A Short History of Weighing

"Pondere, mesurâ et numero Deus omnia fecit."

(By weight, measure and number God made all things)

John Quincy, 1720

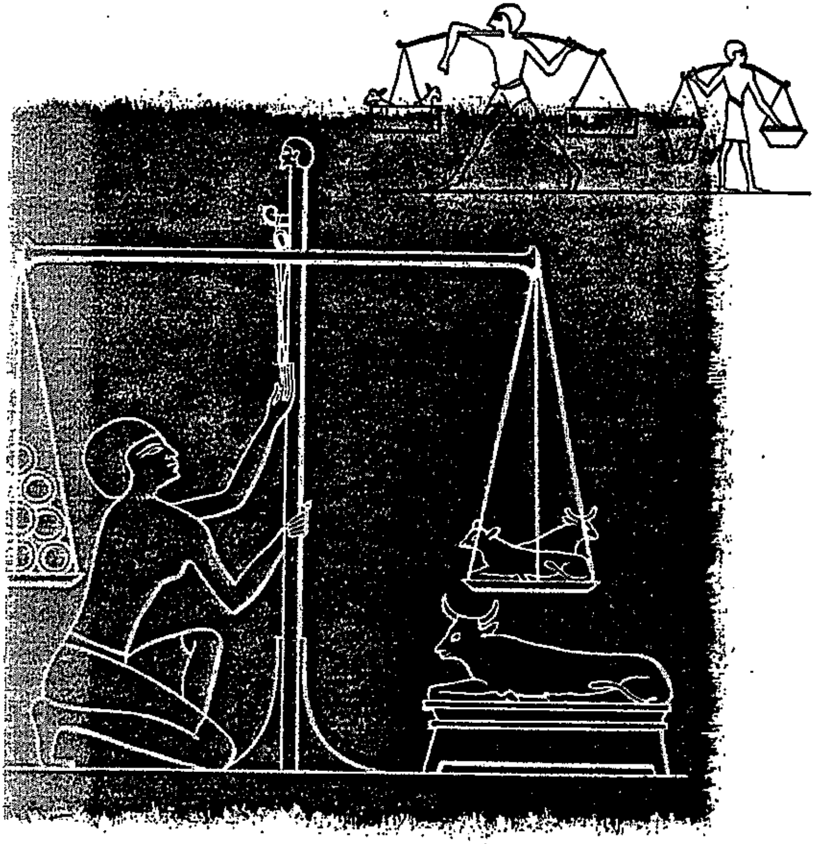
"A Woman Weighing Gold"

The beautiful little picture, illustrated on the cover, of which there is a colour print in the Avery Historical Museum, was painted by Jan Vermeer (1632—1675).

The picture is an authentic record of the method of weighing coins, gold and jewellery on the small scales made specially for the purpose.

A Short History of Weighing

By L. SANDERS



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Completely Revised 1960

Preface

In publishing this very brief history, W. & T. Avery, Ltd., hope to stimulate an interest in that very essential industry in which they have been occupied for a considerable time.

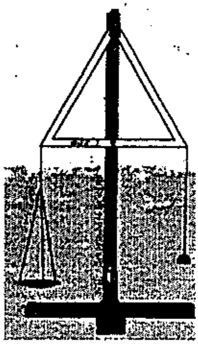
Most trades and industries depend upon weighing at some stage of manufacture or distribution; without weighing equipment modern commerce would break down completely.

The story covers a period of 6,000 years and is a very brief survey of outstanding developments. It is not intended as a text book for the expert.

Controversial subjects relating to the earlier periods, over which expert archaeologists prefer to disagree, have been avoided as much as possible without breaking the continuity of the record. Only a few of the more important developments of the early part of the twentieth century have been described in order to indicate the general trend. Since the publication of the first edition of this booklet the advent of the new Industrial Revolution, with the development of electronics and automation, has sponsored a complete new phase in weighing techniques.

The modern weighing machine is playing a key part in the automatic control of industrial processes.

The material in the text is taken from authentic records in the Avery Historical Museum.



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"JUSTICE."

From the painting by
SIR JOSHUA REYNOLDS (1723-1792).

The original is in New College, Oxford, of which Sir Joshua was an honorary Doctor of Laws.

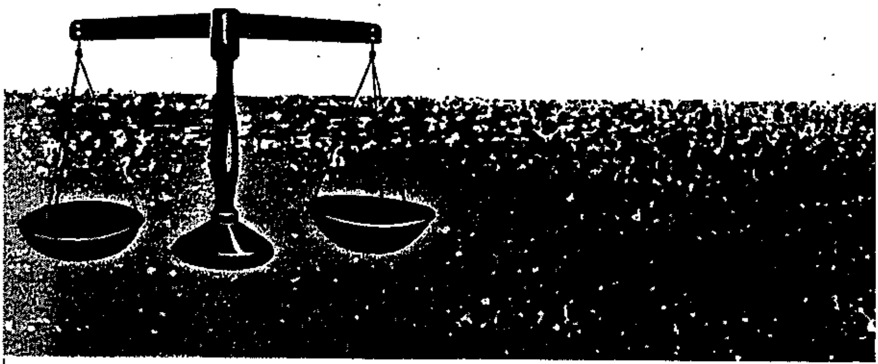
In obedience to the obsession of the day for classical themes the artist used a steelyard instead of an equal-armed beam as the symbol.

Plate 1.

The Balance

In the dim dawn of Egypt's golden day
An unremembered genius shaped the beam,
And poised the trembling scales, and did not deem
His new-made balance other than a way
To serve an end, and in the mart display
Above the clamorous tongues a judge supreme,
Yet gloried in his child 'till eve serene,
When weary in his reed-built hut he lay:
Nor dreamed his balance in Osiris' hall
Against eternal standards weighing men:
Nor saw young Science take his beam, and then
Wax great, her shining aegis shielding all:
Nor caught the seer's vision mystical:
A Balance poised 'midst Chaos come again.

W. A. BENTON, 1927.
First Curator of the Avery
Historical Museum, 1927-1942.



The Origin of Weighing and Measuring

While man was emerging from the pre-civilised state of self-sufficiency as a hunter for food and clothing and builder of his own rude shelter, he began to specialise in elemental crafts such as making of tools and weapons for the chase, growing crops, domesticating animals, weaving, crude carpentry, making pottery and the working of metals.

Over a very long period of time and from these primitive beginnings arose the necessity for means to measure, both for the purpose of barter and to enable the craft to develop.

The earliest concept would naturally have been that of length, probably followed by the appreciation of two dimensional area and of three dimensional bulk.

The early established standards of length were derived from limb measurements and are familiar in their developed form in the ancient Egyptian system of measures.

The more abstract idea of weight may have taken longer to dawn on early man's intelligence.

Before the crudest weighing instrument was devised the process of hefting or lifting an object to assess its weight was probably in use.

Weighing with the balance ranks amongst the few really fundamental inventions of prehistoric times and is equally important to our civilisation as the wheel and axle, the lever and the screw.

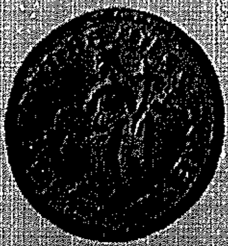
The fascinating story of weighing is linked closely with the moral evolution of the human race. A measure of the real civilisation of a people in any period of its history may be obtained by studying the attention given to the invention and perfection of devices for weighing and measuring.

The Balance in Symbolism

For centuries the equal armed beam scale has figured as the supreme and traditional symbol of Justice and Truth. It stands for equity in the affairs of man and for precision in the acquisition of knowledge.

The Romans identified the idea of Justice with prosperity and expressed this principle on the reverse of their coinage, showing the figure of Aequitas or Moneta representing Justice holding in one hand a balance and in the other a cornucopia or horn of plenty.

Fig. 1

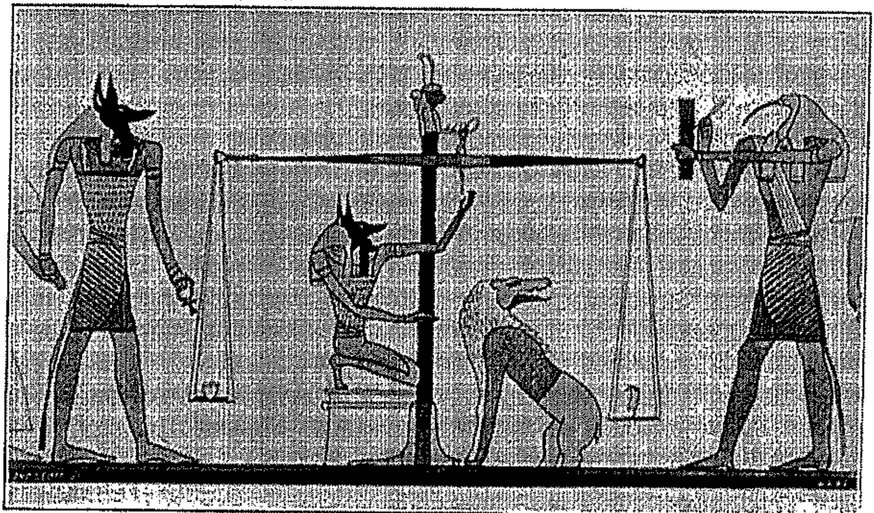


Justice, holding in one hand a balance, and in the other a "Cornucopia," or horn of plenty.

(The "reverse" of a Roman coin in the *Avery Historical Museum*)

In ancient religions psychostasis, or the idea of weighing the soul of the dead, figured prominently and surviving legends, paintings, and even stained glass windows record the persistence of this allegory in the Christian World.

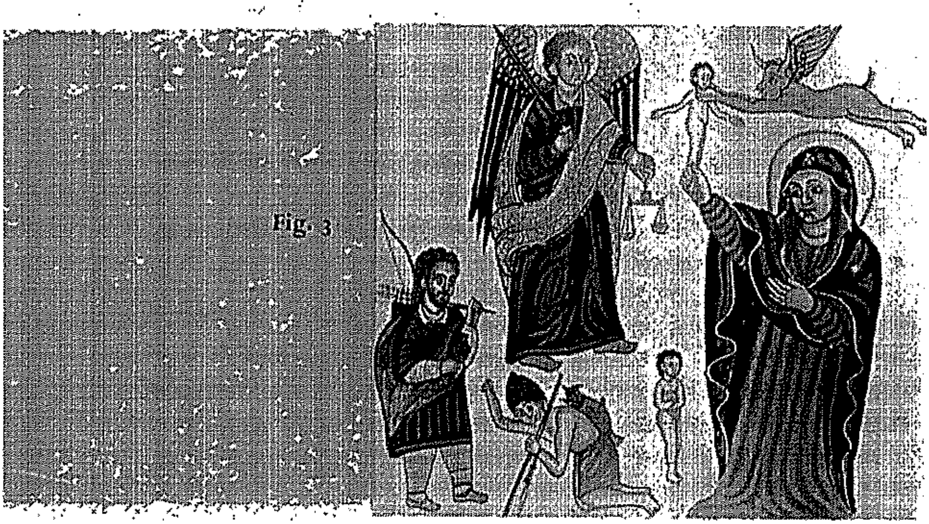
In Fig. 2, which is a reproduction of a part of the Egyptian Papyrus of Hunefer, 1350 B.C., in the British Museum, the heart of Hunefer is being weighed against a feather, symbol of righteousness and truth. The jackal headed god Anubis is in charge of the tongue of the balance and Thoth, the Scribe of the gods, is recording the weighing. The beast Amemit is waiting to devour the heart should it be found light in the balance.



The weighing of the Soul in the Judgement Hall of Osiris.
(Papyrus of Hunefer. British Museum)

Fig. 3 below is taken from E. A. Wallis Budge's reproduction and translation of the 18th century Ethiopic Manuscripts in the Lady Meux Collection.

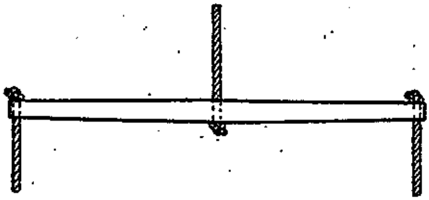
The legend tells how a depraved cannibal is moved to relieve the thirst of a leprous beggar. On the death of the cannibal the Devil attempts to seize his soul but is prevented by the Virgin Mary. An archangel weighs the good deed against the souls of the devoured and the souls are outweighed thereby.



The First Beam Scales

The idea of the balance probably developed from the yoke, Fig. 4, when man came to realise that two equal masses balance each other if hung from the ends of a beam supported at the centre of its length.

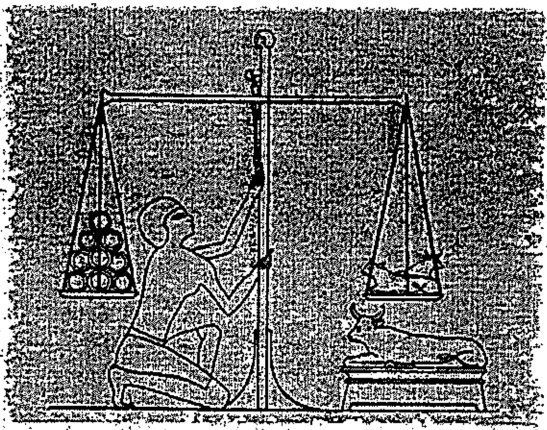
Ancient Egyptian yokes



The early balances were straight pieces of wood or stone with a suspension cord passed through a hole midway between the two ends, which, in turn, were also pierced with holes through which were threaded the cords suspending the scale pans, Fig. 5. They are known to have been in use as early as 4000 B.C. These balances were not accurate because of the difficulty of locating the holes with precision and also because of the wandering of the cords in the holes.

A great invention was made about 1500 B.C. when the Egyptians formed the idea of bringing the cords out of the ends of the beam. By this device it was a simple matter to make the arms of the beam equal by a little scraping, and no matter how heavy the loads, the cords always lay against the ends of the beam. In the best of these balances the ends were lotus-shaped and were rounded into curves struck from the fulcrum of the beam.

Fig. 6



An Egyptian lotus-ended beam

The illustration, Fig. 6, shows a slave weighing ring-shaped ingots of metal against weights fashioned in the shape of a cow, this animal being an ancient standard of value. (Latin, pecus-cattle, pecunia-money.)

The beam he is using has the improved lotus-shaped ends.

Some of the large balances made by the Egyptians were of extraordinary magnificence and costliness.

The Egyptian cord pivot beam has survived as a type throughout the centuries and is still in use today in remote market places of the East, although it is being replaced rapidly by modern scales.

Fig. 7 was made from an Indian beam in use at the beginning of the twentieth century and now in the Avery Historical Museum.

Fig. 7

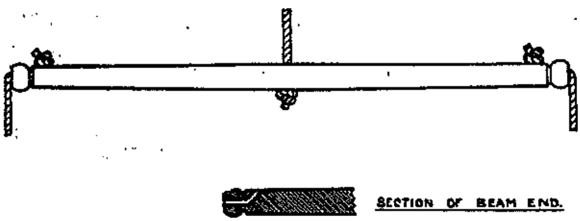


Fig 8

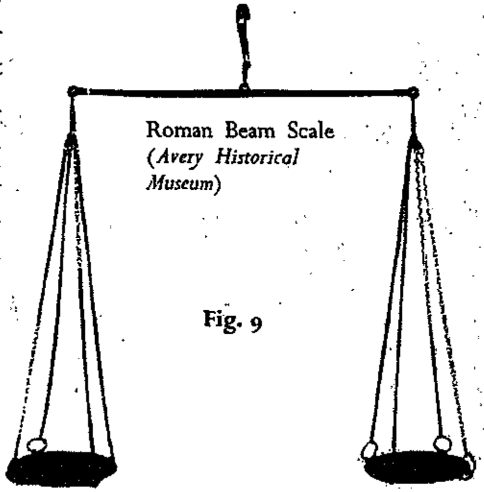
Weighing in a Bikanir Market

Fig. 8 is reproduced from a photograph taken earlier in the century in the market of Bikanir near to the Indian Desert. The beam scale used by the woman is of exactly the same pattern and there can be no doubt that such instruments have been used in the Eastern countries ever since the unknown inventor made the first great improvement in the balance. With care a surprising degree of accuracy can be achieved with them.

Greek and Roman scales were in the form of a beam, usually of bronze, with ring and hole pivots. They could not have been as accurate as the better Egyptian models because of the tendency of the ring to wander in the hole and so to vary the effective length of the arm of the beam. Technically they were degenerate but the ring and hole principle did permit the construction of the first all metal weighing device.

A bronze beam scale, in an excellent state of preservation, is shown in Fig. 9, and is from the Roman collection in the Avery Historical Museum. Parts of the original hand-made bronze chains have been replaced. The beam illustrates the ring and hole pivot of the Classical Period.

This type of scale was in use in European countries until the end of the fifteenth century, for in the sterile years between 1500 B.C., and A.D. 1500, there was no outstanding improvement in its construction. In Rembrandt's "Gold Weigher" reproduced in Plate III, we see a beam scale in which the ring and hole end pivot has degenerated into the form of a ring and hook which would permit even greater arm length variation.



Roman Beam Scale (*Avery Historical Museum*)

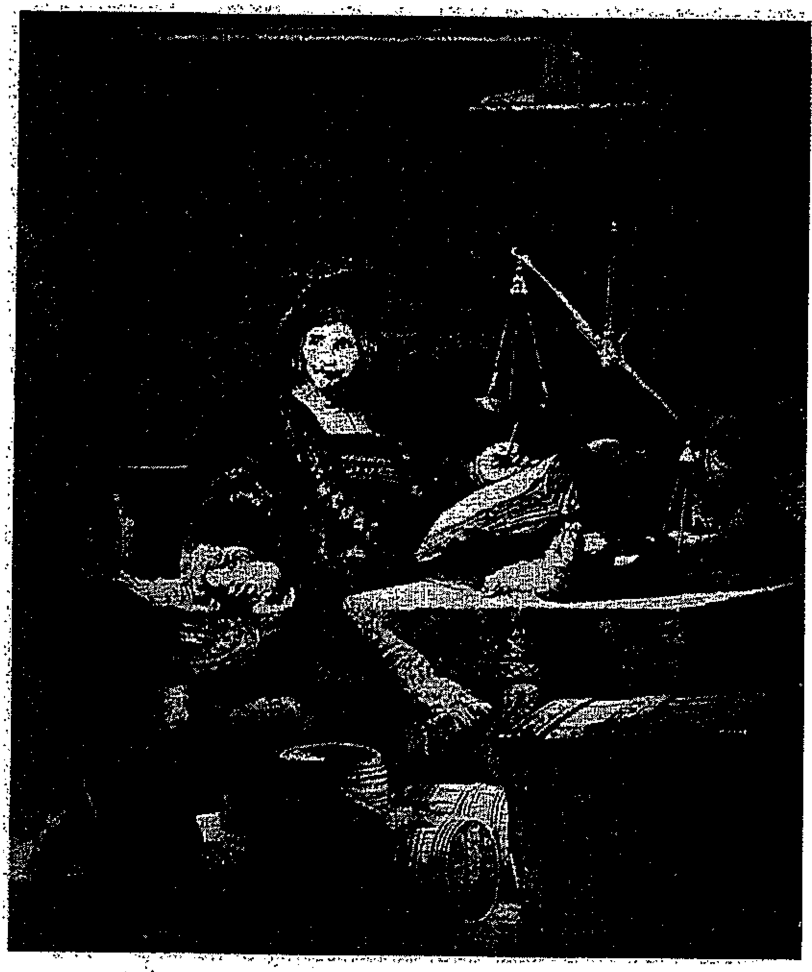
Fig. 9

Evidence of the continued use of extremely crude weighing devices, until the end of the nineteenth century, even in well developed countries, is given by Fig. 10, which shows a wooden scale actually used for weighing butter in an English farmhouse. It is about 300 years old, and was probably the work of a local craftsman.

Fig. 10 Wooden Butter Scale (*Avery Historical Museum*)

A primitive cord-pivot beam scale shown by Caravaggio in the painting of Camillus refusing his consent to the terms of the Gauls, circa 381 B.C. The picture is reproduced from a copy of a reverse engraving, by Saenredam, in the Avery Historical Museum.

Plate 11



"THE GOLD WEIGHER"

By Van Rijn Rembrandt (1606-1669)

(From reverse engraving in the possession of Richard Hancock, Esq., of Birmingham, 1927.)

The beam scale has hook-shaped end pivots. No weights are in use. The bag of gold has been weighed against a counterpoise.

A reproduction of the scale is in the Avery Historical Museum.

Plate III

The Bismar, Danish Steelyard or Auncell

The bismar is one of the simplest and yet the least known of all weighing instruments. It is really a counter weighted lever used to balance the load to be weighed. An idea of how the device was used may be obtained from Fig. 11. The loose loop of cord forming the fulcrum is moved along the lever until a position of balance is reached. In old bismars nail heads served to mark the graduations, which must have been calibrated by trial since they are not equally spaced but follow a harmonic series, which would not have been understood by the ancient craftsmen.

Both the place and date of origin of the bismar are obscure and its distribution was very wide. Among the countries where it has been used are India, Burma, the Malayan Peninsula, Denmark, Scandinavia, and the Orkney and Shetland islands. The Danish invaders introduced it into Britain in the eighth century, and it was in use for trade purposes until made illegal in the reign of Edward III.

Some authorities believe the bismar owes its wide distribution to conquering Aryan tribes of nomadic habits, who found its simplicity so convenient in their ways of life.

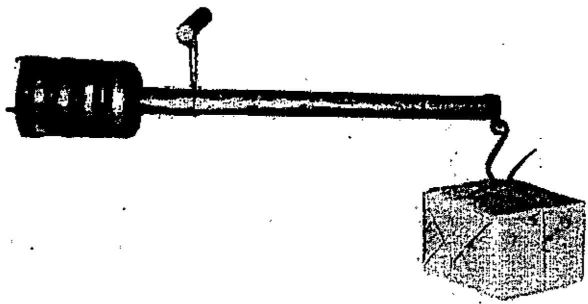


Fig. 11 An Esthonian Bismar (*Avery Historical Museum*)

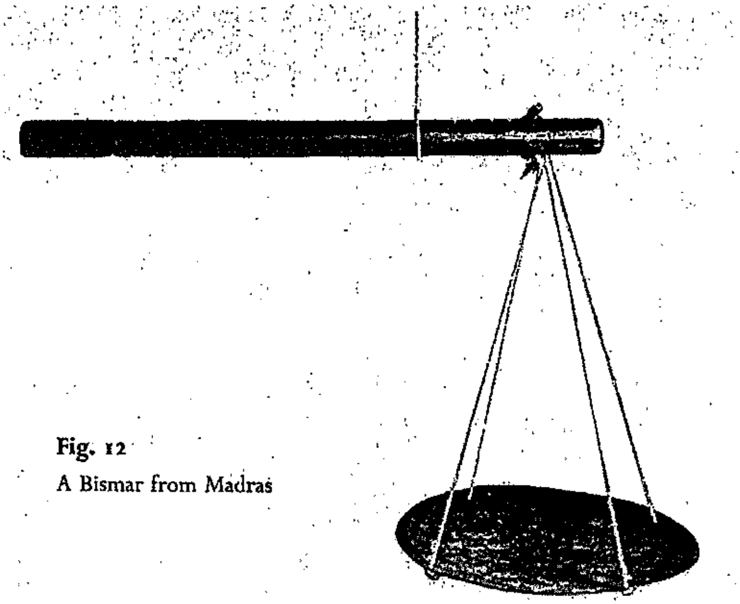
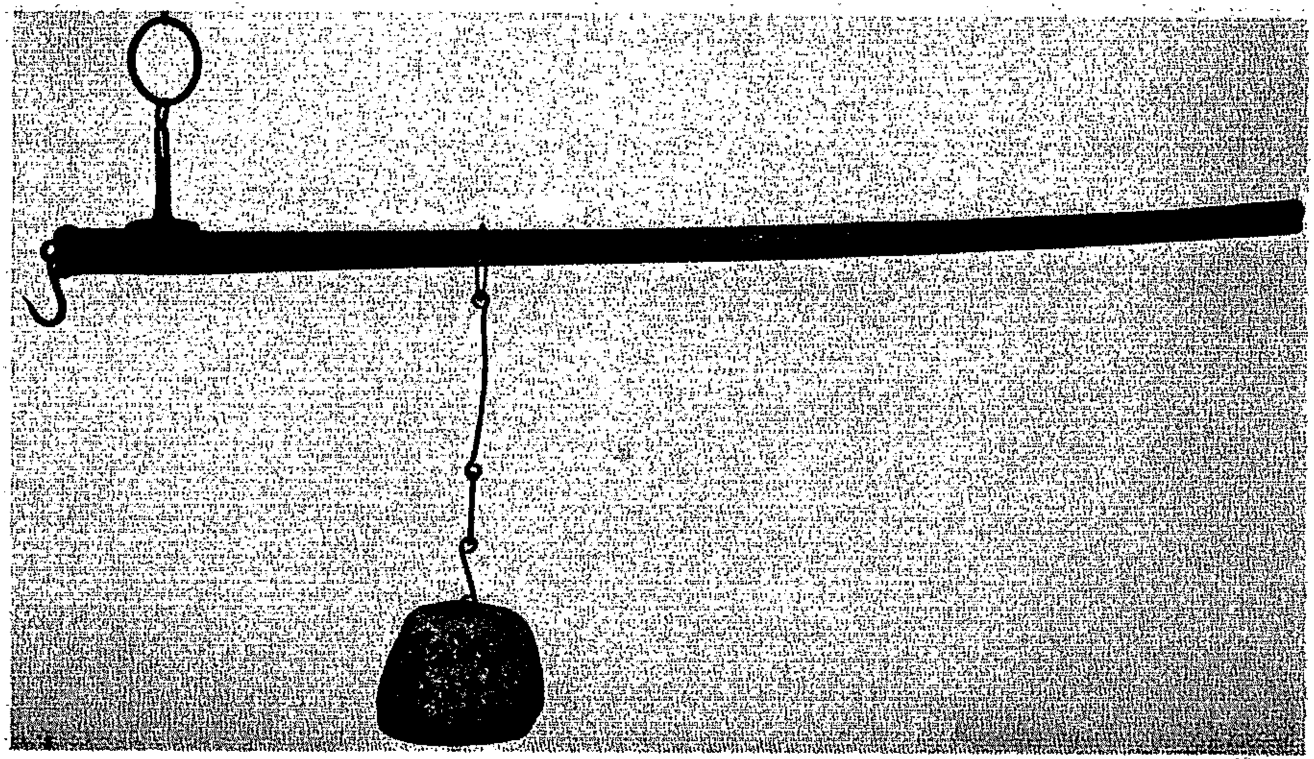


Fig. 12
A Bismar from Madras

Like the crude forms of the equal armed beam scale, the bismar has remained in use throughout the centuries and is still to be found in its primitive form in India, see Fig. 12.
The photograph, Fig. 13, of a woman weighing fish in Helsinki, Finland, was taken in 1939. The bismar she is using is a well constructed instrument.

Fig. 13
Helsinki Fish Woman



A Pundler, or wooden steelyard, from Orkney, now in the Avery Historical Museum. The oaken beam is 6 feet 2 inches long and the stone poise weighs 31 lb. It bears the weight stamp of George III and three older obliterated marks.

Plate IV

Plate V

WATER MILL

By Phillip Galle (1537-1612)

The two steelyards shown are modern in type with fixed pin pivots; each instrument has two fulcra, for light and heavy loads respectively. The "carrier" or stop adapted to limit the movement of the beam is interesting.

The Roman Steelyard

The third basic type of weighing device to be evolved was the steelyard, using the principle of a poise sliding along the arm of a beam to counter-balance a load.

The discovery of this method of weighing was probably made by the Greek speaking people of Campania, at a date somewhat later than the invention of the bismar.

Whilst the Romans are known to have used equal armed beam scales provided with a poise on one arm of the beam, they made considerable use of the steelyard with its leverage or mechanical advantage enabling a light poise to balance a comparatively large load.

The Romans made most of their steelyards in bronze with lead poises, and like their beam scales, they were of the ring and hole pivot construction.

Fig. 14 shows a Romano-British steelyard, now in the Avery Historical Museum, and which was found at Clipsham in Rutlandshire. Like many other relics of the period of the Roman occupation it is of wrought iron with a lead poise and most probably was made by a native craftsman.

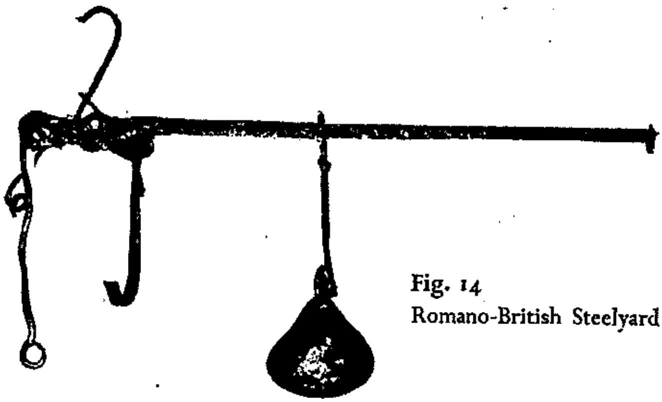


Fig. 14
Romano-British Steelyard

Cart Weighing Steelyard in Soham, Cambridgeshire

Plate VI

Cart Weighing Steelyard in Soham, Cambridgeshire

Plate VI

Wyatt type Cart Weighbridge in Tasmania
(Photograph by permission of Mr. Nainby of Glenorchy)

Plate VII

Early Platform Scales

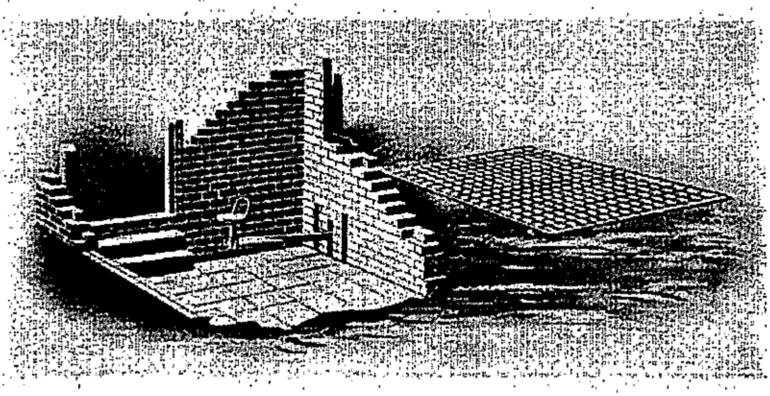


Fig. 15

The Turnpike Act of 1741 authorised all road trustees to erect at the Toll Gates "any crane, machine or engine, which they shall judge proper for the weighing of carts, waggons or other carriages," and ordered them to exact toll according to weight and to employ the money for the repair of the roads.

This act not only created a demand for cart weighing steelyards but also gave an impetus to inventors. The names of Eayre and Yeomans are connected with the invention of platform weighing machines, but in all probability John Wyatt constructed the first true compound lever platform scale at about this time. He is supposed to have been in the employ of Matthew Boulton for a period at the Soho Manufactury. By the invention of his spinning engine Wyatt became the first man to spin yarn without the help of human hands, yet his life's story is one great struggle against poverty.

The first Wyatt weighbridge was erected at the Birmingham Workhouse, sometime in the early 1740's, but no details of the machine have survived. The model from which Fig. 15 was made (based on a Wyatt weighbridge once at Lichfield) is now in the Museum of the Weights and Measures Department of the City of Birmingham.

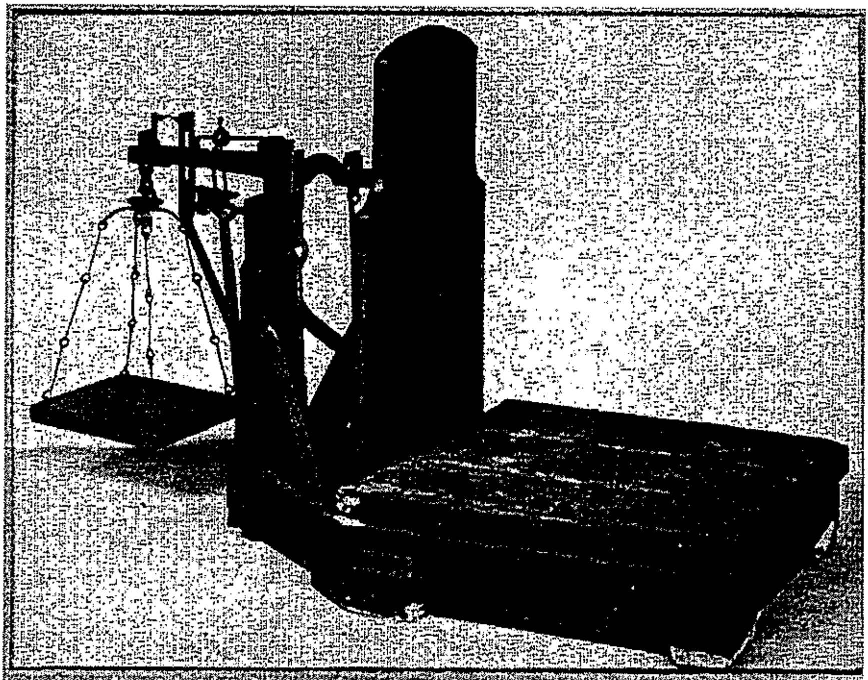


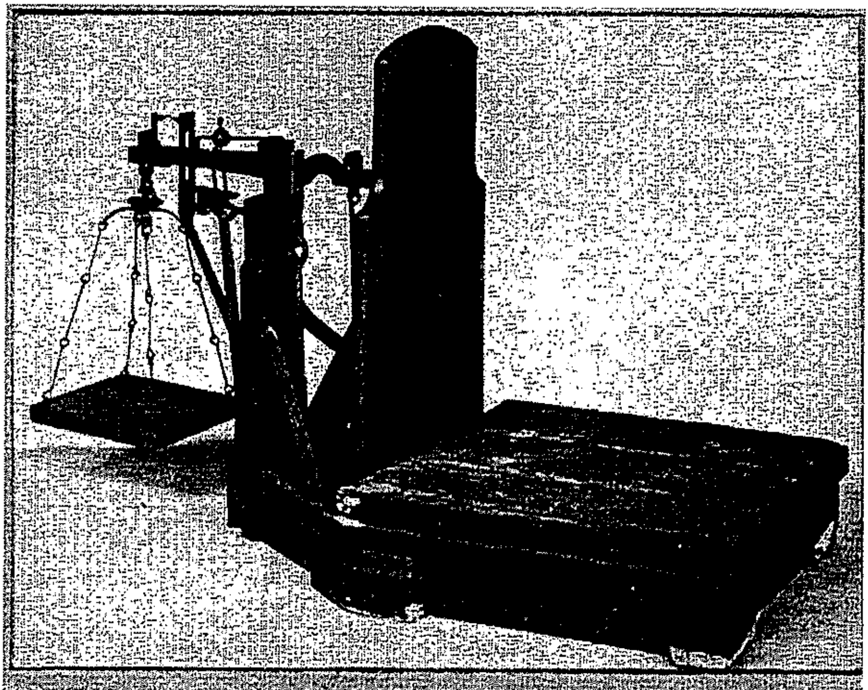
Plate VIII Quintenz Platform Scale (*Avery Historical Museum*)

In Europe the Quintenz platform scale was introduced about 1820 and was popular in France and Germany. In this machine we see the emergence of a steelyard above platform level. Fig. 17 shows the lever system peculiar to the Quintenz design, and a photograph of an actual machine in the Avery Historical Museum is reproduced in Plate VIII.

In 1831 Thaddeus and Erastus Fairbanks took out a United States Patent for a compound lever scale, and their agents obtained a British Patent in 1833.

The latter was however declared invalid when English scale-makers proved that the invention had been in use for a number of years.

A feature of the Fairbanks machine was the combination of the lever system supporting the weighing platform and a steelyard for balancing and indicating the weight. These steelyards were of the pattern in which loose proportional weights were used to balance the major portion of the load and a small sliding poise served to indicate the odd pounds and ounces.



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It is only fair to add that the introduction of Fairbanks' designs led to great improvements in the manufacture of weighbridges and platform scales throughout the world. They came at a time when the impetus of the Industrial Revolution prepared the way for their reception.

Henry Pooley, of Liverpool, England, saw in these machines a convenient means for meeting the demands of the railway companies for weighing heavy goods and, entering into an arrangement with Fairbanks' agents, took up the manufacture vigorously. He placed his first platform scale on the new railway between Liverpool and Manchester in June, 1835.

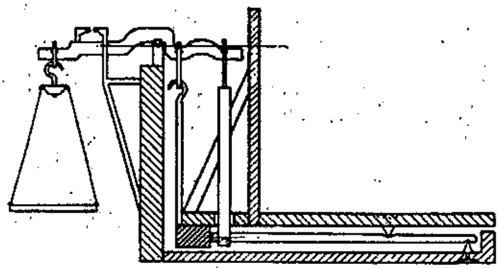
No-loose weight steelyards were introduced later and fitted to platform scales and weighbridges. In these, a major sliding poise balances the greater part of the load, such as the tons, and one or more smaller sliding poises are used to balance the remaining hundredweights, quarters, pounds, etc.

The exact position of the major poise is determined by notches in the steelyard blade, and a notch protection bar is fitted to the better steelyards, to guide the nib on the poise into these notches and preserve the accuracy of the scale.

Fig. 19 is from an engraving in an Avery Catalogue dated 1880, and shows a typical railway wagon weighbridge of the time, with a no-loose weight steelyard indicator.

They were made for loads up to 60 tons.

Fig. 17 Diagram of Quintenz Platform Scale



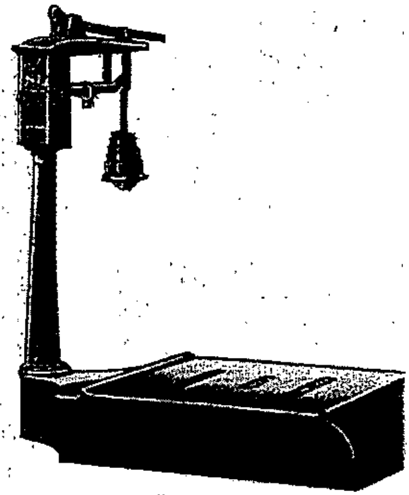


Fig. 18 An early Pooley Platform Scale made in the middle of the 19th century
The scale has a relieving handle and the steelyard is of the "loose-weight" type

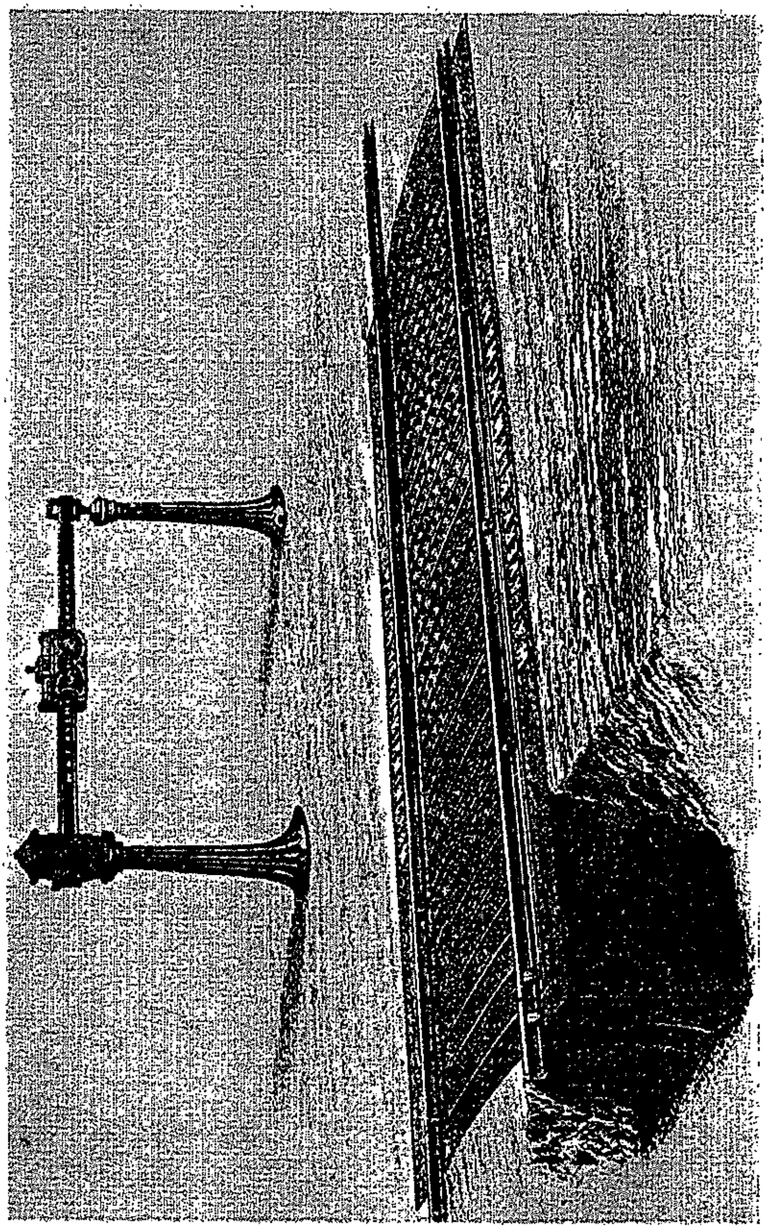


Fig. 19 An Avery Weighbridge of 1880

One of the earliest recorded representations of the true knife-edge is in the famous portrait by Hans Holbein the younger, of George Gisze, the Hanseatic Merchant, Plate IX. Behind the figure and hanging on the wall is a beautiful money weighing scale so accurately drawn that it has been possible to reproduce the actual instrument, see Fig. 21.

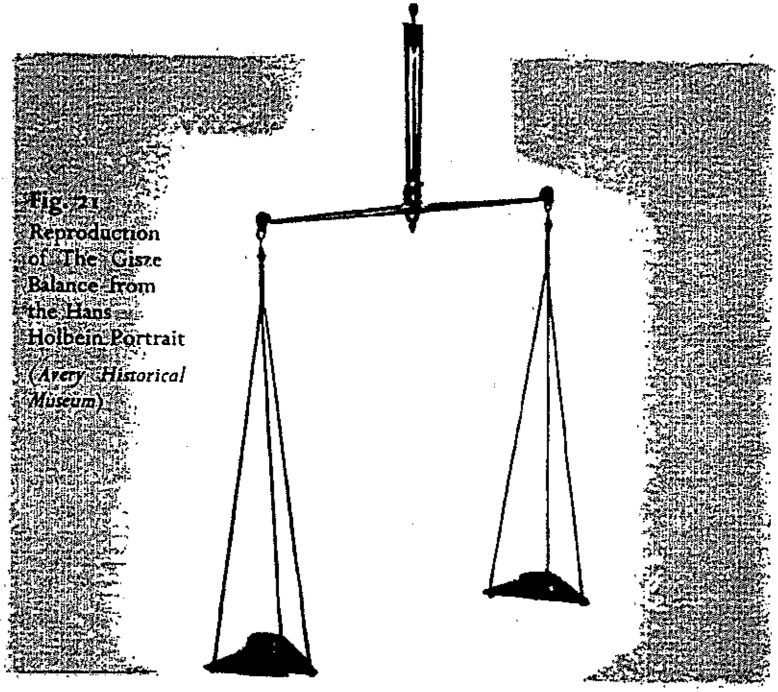


Fig. 21 Reproduction of The Gisze Balance from the Hans Holbein Portrait *(Avery Historical Museum)*.

There is a central knife pivot fixed in the beam end and knife-edges are cut in the transversely flattened ends giving the form of scale beam end known as the swan-neck. Such a beautiful instrument could hardly have been a prototype, therefore there must have been previous efforts in the evolution of this design probably around A.D. 1500, since Holbein was born in 1498 and died in London of the plague in 1543.

The swan-neck beam scale and its contemporary the box-end beam served for two or three centuries for weighing in the retail trades. The beams were often suspended by hand when weighing and the weights and goods were accommodated in copper bowls hanging on three cords or chains.

Fig. 22 shows a typical box-end beam scale as used by an eighteenth century grocer.

W. & T. Avery acquired the manufacturing rights of Sharkey's Patent of 1857 for a new type of end pivot and bearing for a scale which became known as the brass and agate beam. The drawing in the Patent Specification, see Fig. 23, shows clearly the rigid construction of the beam and the protection afforded by the end shackle which housed an agate bearing. The introduction of this design revolutionised weighing in retail shops and set a new standard. These polished brass beams, with their ornate pillars and porcelain goods plates were a familiar sight in all grocer's shops until the introduction of the modern self-indicating scale.

The continuous knife-edge was first developed at the beginning of the nineteenth century for precision balances and is applied now to all forms of scales, from the most accurate balance to the heaviest weighbridge.

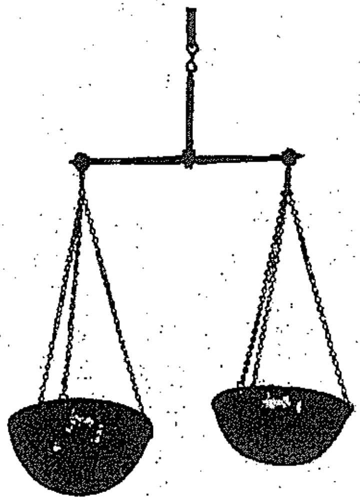


Fig. 22
Box-end beam scales
(Avery Historical Museum)

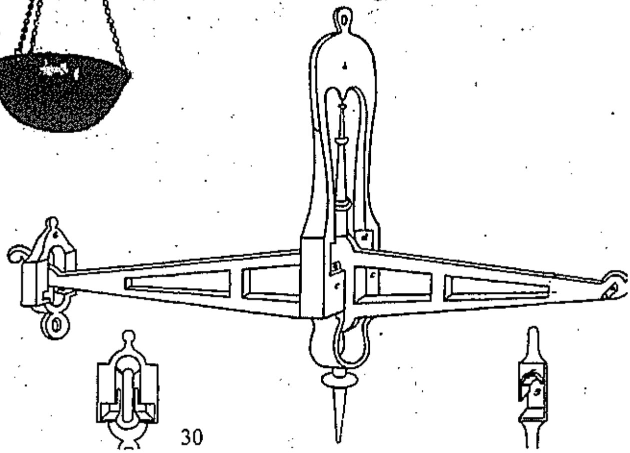


Fig. 23
Sharkey's Brass and Agate Beam Scale
British Patent No. 214 of 1857

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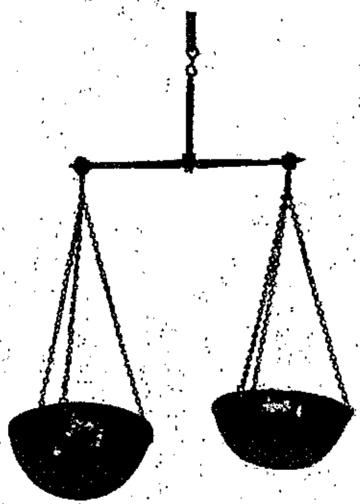
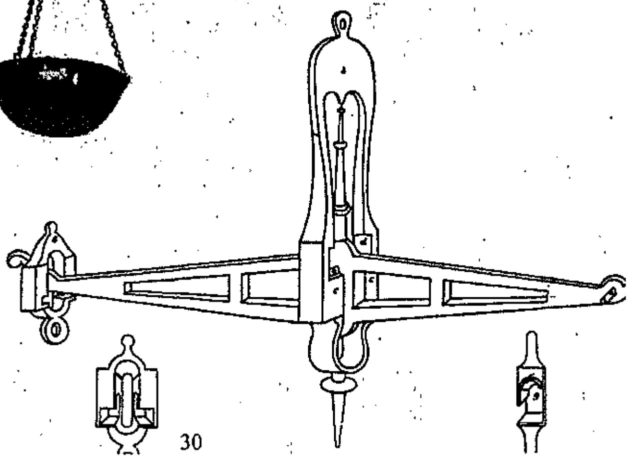


Fig. 22
Box-end beam scales
(Avery Historical Museum)



Sharkey's Brass and Agate Beam Scale
British Patent
No. 2140 of 1857

Plate IX

Portrait of George Gisze, Hanseatic Merchant, by Hans Holbein, the younger, (1498-1543).

Coin scales hang from the shelf behind the figure.

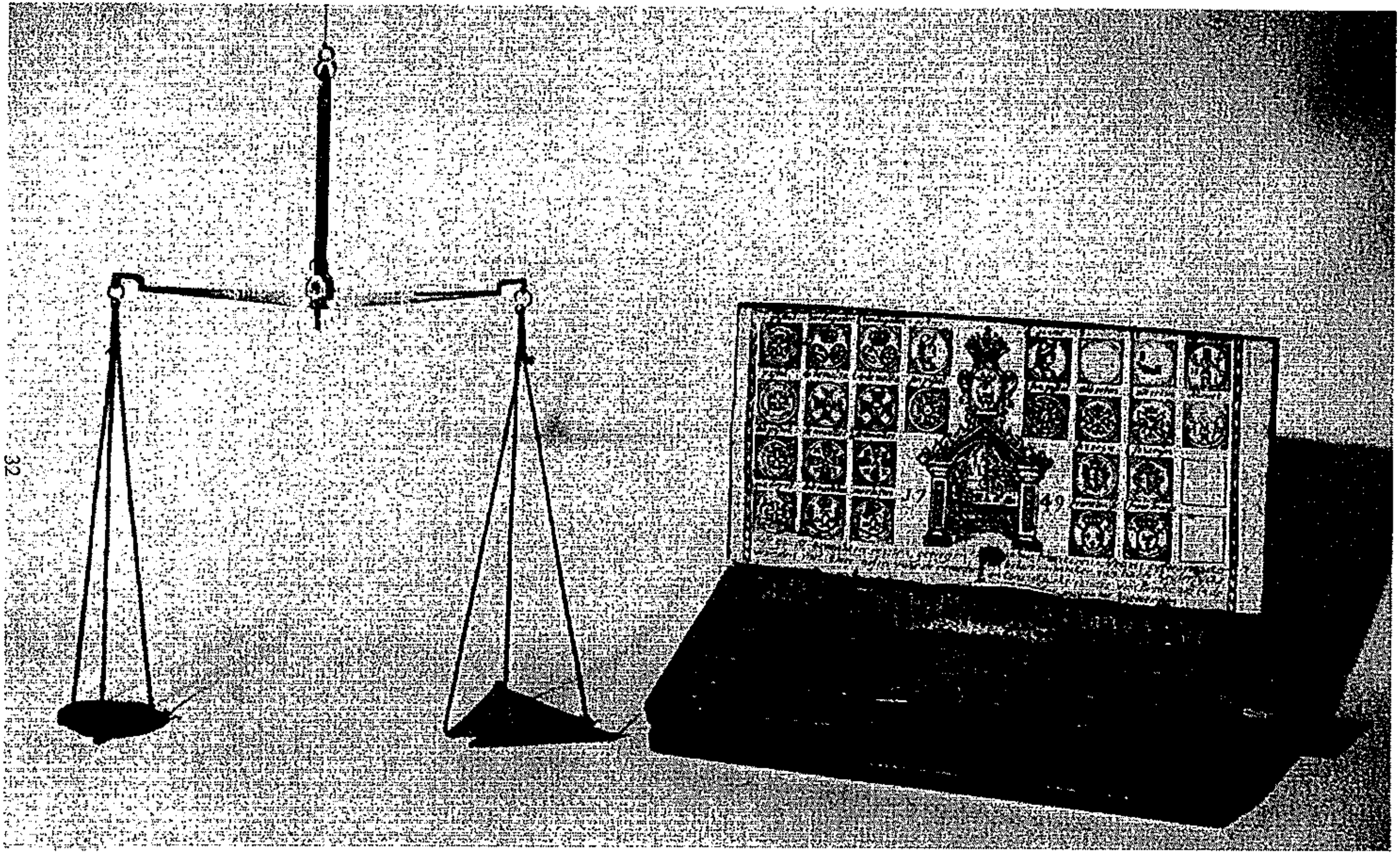


Plate X

Weighing of Coins

Until well into the nineteenth century the coinage of European countries was inadequate for the needs of commerce, and in Great Britain the national currency was supplemented by the use of foreign coins, mainly of Spanish and Portuguese origin. This state of affairs encouraged the existence of gangs of unscrupulous men who made a nefarious living by "clipping" and "sweating" —that is by cutting metal from the edges of gold and silver coins, and by dissolving away some of the precious metal by putting the coins in acids.

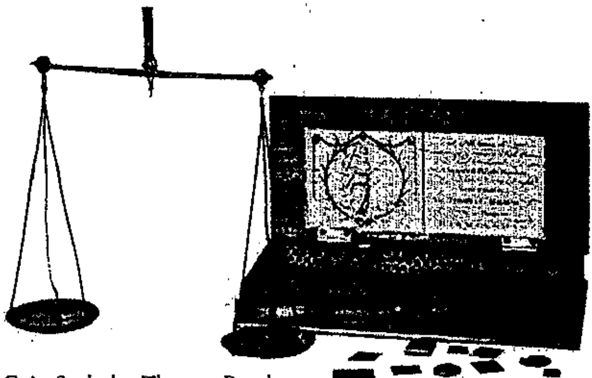
There is no wonder, then, that bankers and merchants would not accept coins at their face value, but insisted on checking them by weight. Large numbers of money-weight scales were made, many of them beautiful examples of craftsmanship, and usually they were small balances of the swan-neck or box-end beam types.

Sometimes they were fitted into cases with sets of coin weights and could be carried in the pocket.

Plate X shows a very fine coin weighing set made in 1749 by Jacobus Franciscus Neusts of Antwerp. The brass beam is delicately fashioned and the dug-out wooden case contains weights corresponding to a variety of contemporary British and European coins.

Fig. 24 shows box-end coin scale made at the beginning of the nineteenth century by Thomas Beach, of No. 11, Digbeth, Birmingham, a predecessor of William and Thomas Avery, whose business was first established in 1730.

Fig. 24



Coin Scale by Thomas Beach

The "spring into position" type of coin balance, Fig. 25, was a popular instrument for the pocket. When the long hinged lid of the case was opened the scale erected itself ready for use. The counterweighted beam was set for check weighing specified coins, and by means of a hinged weight, called a "turn" the scale could be used to weigh guineas and half-guineas according to which way the turn lay on the beam. The coin was placed in the swinging pan. A small slide enabled balance to be obtained and indicated on the graduated beam how many pence in value the coin was short by weight.

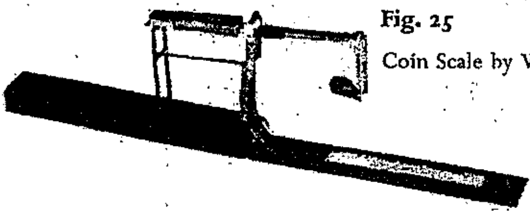


Fig. 25

Coin Scale by Wilkinson (circa 1780)

There is in the Avery Historical Museum an unusual coin weighing steelyard of which only one other example is known, see Fig. 26. The steelyard, which is only 3¼ inches long, has graduations which correspond approximately to the weight of a pennyworth of silver at the beginning of the nineteenth century. Its sensitivity is limited by the crude ring and hole pivots.

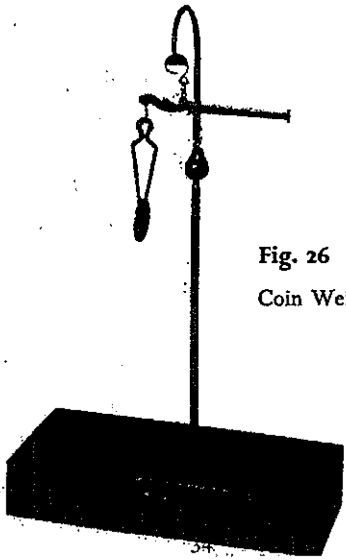


Fig. 26

Coin Weighing Steelyard

Early Counter Scales

Everyone is familiar with the type of scale in which the pans are mounted above the weighing beam, and which does not suffer from the disadvantage of having swinging pans, or from the encumbrance of chains or rods above them. Many of these scales are based on the mechanical linkage discovered by Roberval.

In 1669 Gilles Personne de Roberval invented what is known as the "Static Enigma", Fig. 27, which puzzled the greatest mathematicians of the day, although an average engineering student of the twentieth century, with his understanding of the principle of moments of forces, would have no difficulty in explaining the mechanics of the device.

Providing that the beam, legs and stay of the system form a linkage of perfect parallelograms, and that the two poises are equal in weight, then balance is maintained even if one poise is moved along its arm towards the centre, and the other moved outwards from the centre of the mechanism.

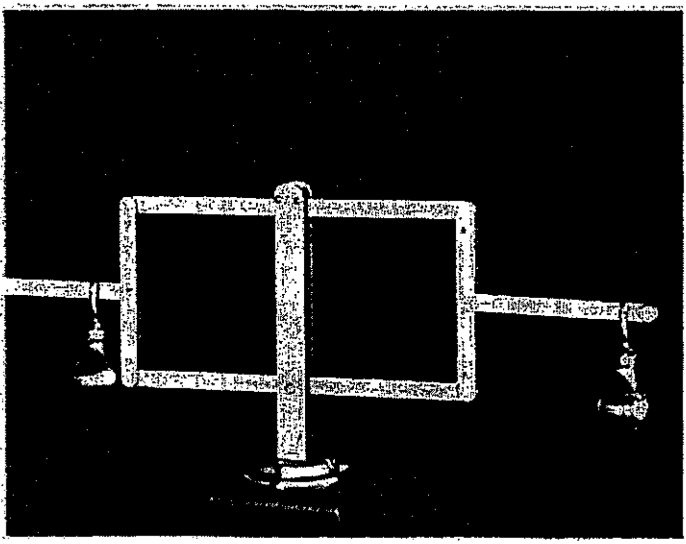
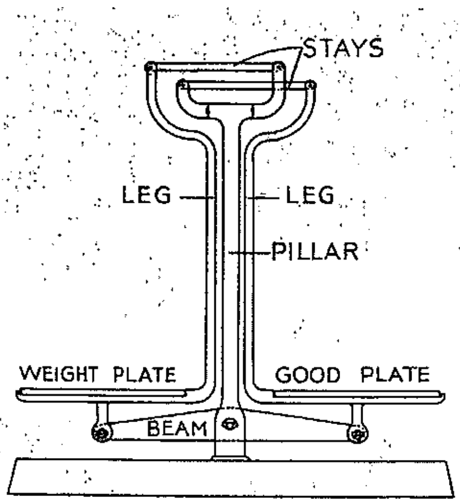


Fig. 27.
Roberval's Stat
Enigma

Fig. 30
The Inverted Roberval Counter Scale, or Imperial Scale



In the middle of the nineteenth century, Joseph Béranger, a French scalemaker, invented the balance known by his name, and in which each scale pan is provided with a four point support on a system of levers. This design, Fig. 31, has some advantages and, although more costly to produce than the Roberval unit, is very reliable and accurate.

The Béranger design permitted of several variations, of which the Phanzeder became popular on the continent of Europe.

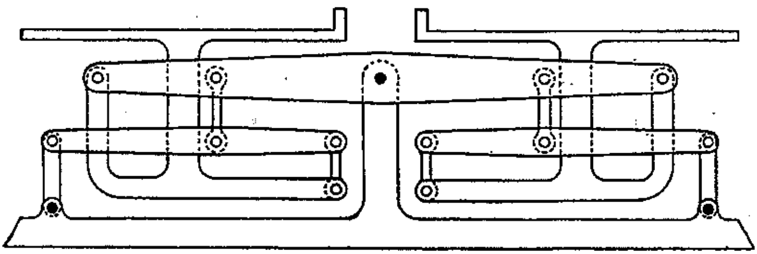


Fig. 31 Béranger Counter Scale

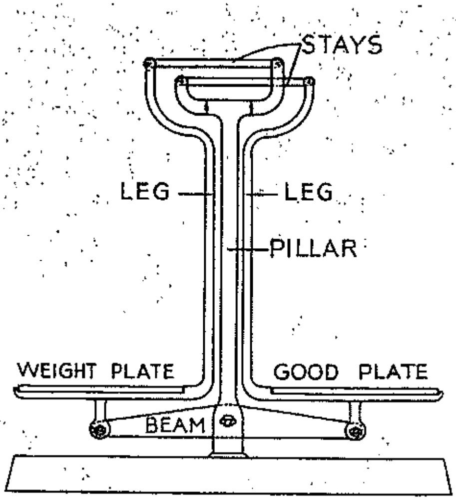


Fig. 30
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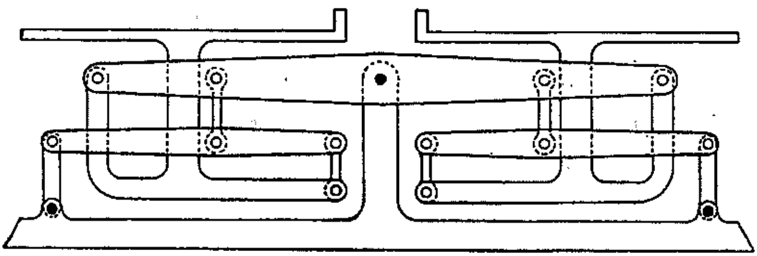


Fig. 31 Béranger Counter Scale

The Self-indicating Scale

A self-indicating scale is capable of balancing a load automatically and giving an indication of its weight without an operator having to manipulate loose weights or sliding poises. These scales, in their many forms and sizes, revolutionised commercial and industrial weighing in the first part of the twentieth century. First records of the invention of the self-indicating scale were made by that universal genius of the fifteenth century, Leonardo da Vinci, whose paintings of "The Last Supper" and "The Mona Lisa" are world famous.

His notebooks, which were compiled over a period of forty years, were written in mirror script and contain sketches and a description of two self-indicating weighing mechanisms, similar in principle, one being semi-circular in form, the other triangular.

Fig. 33, shows two working models made from the original sketches for the Avery Historical Museum. When an article is placed in the pan the semi-circle of metal, which also forms a chart, acts as a pendulum and swings over to a new position of equilibrium. The triangular frame of the other model acts similarly, and in both cases the weight of the article is indicated at the point where the cord of the plumb-bob intersects the graduated scale. Although Leonardo da Vinci's original sketches and description of these mechanisms were essentially practical in conception, no attempt seems to have been made to exploit this outstanding invention until towards the middle of the nineteenth century, nearly four hundred years later.

The organisation of the postal services and the introduction of the penny post in Britain in the mid-nineteenth century inspired inventors and many novel devices were put on the market for weighing postal packets. For the first time the principle of the weighing pendulum was put to real practical use.

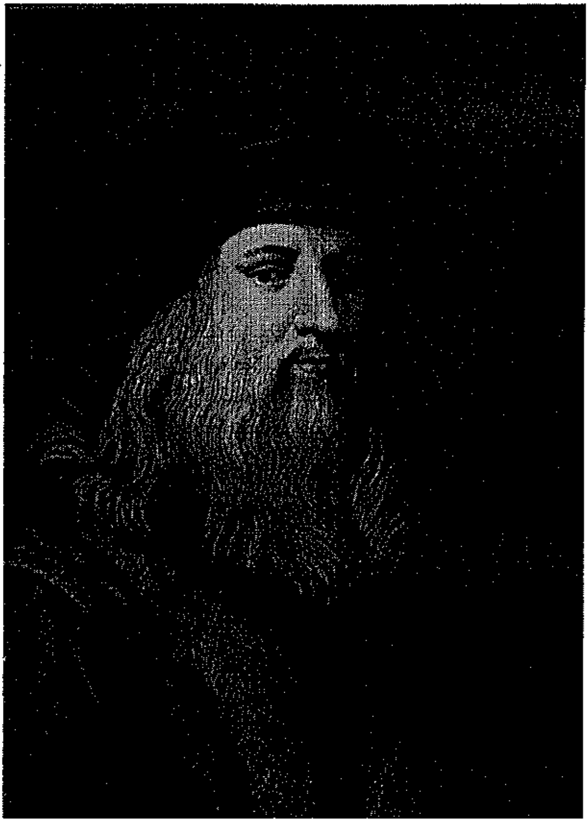


Fig. 32

LEONARDO DA VINCI
(1454-1519)
From a self-portrait
He was a great mathematician and scientist as well as a consummate artist

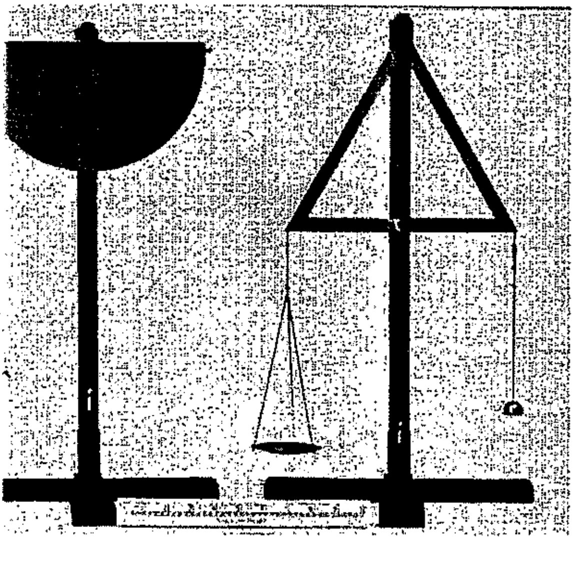


Fig. 33

A simple balance, patented in 1863, consisted of a pendulum formed from flat sheet brass and suspended from a small shackle, Fig. 34. The load was applied by a cord and ring. On the circular pendulum disc was engraved a graduated scale of weight, at the centre of which was freely pivoted a counter balanced pointer which always hung vertically.

When a load was suspended from the instrument the pendulum swung outwards to a position of balance and the pointer, remaining vertical, indicated the correct weight. Such little balances were made for weighing letters and postal packages and were also popular among anglers.

One of the earliest applications of the pendulum to retail weighing is illustrated in Plate XI which shows a machine made by Avery and now in their Museum. It is based on Cartwright's Patents of 1888 and 1902; the outstanding feature is the coupling of a pendulum and indicator to an ordinary counter beam scale. The chart range is one pound and the capacity may be increased by the addition of weights, in multiples of one pound, to the weight plate.

In the opening years of the twentieth century pendulums were applied to Roberval and Béranger type counter scale mechanisms to produce self-indicating scales for the retail counter. The diagram of Fig. 35 shows a typical pendulum weighing unit.

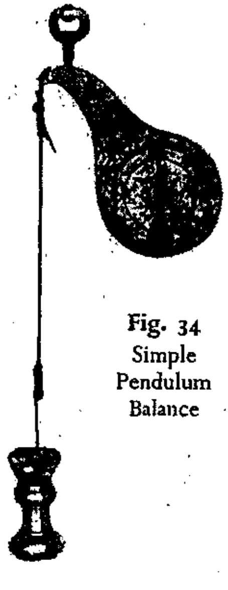


Fig. 34
Simple
Pendulum
Balance

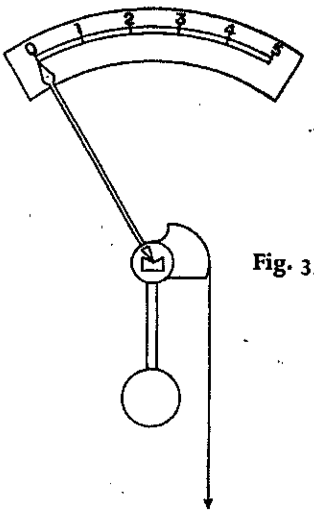


Fig. 35

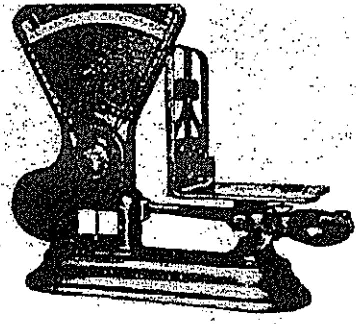


Fig. 36
Early Counter Scale c. 1906

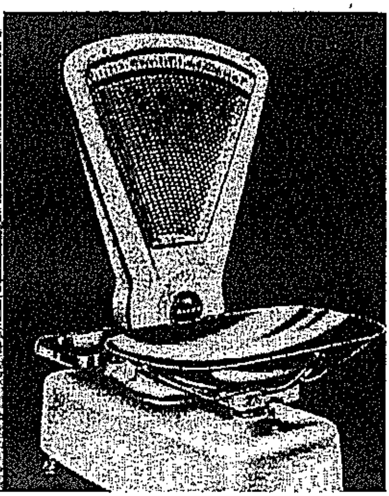
The pull from the scale beam or lever is applied to the pendulum by means of a steel band attached to a cam, introduced about 1906 to enable chart divisions of exactly equal width to be obtained. As the pendulum moves outwards under the influence of the load, to a position of equilibrium, the pointer traverses the chart and indicates automatically the correct weight. In the diagram the pendulum has a knife-edge for a fulcrum.

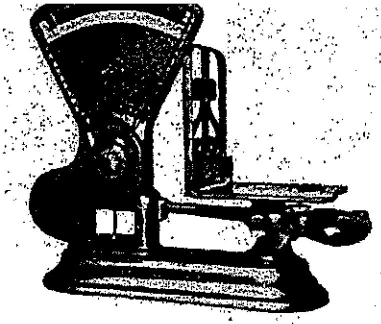
A counter scale of this type was approved for use in trade in Britain under Board of Trade Certificate No. 39 of 1906 and is illustrated in Fig. 36. The scale was made under licence from the Toledo Scale Co. of America and is now in the Avery Historical Museum.

The two scales just described represent important stages in the evolution of retail weighing.

In contrast is the modern styling of the counter scale in Fig. 37 it has a pendulum and cam associated with a Béranger beam and lever system.

Fig. 37
Modern Semi-self-indicating Counter Scale





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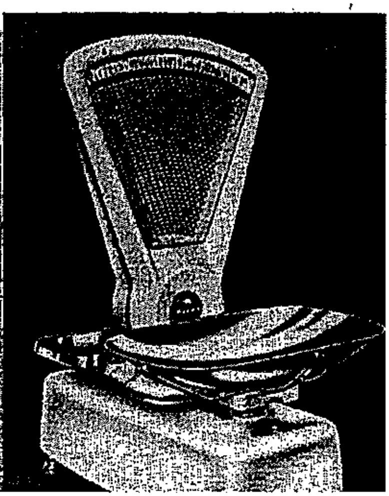


Spring Balances

The spring balance is a convenient and useful instrument because of its portability, robustness and the fact that it provides a simple self-indicating weighing device.

There are references to the spring balance in seventeenth century literature, which described balances with helical and spiral springs. There remain no examples from this period.

Fig. 38
Early Salter Spring Balance of 1770.

Helical, or corkscrew, spring balances have always held the field for popularity and many spring balance mechanisms to-day have two or more such springs in tension as the resistant. The springs are usually connected to a yoke on which is pivoted the rack driving the pinion and indicator. The familiar pocket spring balance has a single spring and is one of the simplest weighing devices. The illustration (Fig. 38) shows an early balance of this type made by Richard Salter about 1770. The graduations are marked on the square bar which slides in and out of the casing. The spring in this balance is used in compression.

An example of a balance known as the sector spring balance, now in the Avery Historical Museum, is shown in Fig. 39. This is graduated up to 36 lb. and is still reasonably accurate. When the load is suspended from the hook, the two straight sides of the balance, made of spring steel, close towards each other and one of them indicates the weight on the edge of the outer curved member. This type of balance dates back to the middle of the eighteenth century.

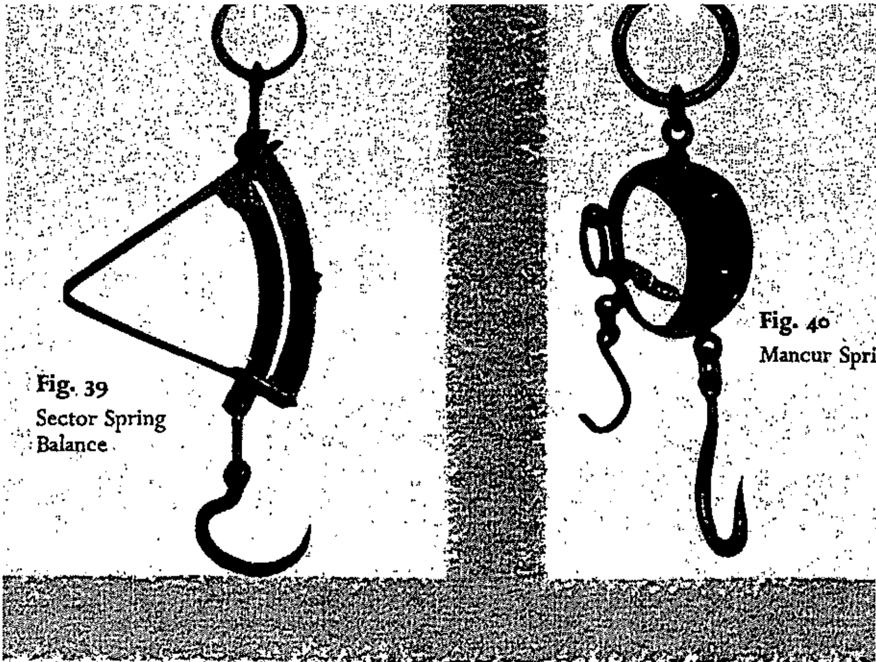


Fig. 39
Sector Spring Balance

Fig. 40
Mancur Spring Ba

The C spring balance received the attention of inventors and one of its most practical forms was known as the Mancur balance, Fig. 40. Large numbers of these were made in America and Europe during the latter half of the nineteenth century, and were used by farmers. The balance may be suspended from either of two rings, and is capable of weighing in two ranges of capacity, according to which pair of rings and hooks is in use. The brass scale has two sets of graduations.

At the beginning of the nineteenth century several inventors were working with springs made from flat strip steel bent into various shapes. One of the most successful of these balances was developed by Augustus Siebe, who, in partnership with H. Marriott, evolved from the early model shown in Fig. 41 the true elliptical spring balance shown in Fig. 42. This latter balance is one made by Henry Pooley & Son under an agreement signed in 1853, with W. Marriott, probably the son of Siebe's partner. Spring dials with this type of mechanism were fitted to the Pooley platform scales previously mentioned in connection with the Fairbank's Patents pp. 25, 26. These spring dial platform scales became a familiar sight on railway stations in Great Britain where they were used for weighing packages and passengers' luggage.

One is illustrated in Fig. 43 which is reproduced from an early weighing machine catalogue published by Henry Pooley & Son in the year 1859. This design was probably the first self-indicating dial platform scale for industrial purposes.

Recent metallurgical developments have enabled scale-makers to produce weighing springs which are almost immune from the effects of temperature and mechanical hysteresis.

Whilst the old spring operated weighing machine was subject to loss of accuracy as the temperature changed, it is now possible to produce springs which, when associated with precision components, can compare favourably with other self-indicating weighing resistant units such as the pendulum.

Weighing springs are of course sensitive to changes of the gravitational pull at different latitudes and altitudes and must be calibrated to suit the local conditions.

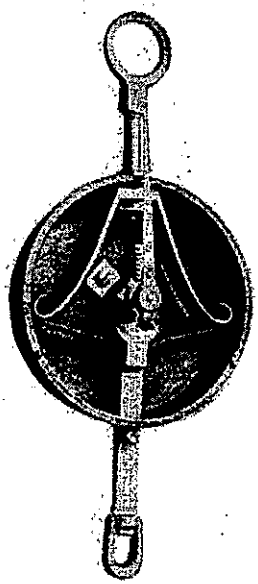


Fig. 41
Siebe Spring Balance

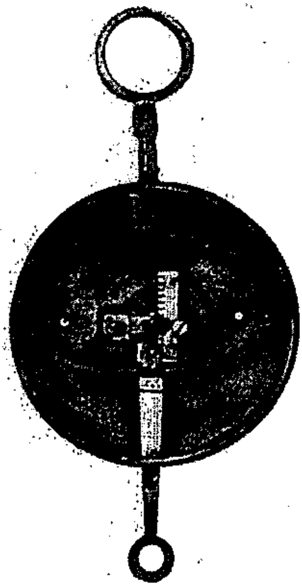


Fig. 42
Elliptical Spring Balance

Price Computing Scales

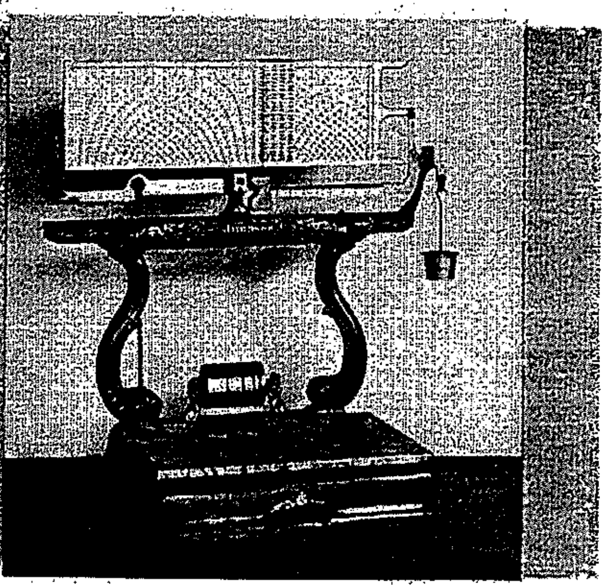


Fig. 44
The Stimpson Steelyard Computing Scale

In retail trade the ultimate purpose of weighing, say a joint of meat, is to ascertain its cash value in order that a transaction may be concluded between tradesman and customer.

The idea of making scales to indicate the value of the goods, as well as the weight, occupied the minds of inventors in the nineteenth century and towards its close many patents to this end were taken out in the United States, Great Britain and Europe.

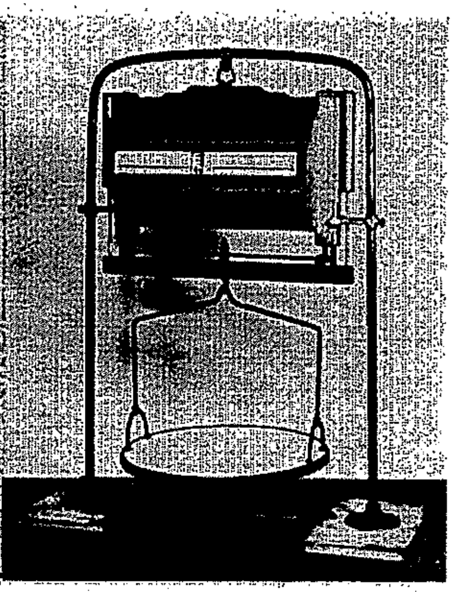
One of the earliest of the price indicating scales to be made on a commercial basis was the Stimpson steelyard computing scale, which made its appearance in 1897, mostly in the American market.

The scale was basically an ordinary counter platform scale fitted with a steelyard indicator, which carried a flat rectangular chart graduated in units of weight and price computations.

A flat weighted cursor slid along the chart or steelyard to balance goods up to ten pounds in weight. On the vertical edge of this cursor were graduations representing prices per pound, and these enabled the value of the goods to be read at any price per unit, within the range of the instrument.

Goods over ten pounds in weight were balanced with the aid of additional loose proportional weights placed on the counter-balance stem hanging from the end of the steelyard.
The scale was not automatic and so was slow in use.
Stimpson's scale was followed by the Dayton automatic computing scale with suspended pan, Fig. 45, familiarly known in Britain as the swinging pan cylinder.
Two helical steel springs balanced the load and a rack and pinion served to rotate the cylindrical chart on which were marked both weights and price computations. Two air dashpots damped out excessive oscillation.

Fig. 45
The Dayton Computing Scale, with suspended pan



The inconvenient swinging pan was soon replaced by a goods fitting, carried on a Roberval lever system and, in 1907, Henry Pooley & Son, Limited, by arrangement with the Dayton Computing Scale Company, and after making several improvements, successfully submitted to the British Board of Trade a scale of the type illustrated in Fig. 46.
This was to be the conventional form of price computing cylinder scale for many years.

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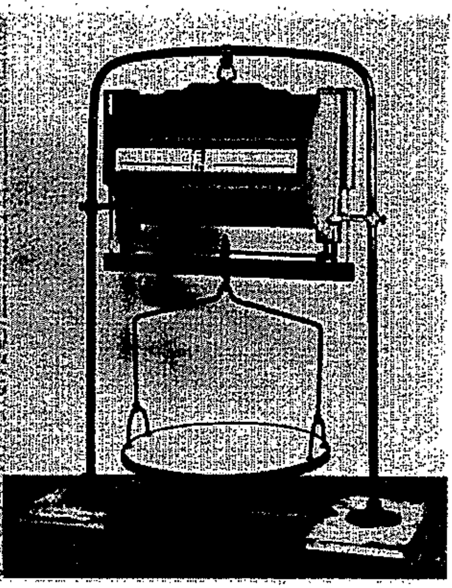

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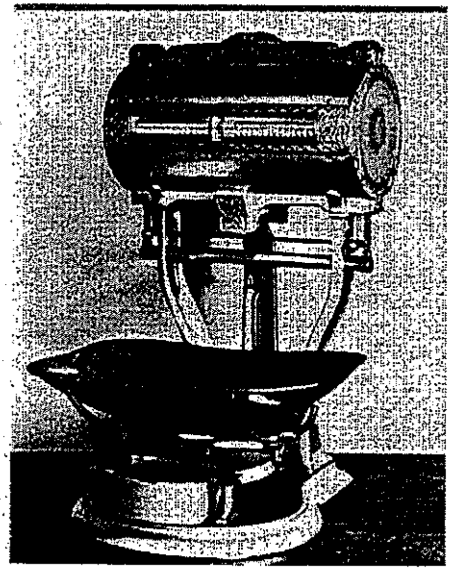
One of the chief modifications to this type was the introduction of a pendulum resistant unit, in place of the springs, by the Toledo Scale Company of the U.S.A., under De Vilbiss Patents. Fig. 47 shows the first machine of the pendulum type brought to England and sold through the agency of W. & T. Avery, Limited, and now in the Avery Historical Museum. The original De Vilbiss Patents were for a fan computing scale with a pendulum resistant.

Modern counter scales of the cylinder type usually have a capacity of twenty pounds, with a minor division on the chart of half an ounce. Since the Weights and Measures Regulations of Great Britain require, on verification of a new scale, an accuracy of half a sub-division, this means that the scale must be accurate to one part in 1,280. Manufacturers would hesitate to submit a new scale of this kind to an Inspector of Weights and Measures if it were not accurate to at least one part in 1,800. Only a great technical skill and extreme accuracy in manufacture have made possible the commercial production of reliable scales to this standard.



'ig. 46 The Dayton "Royal" Computing Scale

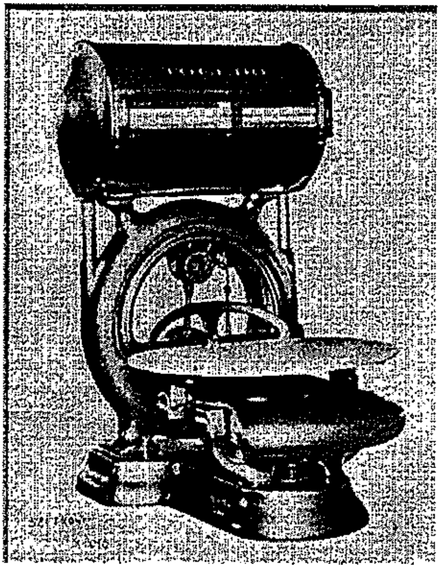


Fig. 47 Avery-Toledo Cylinder Scale,

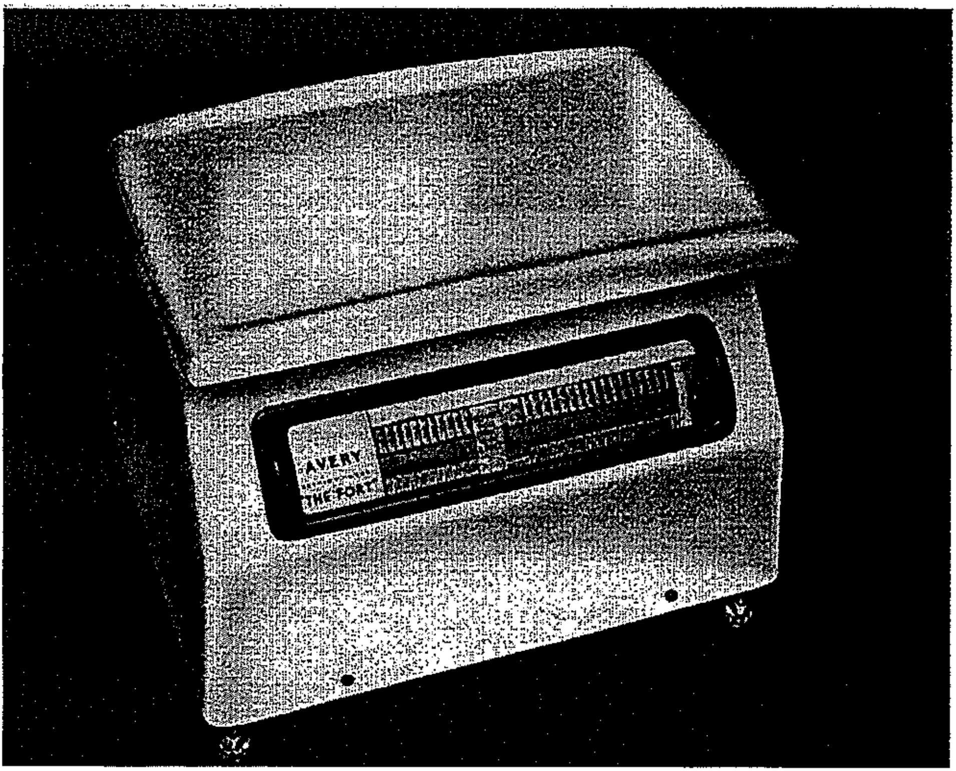


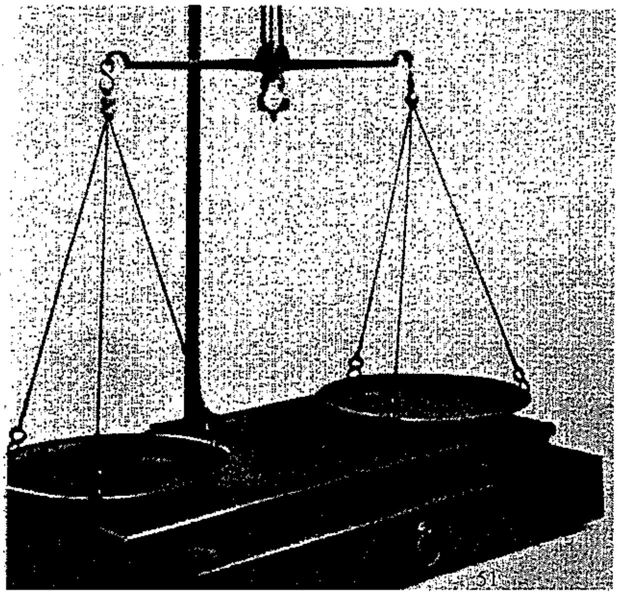
Fig. 48 Modern Avery Box Cylinder Scale

Precision Balances

The scientific research worker of the eighteenth century had to be content with the accuracy of weighing provided by the box-end or swan-neck beam scales. He used very similar instruments to those made for the jeweller and the apothecary and no doubt the best possible craftsmanship was employed to adjust them. They were indeed capable of a very fair degree of accuracy.

Dr. Joseph Black (1728-1799) probably used the swan-neck beam scale shown in Fig. 49, when he conducted his fundamental researches on the alkali substances and laid the foundations of modern quantitative chemistry. This simple and historic instrument is preserved in the Royal Scottish Museum at Edinburgh and contrasts sharply with the improved balance shown in Fig. 50, which was made for his successor, Professor T. C. Hope, who held the Chair of Chemistry in Edinburgh University from 1798 to 1844.

Fig. 49 Dr. Joseph Black's swan-neck Beam Scale
(By courtesy of the Royal Scottish Museum, Edinburgh)



This is a remarkably advanced design. The beam is light and well designed though lacking diagonal struts. The bearings are delicately balanced planes, exactly positioned by the relieving device, which also lifts the central knife-edge from its bearings. Famous names, such as Troughton, Ramsden and Fidler were associated with the construction of fine precision balances in the closing years of the eighteenth century, most of them inspired by the requirements of eminent men of science and medicine.

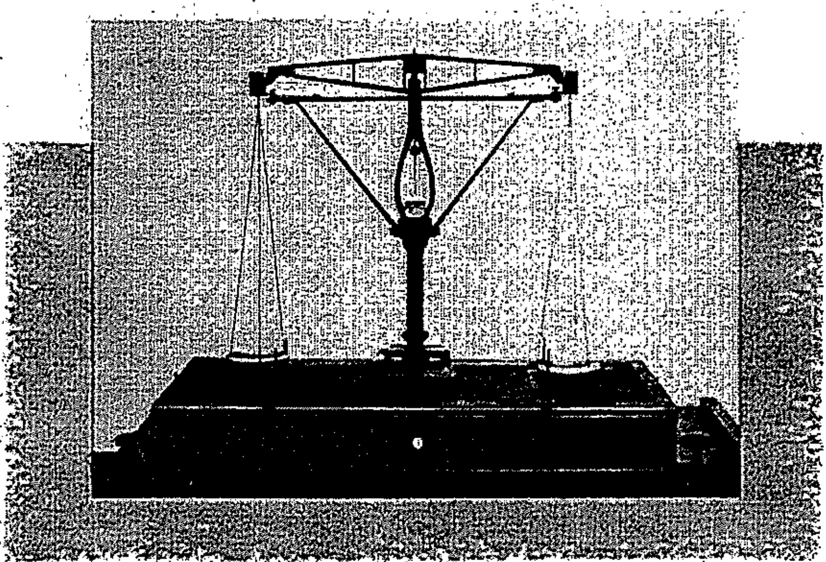


Fig. 50 Professor T. C. Hope's Precision Balance
(By courtesy of the University of Edinburgh)

In the effort to combine lightness with rigidity many designs of beams were tried, one precision balance, which is preserved in the Avery Historical Museum, has a beam formed by two slender cones made from thin sheet brass, joined at their base at the centre of the beam.

From these types the most accurate form of weighing instrument has evolved and today it is possible to weigh with a sensitivity of one part in half a million, which is the most accurate physical measurement known to mankind.

Whilst perfection of basic technical detail may have been reached in the early years of the twentieth century, there have

Industrial Self-indicating Scales

Many ideas for heavy capacity scales of the self-indicating type have been tried and whilst several of these have become obsolete, they were nevertheless ingenious and interesting.
Hydrostatic balances were constructed as early as 1874 by Henry Pooley and some remained in use for many years.
The indicator consisted of a beam or lever, one end, A, of which was connected to a conventional load carrying system of a platform scale or weighbridge, Fig. 52. From the other end, B, was suspended a counterpoise, C, dipping into a tank of liquid, usually water. When a load was applied on the weighbridge, the end, A, was pulled downwards and the counterpoise was raised out of the water, thereby losing part of its buoyancy until a position of balance was found automatically. In one version of the scale an indicator, D, was driven from the motion of the lever by means of a chain and drum, and the weight was thus read on a graduated chart. In cold weather the weighman had to keep a fire near the water container to prevent freezing, and, of course, evaporation of the water had to be made good. In the earlier models the weight was indicated by an inclined glass sight tube showing the level of the liquid in the tank.

Fig. 52
Hydrostatic Balance

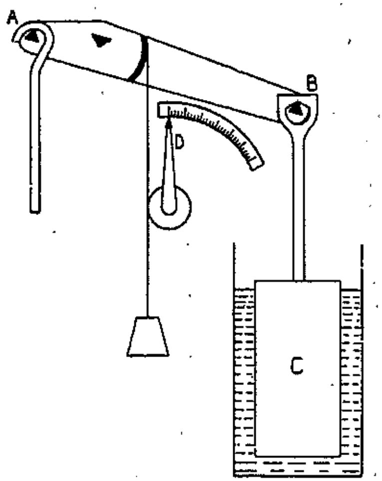


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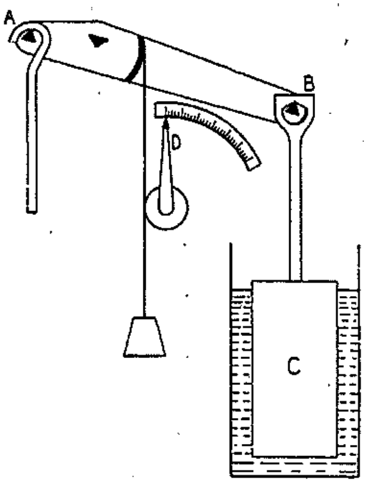
Fig. 52
Hydrostatic Balance



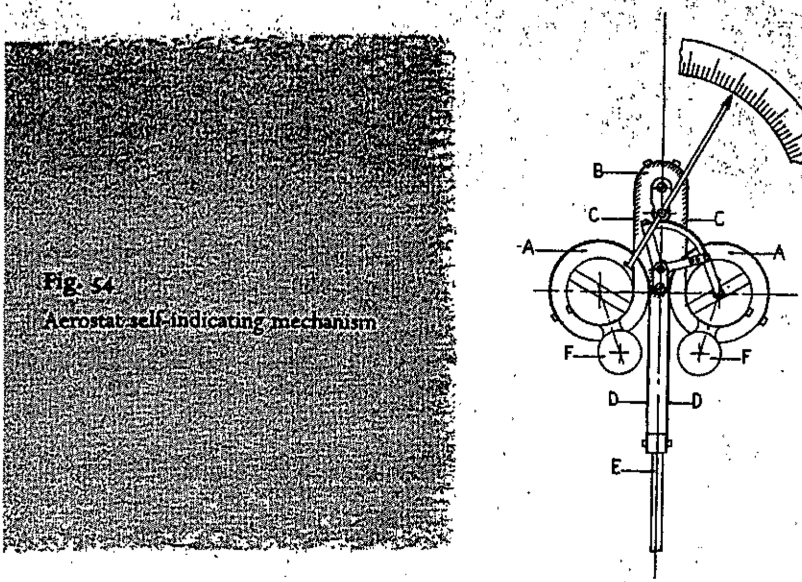


Fig. 54
Aerostat self-indicating mechanism

The Aerostat mechanism was applied to platform scales and weighbridges by W. & T. Avery, Limited, in 1906.

One of the major difficulties with the early designs of dial scales was to provide sufficient indicator movement for a full circular chart and at the same time obtain the necessary accuracy of motion to enable such charts to be divided into a large number of equal divisions.

In 1924 Avery introduced a semi-self-indicating platform scale which was marked with very small sub-divisions of weight. Fig. 55 shows one variation of this model, the invention of C. Mc. G. Sykes. Essentially there was a steelyard with a sliding poise for balancing the major units of the load, such as the tons or hundredweights, and a subsidiary pendulous resistant unit which gave automatic indication of the minor divisions.

A spring-operated pointer indicated to the weighman the correct position in which to place the poise on the steelyard.

In later models the movement of the poise set the appropriate weight figure in a flash opening and the total weight was read at a glance, see Fig. 56.

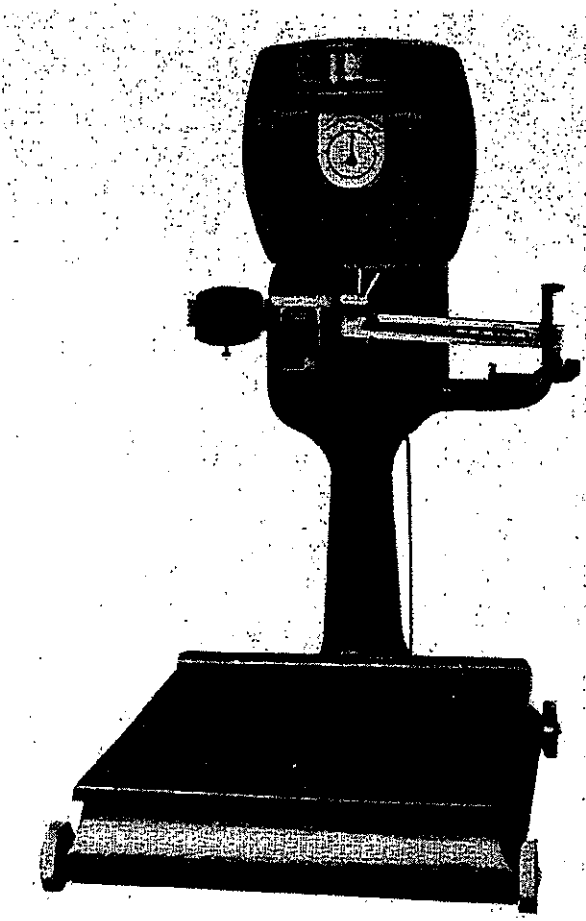


Fig. 55
Semi-self-indicating Platform Scale (1924)

This period saw the introduction of scientifically designed mechanisms for dial scales which revolutionised industrial weighing processes. Many of these mechanisms, improved in detail, are still in production and of these the Toledo double pendulum mechanism (Fig. 57) operates on the same principle as the Aerostat.

In the Toledo mechanism the circular drums are replaced by sectors and the pendulum ball and stem are more in evidence. The method of transmitting the motion from a yoke through a rack and pinion to the indicator is simpler, and equality of divisions on the chart is obtained by mounting the sector faces eccentrically with one another. The Toledo mechanism has been copied extensively since the patents expired. It is used both as a double pendulum unit in dial scales and also as a single pendulum unit in counter scales.

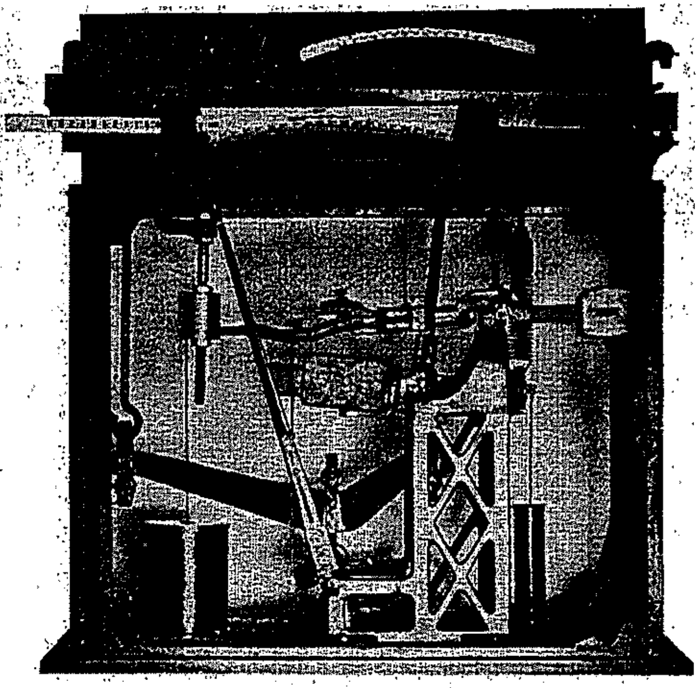
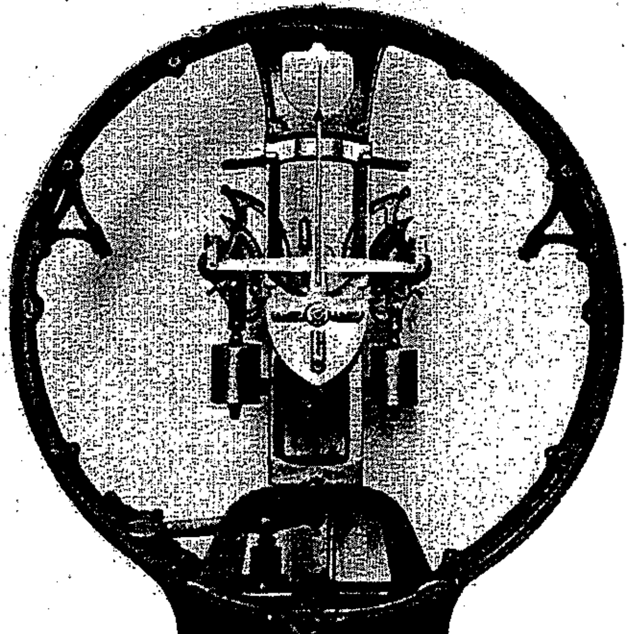


Fig. 56. Semi-self-indicating Mechanism for Weighbridges



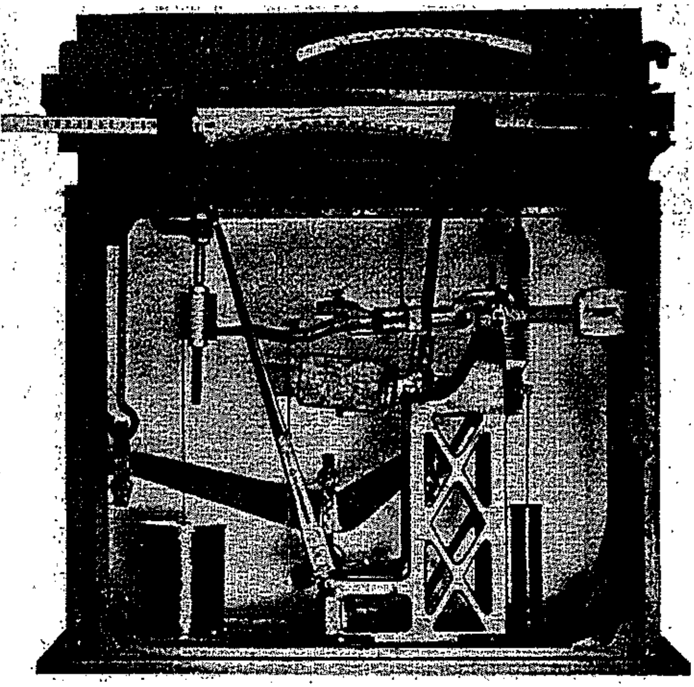
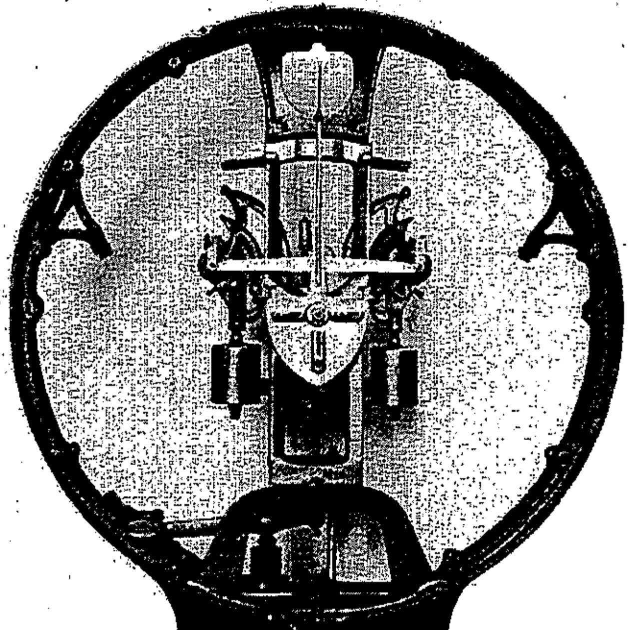


Fig. 56 Semi-self-indicating Mechanism for Weighbridges



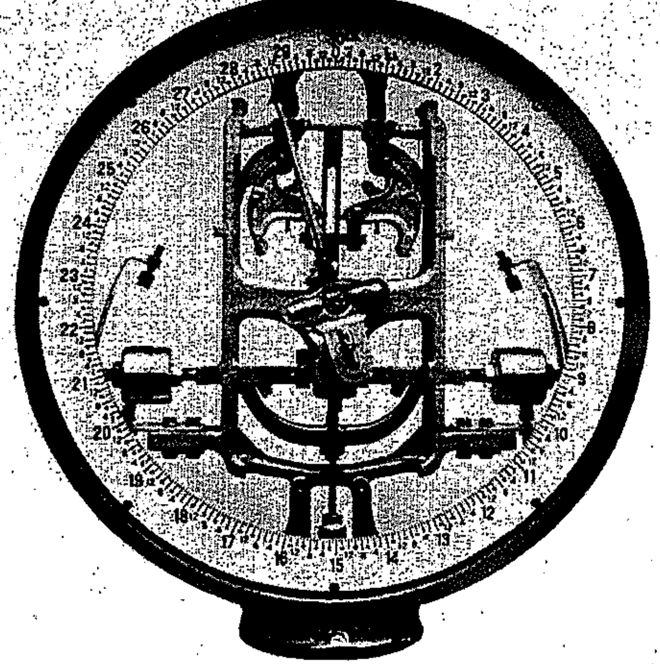


Fig. 58 Avery Cam and Lever Resistant Mechanism

W. & T. Avery, Limited, developed their own resistant unit (Fig. 58) in 1928. It operates on the principle of using eccentrically mounted cams to provide a variable leverage supporting a pair of loaded levers. As the load is applied, the rotation of the cam unit on its ribbon suspension brings the effective leverage of the whole mechanism to a value which enables the weight of the loaded levers to balance the pull from the load.

Many thousands of these dial mechanisms have been installed in scales used by industrial concerns all over the world. They have been fitted to platform scales of a few pounds in capacity and to weighbridges capable of carrying the largest locomotive. The mechanism, patented in the name of its designer, W. Timson, had a production run of thirty years before being superseded by a more conventional design.

Many industrial weighing applications impose conditions of severe shock loading and vibration in atmospheres both corrosive and dusty, but where weighing is vital to the proper control of the process.

For such applications scalemakers have designed spring-operated weight-resistant dial mechanisms which permit a more simple and robust construction than the pendulum counterpart. By using specially wound and heat-treated springs of a suitable alloy, associated with other components of precision design, it is now possible to construct a robust spring dial to compare very favourably with the best pendulum mechanisms for accuracy and stability over a wide range of temperature.

A further development came with the dial recording scale arranged to print a record of weight on tickets and tape.

The Avery dial weight recorder, Fig. 59, was introduced in 1935, and became a popular fitting in weighbridge installations where it provided a fraud-proof record of all weighings. This recording mechanism was the first of its kind to be accepted for use for trade purposes in Great Britain and remained the only one for many years to satisfy the Weights and Measures Regulations.

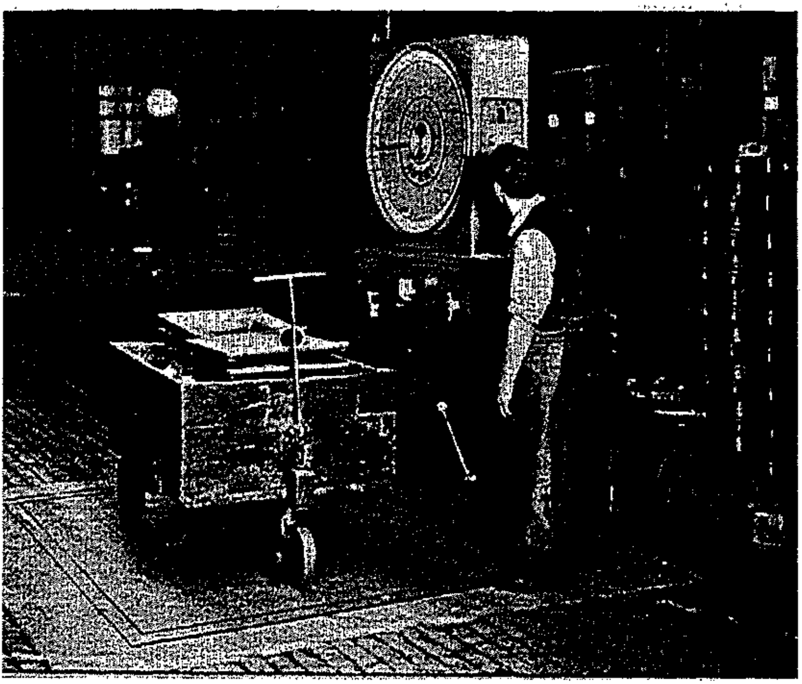
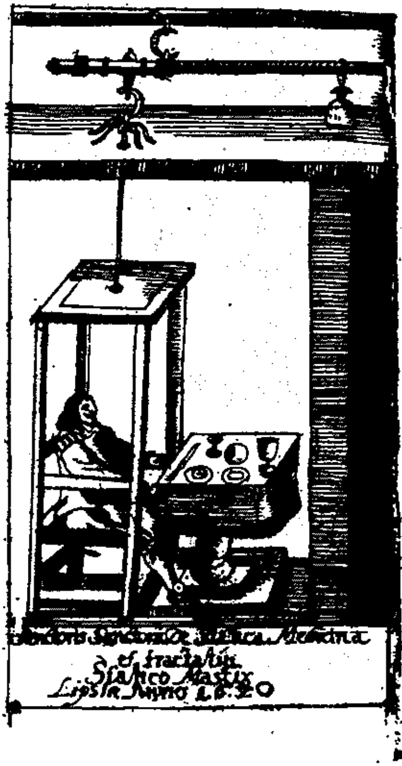


Fig. 59 Avery Dial Recorder

recorded on a counting mechanism so that the total weight of material handled is easily ascertained. In practice the operation is not as simple as described, for compensations have to be made for irregularity of flow and for such factors as the weight of material in suspension when the feed gate closes.

One of the largest automatic grain scales is shown in Fig. 60. This is one of the scales weighing grain for export at Montreal, Canada, and has a hopper capacity of six short tons. After being weighed in these scales the grain is conveyed into the holds of ocean-going ships.

Recently a number of these machines of five tons capacity have been installed for the Clyde Navigation Trust where they serve to weigh and record the grain brought from overseas and discharged from the ships into silos on the docks.



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Correctior.

LIPSIÆ,
Apud Hæred. SCHÜRERI, GÖTZIANORUM, & JOH. FRITZSCHIUM.
Anno 1670.

Plate XII SANCTORIOUS AND THE WEIGHING CHAIR

The illustration is taken from the 1670 edition of De Re Medicina a copy of which is in the library of the Avery Historical Museum.

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The illustration is taken from the 1670 edition of De Re Medicina, a copy of which is in the library of the Avery Historical Museum.

Fig. 61

For a period, ticket printing person scales were in vogue and novelties, such as machines using a special gramophone record, spoke the person's weight.

Fig. 62 shows the modern trend in person scale design. On good sites in the holiday season these scales take many pounds in cash each day. Fig. 63 shows in sharp contrast the style of machine preferred fifty years before.

Fig. 62
A modern Avery Coin-freed Person Scale

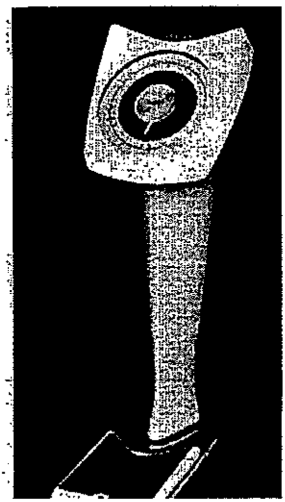
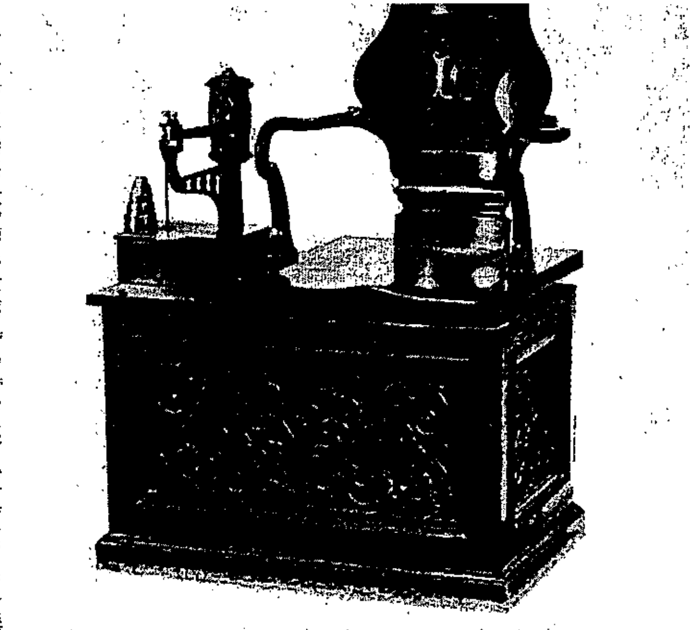


Fig. 61



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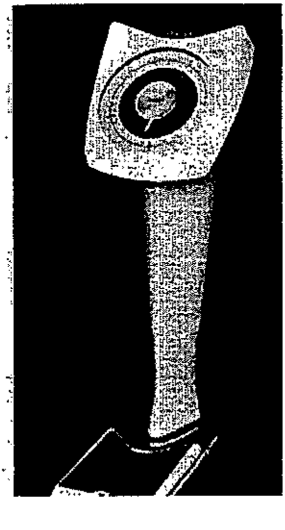

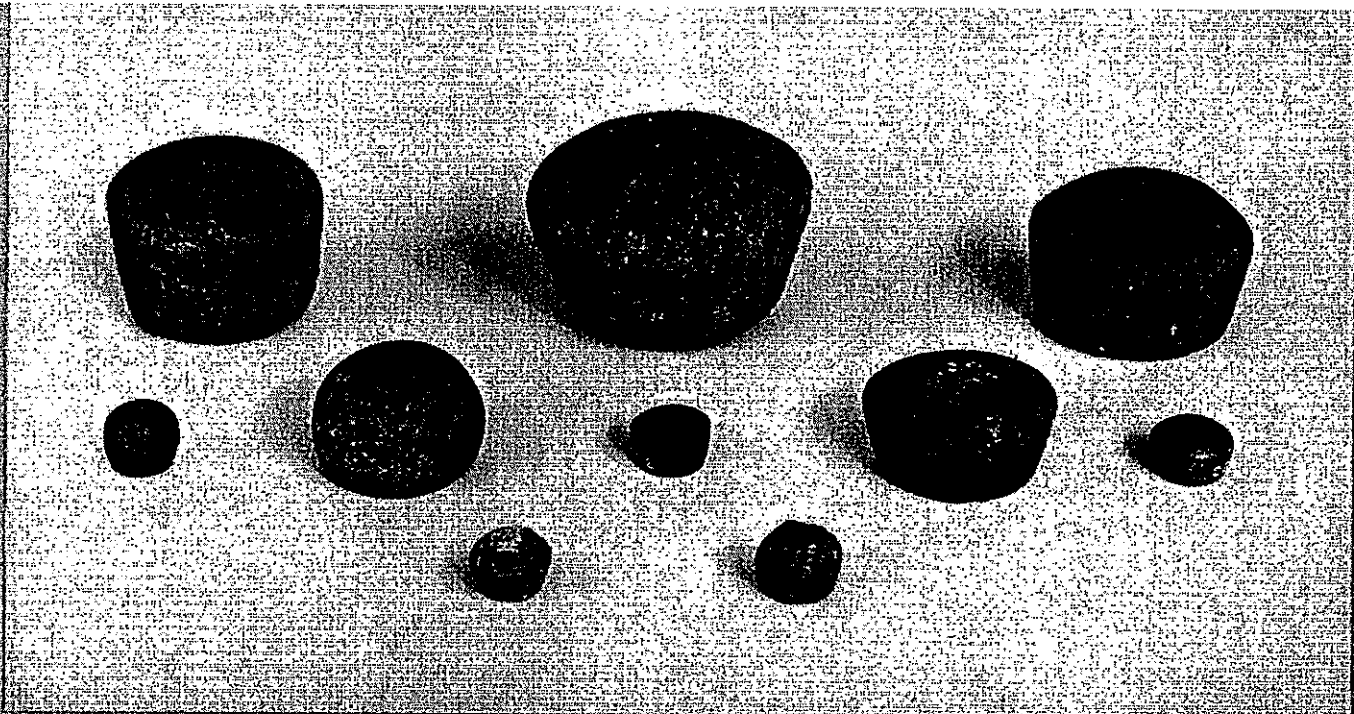

Plate XIII Ancient Egyptian weights in the Avery Historical Museum

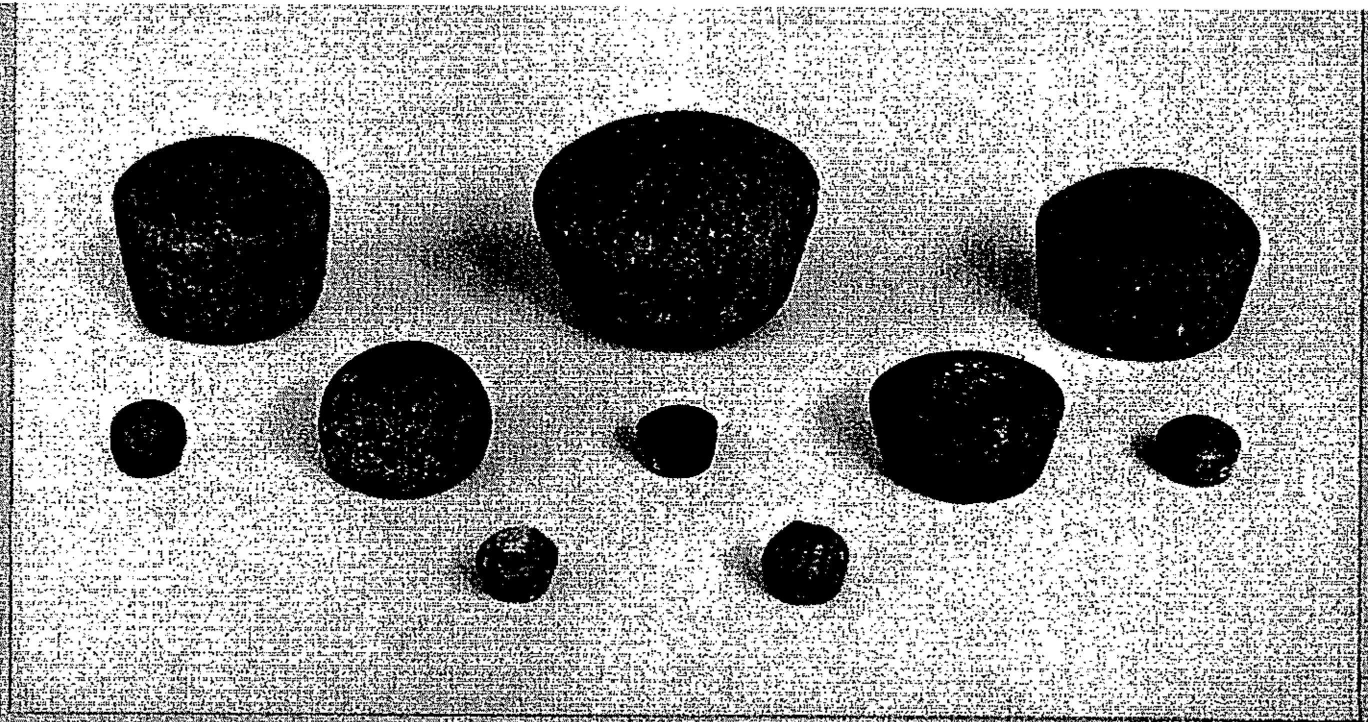

Plate XIII Ancient Egyptian weights in the Avery Historical Museum

Some Interesting Weights

Early weights were as primitive as the scales with which they were used and were originally simple pieces of hard natural stone of convenient size and shape.

Plate XIII shows ten ancient Egyptian weights mostly of syenite, a form of granite found at Syene in Egypt, and dating from about 2500 B.C. The smaller ones are of bronze and are not earlier than about 500 B.C. Corrosion has materially affected the bronze weights whereas the stone ones show no visible signs of deterioration.

The Avery Historical Museum contains a large collection of stone weights of several ancient civilisations, and also some of more recent times from English counties, including a very fine pair of weights made from large rounded granite pebbles and found in Jersey; they are about 200 years old.

Lead and bronze were used by the ancients for the manufacture of their metal weights.

Also in the Avery collection is a number of Arabic Weights made of glass intended for the weighing of coins and dating about A.D. 1200. They bear Arabic inscriptions and are astonishingly accurate.

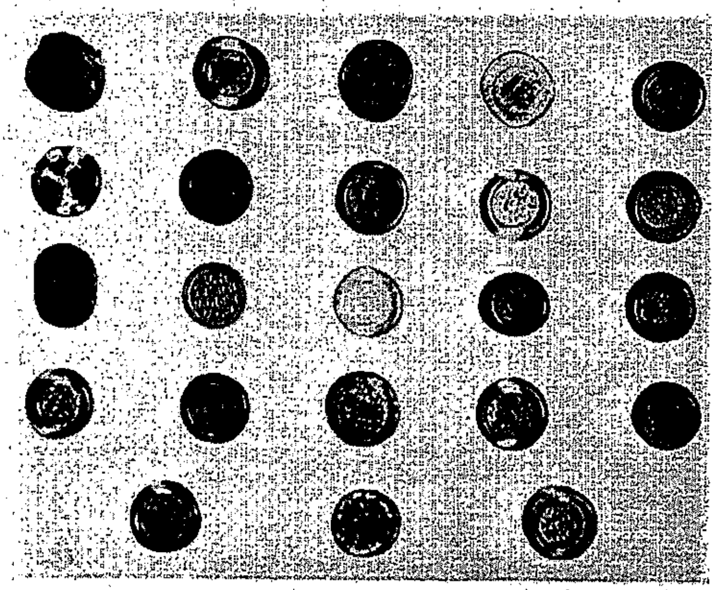

Fig. 64 Arabic Glass coin Weights

English Wool Weights have aroused much interest amongst collectors probably because of the royal coats of arms which they always bear. Plate XIV illustrates a wool weight of the reign of Charles I. It is a seven pound weight bearing the Royal Arms and the Royal Cypher, also the Avoirdupois A, the Ewer mark of the Founders' Company and the Guildhall Dagger of the City of London.

Wool weights were carried, slung on straps across the saddle, by the tronator whose duty was to assess the tax on wool, a staple industry in those times.

Zoomorphic weights have been in use since very early times, for example the bronze animal-shaped weights contemporary with the height of the Egyptian civilisation and shown with the scale in Fig. 6.

A survival until recently is exemplified by the Hentha shaped weight from Burma, Fig. 65, the hentha being a legendary bird supposed to have found a nesting place on the site of the ancient town of Pegu.

Fig. 65

A seven pound bronze wool weight of the Reign of Charles I, in the Avery Historical Museum.

This weight lacks the usual hole for the carrying strap.

Plate XIV

Weights and Measures Systems

Many learned books have been written by famous archaeologists who have devoted years of their lives to the study of the origins and evolution of systems of weights and measures.

The subject has its controversialists and only a very slender outline can be attempted in this brief chapter giving a general picture.

The earliest measures were those of length and were derived from limb measurements, which provided a convenient approximate standard readily available to everyone.

These limb measurements and their derivatives are usually associated with the ancient Egyptians.

The cubit, about 18 inches, was the length of the bent forearm from the elbow point to the finger tip. The span was the length spanned by the outstretched hand from the thumb tip to the tip of the small finger, and was half the cubit, or about 9 inches. The palm was the breadth of the fingers and was one sixth of the cubit or 3 inches approximately. The digit was the breadth of a finger, one twenty-fourth of a cubit or ¾ inch. The fathom was the outstretch of the arms or four cubits.

About 4,000 years B.C. the Egyptian cubit was established at a length equal to 18.24 modern English inches. Some authorities claim that it was deduced from the measurement of the quarter meridian of the earth, the distance from the pole to the equator. One meridian mile is equal to one minute of arc on the meridian and it has been suggested that there were 4,000 cubits to the meridian mile. This unit was common to Babylonia, Egypt and later to Assyria, and probably originated in Chaldea.

The Egyptian foot was created as a more convenient unit and was made equal to two-thirds of a cubit, or 12.16 inches.

Other cubits were later established arbitrarily, notably the Egyptian Royal cubit of 20.64 inches. Egyptian standards passed to Greece and became known as the Olympic standards.

Standards of weight followed and were based on the measures of length. The talent was the weight of an Egyptian Royal cubic foot of water, and was divided into 3,000 shekels. Its weight was 93.65 pounds, making the shekel 218.5 grains, exactly half the ounce of Plantagenet times. The English silver halfcrown weighed 218.8 grains.

The Egyptian Royal cubic foot, containing one talent weight of water, was increased in size by 22 to 25% by volume to contain one talent weight of grain and so became the Egyptian bushel.

The Roman libra of 12 ounces, each of 437 grains or two shekels, passed to Britain and was raised to 16 ounces.

The Imperial pound was established in the reign of Queen Elizabeth I as a pound of 16 ounces each of 437.5 grains, the same subdivisions as for the present standard.

Before the Norman Conquest the Marc of Cologne was brought to England probably for use only as a mint standard for the later Saxon Kings, since the 16 ounce Roman pound was already established as the commercial weight.

With the Conquest, the Saxon pound became the Tower pound, the king's treasury or mint being in the Tower of London. From the Tower pound were coined 240 silver pennies of 22½ grains giving 5,400 grains to the pound.

The pound of Troie is mentioned during the reign of Henry IV and was proclaimed the Royal pound in 1527, when by 18 Henry VII—"The pound Towre shall be no more used, but all manner of gold and sylver shall be weighed by the pound Troye which excedith the Pound Towre in weight 3 quarters of the ounce." Troy weight is now used only in the bullion market.

The present pound avoirdupois may therefore be said to have its origin in the remote past, but its present exact and legal value is defined in relation to a purely arbitrary standard by Section 13 of the Weights and Measures Act of 1878, and is known as the Imperial Standard Pound. This was constructed in 1844 in the form of a cylindrical piece of platinum of diameter slightly less than the height, and with a circular groove for an ivory lifting fork.

The Imperial Standard Yard is now also an arbitrary standard and is a bar of Bailey's metal (an alloy of copper, tin and zinc), into which are set two polished gold studs whose faces coincide with the neutral axis of the bar. Three fine lines are ruled on each stud at right angles to the axis of the bar. The length of the yard is defined, in the Weights and Measures Act of 1878, as the distance between the central lines at the two ends when the bar is at a temperature of 62 degrees Fah. These are in the custody of the Controller of the Standards Department of the Board of Trade.

Similar arbitrary standards exist for the International Prototype Metre and the International Prototype Kilogram. The original basis for the metric system was considered to be a metre equal to one ten millionth of the quarter meridian.

The arbitrary material standards of modern times are necessary for the irregularity of the spherical form of the earth makes exact natural measurements impossible.

Different standards of weights and measures have persisted in use throughout the World particularly in Eastern countries, many of them loosely controlled and indeed varying from one community to another and sometimes even between buyer and seller. Such countries are generally underdeveloped both commercially and industrially and are in a favourable position to rationalise their weights and measures systems. Indeed many of them are doing so and are adopting the metric system.

Meantime the century-old controversy still flourishes between the supporters of the metric and the avoirdupois and foot systems, both of which are so firmly established amongst highly industrialised nations that there still seems little likelihood of one being abolished in favour of the other.

Modern developments in electronic computing and control systems, which are becoming accepted practice in weighing machine applications in trade and industry, leave no doubt in the mind of the technologist as to which system he would prefer.

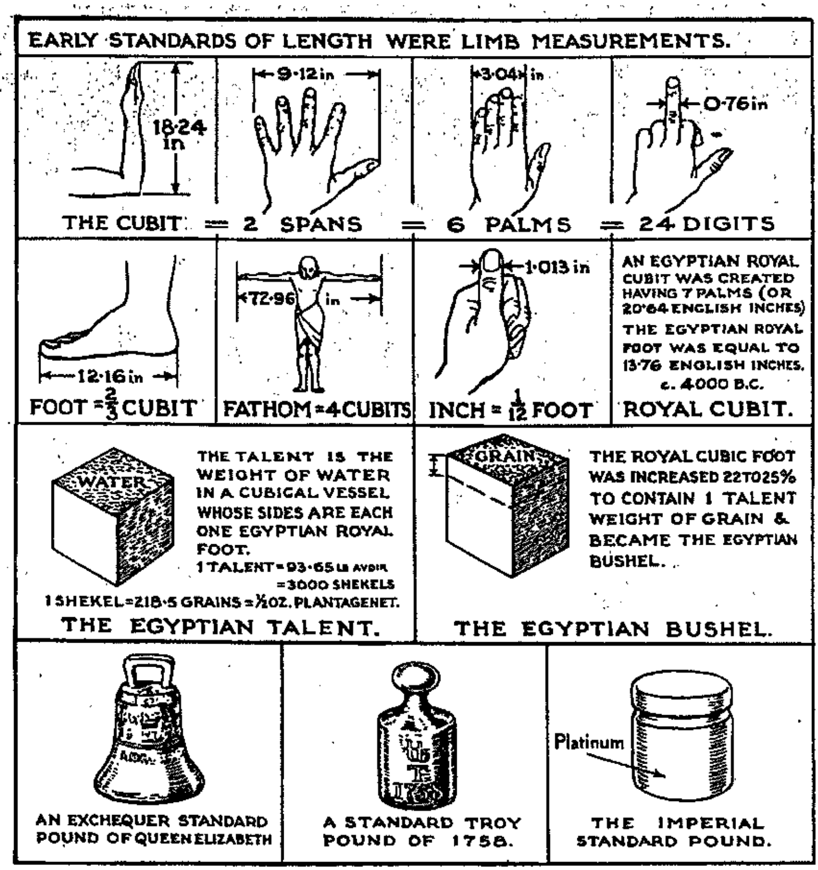

Fig. 66

Another landmark in the history of weighing and measuring was set up on July 1st 1959, when new international standards became recognised for the pursuit of exact scientific work.

They are:

The international yard equals 0.9144 metres

The international pound equals 0.45359237 Kilogramme