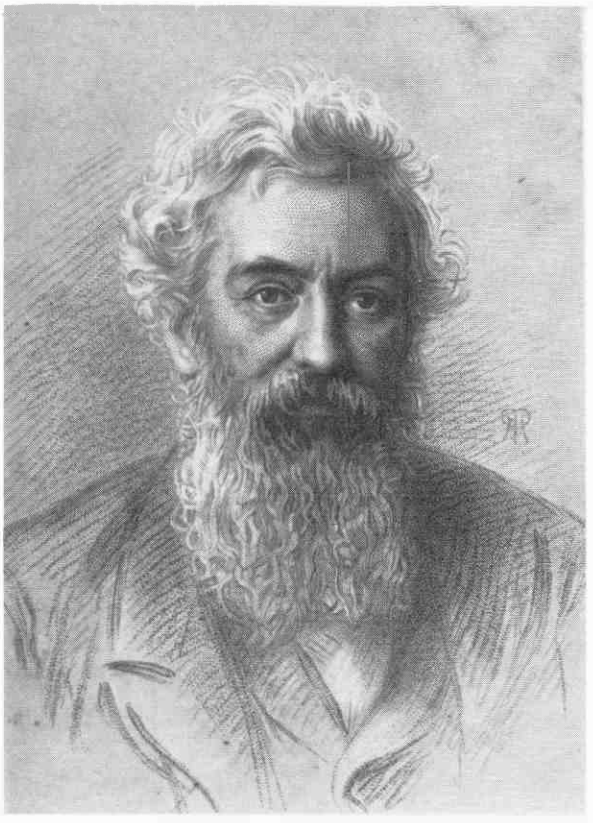
He had earlier, in a paper on the battery given to the Royal Society of Arts for which he was awarded their Gold Isis Medal, made something of a disclaimer:

> "I wish it to be clearly understood that it does not possess the absolute constancy of Daniell's, or the intensity of Grove's battery" (8)

An amusing aside on this point was made some years later by Clerk Maxwell, who was rather given to composing humorous verses, and who composed an "electric valentine" beginning:

> "Constant as Daniell, strong as Grove;
> Ebullient through all its depths like Smee;
> My heart pours forth its tide of love,
> And all its circuits close in thee." (9)

Smee's battery relied upon his observation that an electrode having a roughened surface caused the hydrogen formed during the reaction to disperse, preventing the build-up of a film of bubbles. His cathodes were either of silver etched with acid or of platinum abraded with sandpaper, both being placed in a cell containing "nitro-muriate of platinum" as the electrolyte. This produced a thin layer of platinum in the form of a black powder, yielding an electrode simply and cheaply and one unaffected by the strength of acid in any cell. Banks of cells could be employed varying "from the size of a tumbler to a 10 to 12 gallon vessel". Its success lay, however, in its simplicity, and it aroused great interest in the art of depositing one metal upon another.



Alfred Smee

1818–1877

Born in Camberwell, educated at St. Paul's School and King's College, London, and then trained as a surgeon at St. Bartholomew's Hospital, Smee carried out all his researches in electroplating in a room set aside for him in the Bank of England where his father lived as Chief Accountant. He was elected a fellow of the Royal Society in 1840, the year in which he published his "Elements of Electrometallurgy, or the Art of Working in Metals by the Galvanic Fluid", at the age of 22

By the end of 1840 Smee, still only 22 years old, had compiled and published a remarkable text book, "Elements of Electrometallurgy", a term he himself coined. Dedicated to the Prince Consort, who, with Queen Victoria, had been shown some of Smee's specimens of electroplating, the first edition was soon exhausted and a second and much larger edition was published in parts during the year 1842 while a third revised and enlarged edition appeared in 1851 following upon a French translation published in 1845.

In his first edition Smee described his processes for both platinum and palladium plating, writing that:

> "Hitherto the reduction of these metals, in any other state than that of the black powder, has been always considered impossible."

He claimed that processes for "platinating and palladiating" rested upon the authority of his book and went on:

"Platinating metals by the galvanic current is a new feature in science. The process is similar in all respects to gilding but is more difficult. The solution of the nitro-muriate of platinum must be very weak, and the battery must be charged with dilute acid. The object to be coated must be very smooth, and thoroughly cleansed by potash, before the process is commenced. Having proceeded thus far, and the solution of platinum being ready, a very fine platinum wire, in connection with the silver of the battery, must be placed so as to dip into the solution, but must not be immersed beyond a very short distance. The object to be platinated is now ready for connection with the zinc of the battery, after which is effected, it is to be dipped in the solution. Immediately, oxygen gas will be given off from the platinum wire, in connection with the silver. From the copper or other metal to be platinated, no gas will be evolved, provided too much electricity be not generated. In a few minutes the object will be coated with platinum. During the process, the object should be withdrawn from time to time, and rubbed over with a little whiting. The colour of the metal thus reduced is so similar to polished steel that it would be difficult to distinguish the one from the other. It

is needless to say that it has a beautiful appearance. It would be of great value as a coating for telescopes, microscopes, quadrants, and a hundred other articles which must be exposed to the action of the weather." (10)

For palladium plating Smee used a similar electrolyte, nitro-muriate of palladium with a palladium anode:

"This metal is whiter than platinum, but not so bright as silver. It might be used in the same cases, and with the same advantages as platinum; and we have, besides, twice the bulk of metal in the same weight." (10)

In the second edition of his work he proposed the addition of "sufficient soda" to neutralise the acidic platinum solution and of ammonia to the palladium electrolyte. He had to admit, however, that his specimens of platinum plating

"will not resist the action of nitric acid because there are generally some little fissures uncovered, some little crack which admitting the nitric acid tears off the platinum in thin scales."

Smee's reputation as an electrochemist was rapidly established. He was elected a fellow of the Royal Society in June 1841, while earlier in the same year a special post, somewhat honorary in its duties, was created for him in the Bank of England.

Surgeon to the Bank of England

This appointment was made largely upon the recommendation of Sir Astley Cooper, the distinguished surgeon, who was a friend of Sir John Rae Reid, the Governor, and who had sometimes visited Smee's laboratory to see his experiments. He considered that the Bank should "turn Smee's scientific genius to good account", and accordingly the young man was appointed Surgeon to the Bank of England on January 1st, 1841. (This forecast came to fruition a few years later when Smee devised a new method of printing bank notes by an electrotype process.)

Now Sir Astley Cooper had many years earlier married the sister of Thomas Cock who had worked on platinum with William Allen at Plough Court and who was in turn the brother-in-law of Percival Norton Johnson, with whom he was closely associated in the refining of platinum. There can be little doubt therefore



A sketch of Alfred Smee's laboratory made by his brother-in-law William Hutchinson and autographed by the sole occupant. It lay between the family drawing room and the ledger room of the Bank of England, and the occasional dropping of a ledger would be sufficient to ruin one of Smee's experiments by breaking the contact with his battery. This is taken from "Memoirs of Alfred Smee" written by his daughter Elizabeth Mary who had married William Odling, the distinguished chemist who had put forward a rudimentary Periodic System four years before Mendeleev and who had succeeded Faraday at the Royal Institution, later becoming Professor of Chemistry at Oxford



Sir Astley Paston Cooper

1768–1841

In the last year of his life the distinguished surgeon interested himself in the career of the young Alfred Smee, and it was upon his emphasising to the then Governor of the Bank of England that "you don't know what a treasure you have got in that young man" that Smee was given an appointment there as surgeon. Sir Astley was related by marriage to both Thomas Cock and Percival Norton Johnson and it is likely that Smee's interest in platinum and palladium was encouraged and supported by them

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that Smee's interest in platinum and palladium plating was encouraged by Johnson, who doubtless supplied the necessary metals and salts.

The French Controversy

The commercial development of gold and silver electroplating is closely associated with the name of George Richards Elkington of Birmingham and his cousin Henry. Perhaps because of their early success in this field they did not seriously embark on platinum plating. In 1837 Henry had filed a patent (11) for the immersion coating of sundry metals with platinum or palladium, using a solution of platinum and gold chlorides with excess of sodium and potassium bicarbonates. Later, in 1841, one of Elkington's assistants, Oglethorpe Wakelin Barratt, took a patent in parts of which he claimed a method of "precipitating platinum from its solutions as a covering to other metals" (12). His process is difficult to credit today, as it involved dissolving platinum in a boiling solution of sodium chloride, alum and cream of tartar. This was intended for immersion coating, but he claimed that

> "if a stronger coating be required, I attach the battery and an anode of metal platinum and continue the action until the desired thickness is obtained. Palladium may also be employed in like manner."

But it was the British Patent 8447, filed jointly by George and Henry Elkington in 1840 and mainly covering gold and silver plating from their cyanide solutions, that was to cause great controversy and litigation that spilled over into the area of platinum plating. Only a few days after the corresponding French patent had been published in December of the same year a specification was filed in the French patent office by Henri-Catherine-Camille Ruolz, otherwise known as the Comte de Ruolz-Montchal, while on the following June he filed an addition to his patent covering the use of the battery and "the employment, for the first time, of the compounds of cyanogen with gold and silver". A further patent of addition, published in January 1842, covered the platinum plating of iron, steel, copper, brass and silver (13). This claimed a solution of platinum chloride neutralised with sodium carbonate with the addition of potassium cyanide, the electrolyte to be operated at 80 to 90°C.

Ruolz was financially embarrassed and sold his patent rights to a Paris dyer, Guillaume-

Edouard Chappée, who filed a further addition to the same patent for the use of the double chloride of platinum and potassium, but Ruolz swiftly repurchased his rights on finding another interested party.

The great possibilities disclosed by Ruolz's main patent were quickly realised by Charles Christofle, the founder of a then small but enterprising firm of goldsmiths and silversmiths in Paris that still bears his name, and he immediately secured an exclusive license from Ruolz for gold and silver plating, retaining the inventor as a consultant. Only a few months later a further addition to the Ruolz patent was filed in the name of Christofle claiming the addition of potassium iodide to the electrolyte. Still further additions followed, including one for palladium plating from a cyanide solution.

In the meantime the Académie des Sciences had appointed a commission to examine the methods proposed by Ruolz and by the Elkingtons. This comprised the distinguished scientists Thenard, d'Arcet, Pelouze, Pelletier and Dumas, who managed to complete their long report rather hastily by the December of 1841 (14). In this they tended to prefer the technique of their countryman Ruolz, although they later awarded a prize of 6,000 francs to each party for the new methods of gold and silver plating. In a section on platinum plating they reported on the extremely slow rate of deposition from a cyanide solution compared with Ruolz's double chloride bath, with which "the deposition of platinum goes with at least the same rapidity as that of gold and silver".

They went on rather fulsomely to extol the potential benefits to science and industry of platinum plating in the areas of chemical and pharmaceutical apparatus, watch and clock making and armaments.

Christofle now secured a license from the Elkingtons for gold and silver plating, relying upon his license from Ruolz covering the plating of platinum and palladium. He entertained great hopes of making a commercial success with these metals, but was never able so to do, although he became the leading gold and silver plater in France.



Charles Christofle
1805–1863

Founder of the well known Paris firm of goldsmiths, silversmiths and cutlery manufacturers that still bears his name, Christofle foresaw a use for the electroplating of platinum but had to engage in extensive litigation to secure his rights and to undergo an examination by a committee of the Académie des Sciences

From a portrait in the possession of L'Orfeverie Christofle, Paris

Leeson's Voluminous Patent

Smee's electrolyte was only one of a number put forward during the course of the next twenty years or so, and his remark that platinum plating was "similar to gilding but more difficult" proved to be well founded.

In 1842 Dr. Henry Beaumont Leeson filed a voluminous patent, "Improvements in the Art of Depositing and Manufacturing Metals and Metal Articles by Electro-Galvanic Agency, and in the Apparatus Connected Therewith". This ran to 28 pages and 12 diagrams and included the idea of agitating either the articles to be plated or the plating solution in order to obtain smooth deposits at higher current densities (15). Leeson was an assistant lecturer in chemistry and forensic medicine at St. Thomas's Hospital in London, later becoming a senior physician and dean, but he evidently gave a great deal of his time to his studies in electroplating. His patent, very soon acquired by the Elkingtons, claimed processes for depositing a whole range of metals and alloys including not only platinum and palladium but also rhodium and iridium! In all there were some 430 possible electrolytes listed, and it is not surprising that W. R. Grove in a critical opinion of the patent in 1844 stated that it "contained so many alleged inventions that it would be dangerous to rest a case on it, and that while many of Leeson's statements were such that chemists might know and discover by experiment, they were not such as a competent workman could apply without many unsuccessful trials." (16)

Leeson did, however, realise the cause of Smee's difficulties:

> "The solution must be supplied with a fresh portion of the metal by adding to or placing within such solution or electrolytic fluid a further supply of some suitable salt to be dissolved or taken up from time to time as the fluid becomes exhausted."

Activities in Germany

Contemporarily with Smee, the possibility of electroplating with platinum had been studied by Rudolph Christian Böttger who had studied under Professor Schweigger at Halle and who for many years taught physics and chemistry at Frankfurt. In 1840 he described the production of electroformed copper plates in relief which were then gilded and platinum plated from the double chloride of platinum and sodium, but his process was not commercially viable (17). Three years later he reported that he had worked at some length with the alkaline solution of potassium chloroplatinate proposed by Ruolz but without success (18). He did however succeed in producing bright deposits on copper and brass from a solution of ammonium chloroplatinate to which a few drops of ammonia had been added.

Similarly good results were obtained by Professor Hermann von Fehling of Stuttgart (19).

Some further work was carried out in Germany a few years later by Joseph Konrad Bromeis of the University of Marburg. Later still, however, in his text book on chemistry published in 1854, he admitted that:

> "The platinum deposit obtained on other metals by this method is not sufficiently thick to protect the underlying metal from oxidation or from attack by acids. This can only be achieved by platinum cladding, just as with the rolling of silver onto copper." (21)

George Howell and Thomas Henry

Returning to the development of electroplating in England in the mid-nineteenth century, we find a patent filed by George Howell of London in 1846 (22).

This contains the first reference to a solution that became known as the stabilised platinum electrolyte, made by dissolving platinum chloride in caustic soda and adding oxalic, citric, tartaric or acetic acid followed by caustic potash.

The Great Exhibition of 1851, promoted by the Prince Consort and held in Hyde Park, proved against all forecasts to be a magnificent centre for the display of manufactured goods of all types and included elaborately designed and gold plated items. Among the exhibits of scientific instruments was a balance made by

Ludwig Oertling, the founder of the firm of precision balance makers that still bears his name, "having a beam three feet in length coated with platinum ... and another sixteen inches long coated with palladium".

The report of the Juries, who awarded Oertling a Council Medal, adds in a footnote:

> "These beams were coated by T. H. Henry Esq., F.R.S., by a peculiar process in which the electric current was employed in depositing these metals. It would seem from this successful application that the same process is applicable to graduated instruments." (23)

The Henry referred to remains a rather shadowy figure, and it is not known by what process or electrolyte he succeeded in plating these balance beams. Thomas Hetherington Henry was for many years from 1837 employed as a chemist in the brewery of Truman Hanbury and Buxton in Spitalfields, London (24). He was among the founder members of the Chemical Society in 1841 (as were Daniell, Grove, Leeson and Johnson as well as Thomas Cock's son William, then Johnson's partner) and had succeeded Robert Warington, the moving spirit in its foundation, at the brewery. He was elected F.R.S. in 1846, and later established himself as a consulting analytical chemist in Lincoln's Inn Fields. Among his clients was the famous John Percy, Professor of Metallurgy at the Royal School of Mines, who described Henry as:

> "certainly one of the most careful, accurate and trustworthy analysts whom I have ever known". (25)

It is to Percy that we owe the only surviving example of Henry's plating technique, now preserved in The Percy Collection of specimens in the Science Museum. It is merely a thin sheet of copper plated on both sides with palladium and accompanied by a note from Percy stating that he was given it by the late T. H. Henry before the year 1855.

Despite the success of the exhibit at the Great Exhibition and the abundant publicity for platinum and palladium that accrued, by 1860 Oertling catalogues no longer offered beams plated with those metals, nor have any surviving examples been found in a long search. It is possible that the deposits did not withstand constant use and that any beams so treated were returned for the normal re-gilding.

The Roseleur Electrolyte

Once described as one of the landmarks in the history of platinum plating (26), a new formulation was proposed in 1850 by Alfred Roseleur, a chemical manufacturer in Paris who had been active in gold and silver plating for some years, and his colleague Lanaux (27). This was made up as follows:

> "We dissolve 750 grams sodium phosphate and 400 grams sodium pyrophosphate in 15 litres of water and filter. We also take 15 grams of platinum chloride, as free as possible from acid, dissolve it in 200 grams distilled water and precipitate the platinum as double salt by adding 160 grams ammonium phosphate. The precipitate together with the supernatant liquid is mixed with the first mentioned solution and the mixture boiled for four hours. Ammonia escapes and the bath, previously alkaline, becomes strongly acid; the liquid loses its yellow colour and can now be used successfully for platinum plating, also for thick deposits."

A platinum anode was used, and the strength of the bath was maintained by additions of platinum chloride.

This phosphate bath, with or without some modification, was used for very many years. It furnished thicker deposits than had previously been obtainable, and some years before the date of his patent—which Roseleur offered openly without royalties—he is said to have presented King Louis Philippe with a ewer and a basin on which he had deposited some 400 grams of platinum.

One measure of its success is found in the correspondence of George Matthey, in which there survive two letters from him to the Birmingham firm of J. and C. Ratcliff, brass founders and lamp and lantern manufacturers who had taken a license under the Elkington patents for gold and silver plating. Dated 1865, these letters urge upon Ratcliffs the merits of platinum plating on gunmetal screws and on brass components in general (28).

A Roseleur electrolyte modified by the addition of common salt and borax was patented in 1886 by William Arthur Thoms of London (29), the founder of the Bright Platinum Plating Company. Thoms claimed in his patent that he obtained a deposit that was so bright that it required no subsequent polishing, but his business was not long lasting and was wound up in 1890.

Interest in America

By this time interest in platinum and palladium plating had developed in the United States and in 1883 Dr. William H. Wahl of Philadelphia, for many years the secretary and editor of the Franklin Institute, published an important text-book, "Galvanoplastic Manipulations" (30). In his chapter on "Platinising" he dealt first with Roseleur's procedure and with the method developed by Professor Böttger and then described an electrolyte advocated by Jewreinoff back in 1853 (31). (Peter von Jewreinoff was a colonel in the Russian Mining Engineers and director of the chemical laboratories of the Mining Department in St. Petersburg, but his platinum bath was virtually that of Howell's of 1846.) On palladium plating he referred to an electrolyte proposed by A. Bertrand in 1876 consisting of neutral ammonium chloropalladate (32). He also referred to a process for electroplating iridium just developed by Dr. W. L. Dudley of Cincinnati but declined to publish the details pending patents being filed.

In a paper read to the Franklin Institute in 1890 (33) Wahl reviewed the whole problem of platinum plating, saying that while each of the earlier baths would yield satisfactory results for a time

> "the peculiar difficulties met with in the practice of platinum plating render it impossible to maintain the chemical integrity of those electrolytes and in consequence thereof they soon become inefficient or inoperative by reason of contamination with the secondary products formed therein."

Wahl therefore experimented with anodes consisting of porous carbon impregnated with platinum to provide a means of dissolution in acidic electrolytes, but his deposits were black and non-adherent. He then turned to alkaline baths containing oxalic acid such as those patented by Howell, of whom he appeared to have no knowledge. He was, however, the first to employ an electrolyte free from chloride and to use "platinic hydrate" to maintain the metal content of his bath, so avoiding the build-up of undesirable compounds.

Twentieth Century Electrolytes

The electrolytes described so far seem to have been found reasonably adequate for the needs of the late nineteenth and early twentieth centuries. The Roseleur and Wahl types of bath were, however, deficient in several respects, low cathode efficiency and short life among them, but not until around 1930 were more satisfactory electrolytes developed. A process developed by W. Keitel and H. E. Zschiegner of the Baker Platinum Company (34) employing diammino dinitro-platinum, colloquially known as Platinum P salt, and free from the build-up of unwanted salts, was the starting point for a number of researchers in the next few years seeking superior electrolytes capable of giving bright adherent deposits in reasonable time. It was quickly followed by the hexa-hydroxy platinate bath of A. R. Powell and A. W. Scott of Johnson Matthey (35). Similar formulations were put forward at the same time for palladium plating and were described by Atkinson and Raper in 1933 (36).

The Advent of Rhodium Plating

At this time it appeared that there might well be a substantial increase in the usefulness of platinum plating, but somewhat unexpectedly a third member of the group now appeared, offering greater hardness, higher reflectivity, greater resistance to wear and reasonable ease of deposition. This was, of course rhodium which, despite the difficulty of getting it into solution—it is insoluble even in aqua regia—began to find applications in the jewellery industry but became of great importance in the

electronic equipment developed so intensively in World War II.

The first description of rhodium plating was given by Professor Colin G. Fink and G. C. Lambros of Columbia University in 1933 (37). They obtained satisfactory deposits from both sulphate and phosphate baths and these, or modifications thereof, have largely remained in use up to the present.

The more recent history of the electrodeposition of the platinum metals has been well reviewed by E. H. Laister (38) and in greater detail by F. H. Reid (39). The emphasis has shifted markedly from decorative to industrial uses more reminiscent of the ideas of the early workers who foresaw the principal applications in the coating of instruments and, as is well known to readers of this journal, each of these three metals finds a place in modern electronic engineering, while a fourth member of the group, ruthenium, is more recently showing signs of receiving more consideration in the same field.

By the very nature of these applications these electrodeposits generally remain hidden from view inside the components whose performance they enhance—unseen, and in a satisfactory electronic device quite unheard. All of which would have considerably astonished and mystified the pioneers of electrodeposition, Daniell, Leeson and Henry, but probably most of all the young Alfred Smee working away with his nineteen batteries murmuring to him in his small laboratory in the Bank of England.

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