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The Design and Production of Pressure Gauges.

By R. A. COLLACOTT, Ph.D., B.Sc.(Eng.), (Associate Member of Council).

Introduction.

Pressure gauges are required for many purposes in engineering. These gauges must indicate accurately the pressure existing within a certain space when the pressure medium is either hot or extremely cold, under fluctuating or constant conditions, and when the gauge is subjected to vibration. Many devices have been developed to ensure that the gauge is capable of functioning properly under these conditions.

General Construction.

Pressure gauges usually function by measuring the distortion of a flexible envelope. In practice the envelope is either a bourdon tube or a flexibly mounted diaphragm, usually the former. The deflection of the envelope or tube is proportional to

(a) its rigidity, and

(b) the pressure applied,

so that provided a suitable means of measuring the deflection is fitted, the pressure acting upon the envelope can be indicated.

This deflection measuring device is referred to as a movement and is generally designed in such a manner that the motion of the free end of either the tube or the centre of the diaphragm operates one arm of a toothed quadrant, which in turn rotates a pinion. The angular rotation of the pinion is proportional (by means of a magnifying-ratio gear) to the movement of the envelope.

These gauges must be provided with a suitable calibrated scale over which a pointer moves to indicate the angular rotation of the pinion, and also a case to which the movement, scale and other fittings are connected as well as tappings to the flexible envelope (either bourdon tube or diaphragm) to admit the pressure medium at its working pressure.

For a satisfactory gauge all these components must be correctly designed, carefully constructed and intelligently employed.

Diaphragms. For pressure variations up to about 5 or 10lb./sq. in. it is generally practical to use a diaphragm as the flexible envelope; above this pressure, bourdon tubes are more generally employed. Gauges to test aircraft tanks can be produced with bourdon tubes to read with extreme accuracy down to 2½lb./sq. in.

Diaphragms possess considerable radial stiffness, but can be made very flexible in the axial direction. The flexibility of these diaphragms depends upon the thickness of the plate, material and number of the circular corrugations which are pressed into it. When secured at its edges, the centre can be flexed within reasonable limits without exceeding its elastic limit.

It is usual for diaphragms to be made from either copper, "yellow" brass or phosphor-bronze—preferably the latter, since this is stronger than the others for manipulative operations and possesses superior corrosion as well as fatigue-resisting properties. The material from which the diaphragm is made must be free from metallurgical impurities, uniform in thickness and composition and must comply within very close limits to the specification. Discs are then trepanned or punched out of the stock plate, annealed and then, after pickling to remove any scale, the corrugations are formed into the plate by pressing them on to a hydraulic press between suitable dies. Although this operation forms part of an automatic process, it requires considerable control to ensure that the corrugations are equally and uniformly made. The number of corrugations depends upon the stiffness (or flexibility) required. These corrugations are usually of circular design, for ease of construction, and the greater the number of corrugations the more flexible does the diaphragm become.

Within recent years, oiled silk diaphragms have been introduced in the place of these metallic diaphragms. This material has not, however, proved successful, due to the failures which have occurred.

The design of diaphragms for pressure gauges is a matter of experiment, in which experience is a very important factor. A plain disc, when flexed at the centre, will bend somewhat as shown in

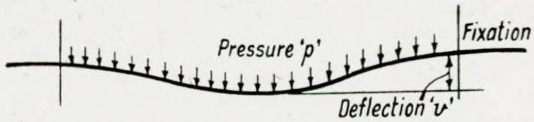


FIG. 1.—*Deflection of a plain disc evenly loaded.*

Fig. 1, in which the deflection at the centre is given theoretically by Morley* in the formula

$$v = \frac{3}{16}\,\frac{(m^2-1)}{E\,m^2 t^3} \times p r^4$$

where v = vertical deflection, in.

$1/m$ = Poisson's ratio

E = modulus of elasticity, lb./sq. in.

p = pressure lb./sq. in.

r = radius of diaphragm, in.

t = thickness of diaphragm, in.

The deflection produced in this way is, however, restricted to a very low value before the metal is strained beyond its elastic limit; it cannot be used in the "plain" state for small, sensitive gauges. When a corrugated impression is formed the diaphragm bends in the manner

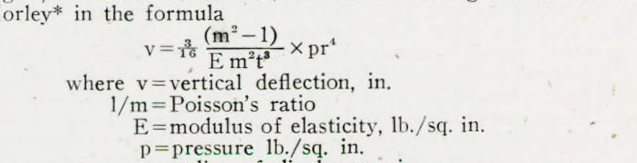


FIG. 2.—*Flexure of a corrugated disc.*

shown in Fig. 2, in which the initial flexure takes place in "unwrapping" the corrugation. Further corrugations increase this unwrapping effect and further increase the flexibility of the diaphragm.

Diaphragm Gauges. These diaphragm gauges are used principally for measuring the pressure of chemical systems, and are designed somewhat as shown in Fig. 3, which illustrates the Schaffer diaphragm gauge. The pressure element of this gauge is a corrugated disc which actuates a plunger which in turn applies a torque to the movement and so deflects the gauge pointer.

These gauges are much stronger at low pressure than the bourdon tube types, since a bourdon tube with equivalent sensitivity must be made very thin to operate at these low pressures. It has been suggested that these gauges should be used for pressures in the range of ½ to 10lb./sq. in.

* "Strength of Materials", by A. Morley, publ. Longmans.

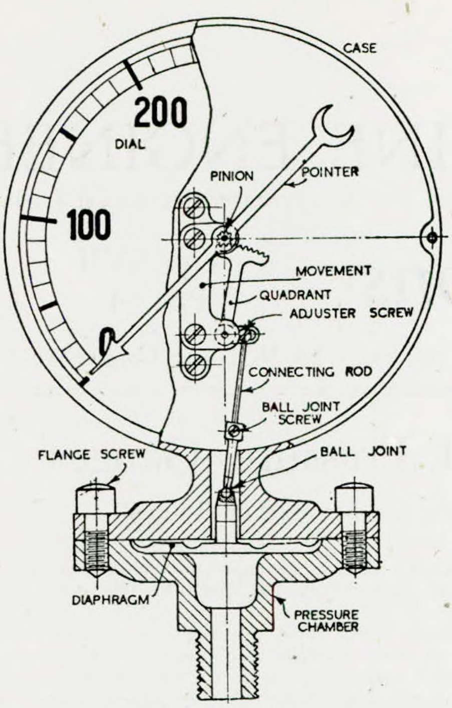


FIG. 3.—*Schaffer diaphragm gauge.*

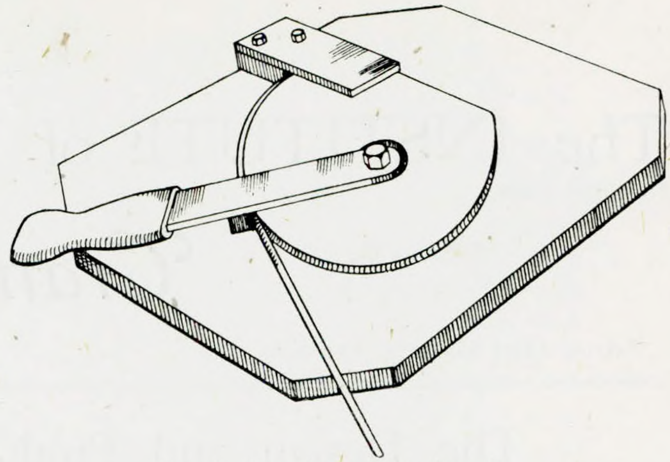


FIG. 4.—*Bourdon tube bending jig.*

Bourdon Tubes. These tubes are used very extensively for pressure-responsive elements in gauges of all sizes. They are bent into a circular shape, plugged at one end and secured to the pressure connection at the other. An elliptical section is usually given to the tube for the provision of greater flexibility, by reducing the "second moment of area" of the tube in the plane of bending. As is well known, the flexibility of the tube is acquired through the tendency of the curved tube to "unbend" when pressure is applied to the inside.

Bourdon tubes may be made from copper, brass, beryllium-copper, phosphor bronze, steel and Monel "K": the last two are generally used for large high pressure gauges. These tubes are made as small, round, seamless pipes, usually in lengths of 5 ft. (it is harder to control the quality of larger ingots to produce longer tubes); they are then rolled down in between two disc rolls, each with the half-tube shape turned into its circumference. The elliptical section is usually formed into the tube in one operation, the work-hardened tube being then cleaned (and received by the gauge manufacturer) in this condition.

These tubes must have a wall thickness designed to give sufficient strength to withstand overload pressures. Naturally the tube thickness influences the tube stiffness so that for a certain flexibility, the length of the tube varies as the thickness (and the tube thickness increases as the tube diameter); alternatively, the stiffness varies inversely as the tube dimensions. The actual tube dimensions are therefore a compromise between the requirements for strength and for flexibility. The following limits to which phosphor bronze bourdon tubes should be calibrated are given by Messrs. David Harcourt, Ltd. :—

Table I.

Bezel diameter, in.	1⅝	2	2½	3	4	5	6	7	8	9
Pressure, lb./sq. in.	5,000	4,000	3,000	2,000	1,500	1,200	1,200	1,000	800	800

As will be explained later, these pressures should refer to the "overload" pressures and not the maximum pressure.

At the gauge manufacturer's, the tube is bent in a jig (shown in Fig. 4) to the required shape. This jig is similar to the ordinary tube benders, except that a shaped former takes the place of the usual rounded former. Before bending, the tube is filled with a fusible alloy such as Cerrobend (Fry) or a fine sand, which helps to keep its sectional form when bending. Every care must be taken to ensure that the tubes are all bent in the same horizontal plane; slight hammering with a mallet may be necessary to preserve their shape. The fusible alloy is taken out of the tube after bending by immersion in warm water. Another process involves the forming of the tube when packed. While simple in principle, the forming of the tube is a critical process in the production of bourdon-type pressure gauges.

After shaping and pickling the tube is cut to size, again in a jig, plugged at the working end and secured to the pressure connection at the other. The design of the plug at the end of the tube must be such as to ensure its being effectively secured to prevent leakage, and to form a suitable bearing to connect the linkage to the movement. Various devices are available; their design depends upon the gauge specification, but in nearly all cases they are machined on automatic forming machines from round or rectangular stock and have a spigot at one end to enter or cap (and be soldered to) the bourdon tube, while hinge arms are milled into the other end. The tube is either soldered or brazed into the pressure connection. For very high pressures, particularly where steel is used, the tube is also screwed into the connection.

Bellows. Only very sensitive pressure gauges use bellow elements in their construction; they are, in fact, more frequently employed as the pressure-responsive elements for sensitive instruments and automatic controls, than in industrial gauges. The following notes, however, illustrate the precision involved in the manufacture of such pressure-responsive elements.*

Bellows are formed by means of a hydraulic process which forms them in one continuous operation. The basis of the one-piece bellows used for hydraulic forming is a thin seamless tube, the wall thickness of which is seldom greater than 5/1000 in., the equivalent of a sheet of paper. These tubes are deep-drawn in dies—a very difficult process—and entirely free from flaws. When this tube is inserted within dies (consisting of a number of plates equal to the number of the convolutions and spaced equidistant on and surrounding the tube) and subjected to high internal pressures, the thin wall metal flows into the cavities of the die, causing the tube to collapse endwise and form the bellows in one continuous operation. Besides being simple to employ for mass-production, the high pressures used during this process automatically test the bellows, which fail if the slightest flaw exists in their wall metal. Bellows are usually made from either brass or phosphor bronze, although cupro-nickel containing 30 per cent. nickel, 69 per cent. copper, and 1 per cent. tin, has been used quite extensively.

Movement. A movement is the mechanism used to transfer the movement at the end of the bourdon tube into rotary movement for the pointer. It consists essentially of a pinion and shaft (to which the pointer is secured), which engages with a toothed quadrant which is itself connected to the bourdon tube through a linkage rod. The whole movement is usually produced as a separate sub-assembly and screwed on to a mounting block in the gauge as in Figs. 5a and 5b.

Most of the components of the movement are punched out through dies and pressed to shape. The holes which are required are then drilled—again in jigs—into the various components. The toothed quadrant and pinion, originally blanked out in dies under the punching machine, are placed on gear cutters and toothed. The springs are usually bent up in the hardened condition. While it has been stated quite generally that the components are made up from jigs, most of the work involved is very exacting, so that while the

* These notes have been taken from a publication by the Drayton Regulator and Instrument Co., Ltd.

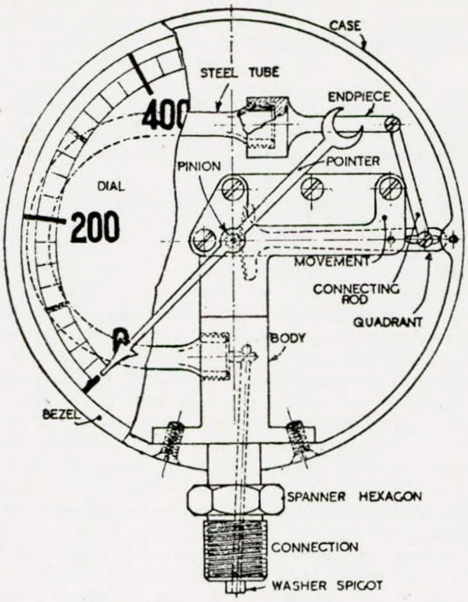


FIG. 5A.—*Steel bourdon tube pressure gauge.*

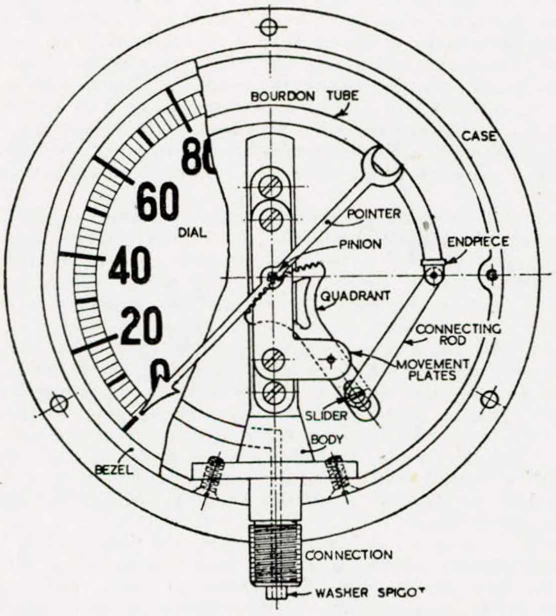


FIG. 5B.—*Ordinary bourdon tube pressure gauge.*

basic principles involved are elementary the maintenance of accurate dies occupies a considerable time.

Ratios vary from 5 to 1 in a great variety up to 24 to 1 and even higher with single stage gearing. The selection of ratio is dependent upon

(1) the application of the instrument,
(2) the pressure responsive element used;

i.e. for a very flexible phosphor-bronze tube indicating low pressures a fairly low ratio may be used, but if this tube had to stand a severe overload pressure it would be stiffened up, as the result of which its flexing or the movement of its free end is reduced; consequently, it would be necessary to employ a higher gear movement. Another example would be, say, a 6in. dia. pressure gauge of 10,000lb. per sq. in. dial reading. This gauge would employ a steel bourdon tube providing small flexibility, therefore a high ratio geared movement would be used—say, 24 to 1. No definite easy rule can be laid down as to either gear ratios or tube sizes.

The moving parts of commercial movements function within simple bearings comprising a plain journal and a reamered hole in the case of the movement. It is considered that as the loading and movement upon this bearing is small, a plain design such as this is sufficient for all practical purposes.

When assembled, the two casings of the movement, between which all the mechanism is placed, are generally secured together by means of two or more long bolts passing through tubular packing pieces. The gear wheels—the rack and the pinion—are generally pressed on to a spindle, although sometimes they may be locked by a nut running down the threaded spindle. These spindles are not usually provided with a positive method of preventing lateral movement; the force due to the "springing" of the case is simply used to retain them in position. The hair spring used to assist the return of the pointer is usually threaded through a fine hole in the pointer spindle and is locked to the case. This spring is used to ensure constant facet engagement between the teeth of the quadrant and pinion: the tension should just overcome the friction of the movement and may assist in recovering some hysteresis distortion of the tube. These forces are very small, hence the usual hairlike design of this spring.

Movements are usually made of ordinary commercial brass. The pinion and axle of the quadrant may be of nickel silver but otherwise even the spring is made from tempered brass or a near cuprous alloy, such as bronze, in order to eliminate corrosive influences as far as possible. A small amount of fine instrument oil may be used to lubricate the mechanism when it is first made, but even this should be minimised to prevent any possible "gumming up". After testing for back lash, the mechanism is then packed in cellophane in a cardboard box for despatch to the gauge manufacturer.

Mounting Block. A large block of metal holds the movement, contains the bourdon tube and embodies the connections between the pressure gauge and pipe line. Owing, therefore, to the diversity of movements, tubes and pressure connections, no standard form of mounting block has been designed.

Two types of block are illustrated in Fig. 6. The block Fig. 6a is used very considerably with steam, air and water gauges with

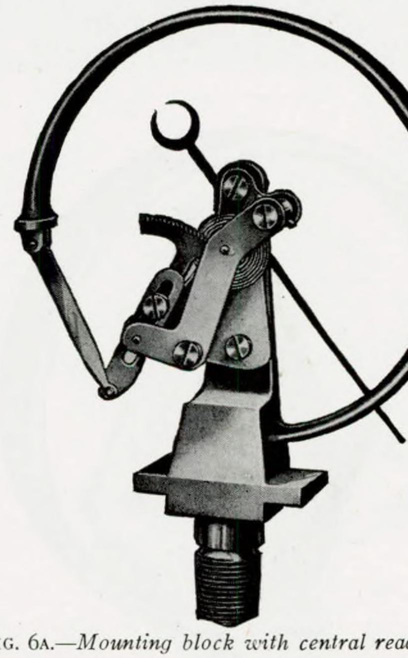


FIG. 6A.—*Mounting block with central reading dial.*

central dial reading mechanisms and open-back, rear flange type casings. The design illustrated in Fig.6b is of more robust construction; it is used with oxygen and acetylene gauges. With gauges for which the pointer is not centrally located as in Fig. 6c, a still further alternative design of mounting block may be required, as also with those gauges for which the pressure connection is taken through the back of the case.

Cast mounting blocks are seldom used these days in good quality gauges owing to their possible porosity. The modern method is hot press pressings or extruded brass. In all constructions the final thread must be machined out, generally by an individual process on each block. The core of the mounting is frequently machined at the connection to take a small orifice which is used to restrict any sudden pressure surges in the pressure line.

Pipe Connections. There does not appear to be any settled policy among engineers regarding the connections to be used when installing pressure gauges. Although B.S. Specifications Nos. 759

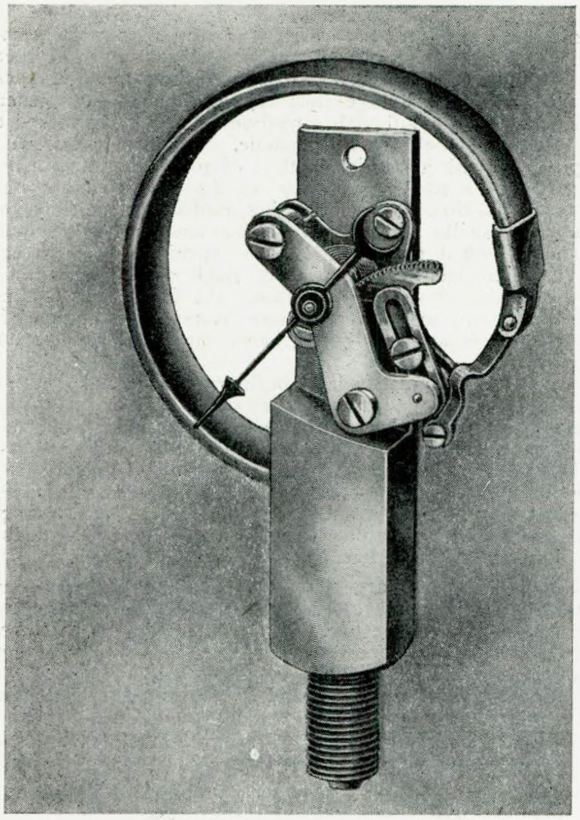


FIG. 6B.—*Mounting block for oxygen and acetylene gauges.*

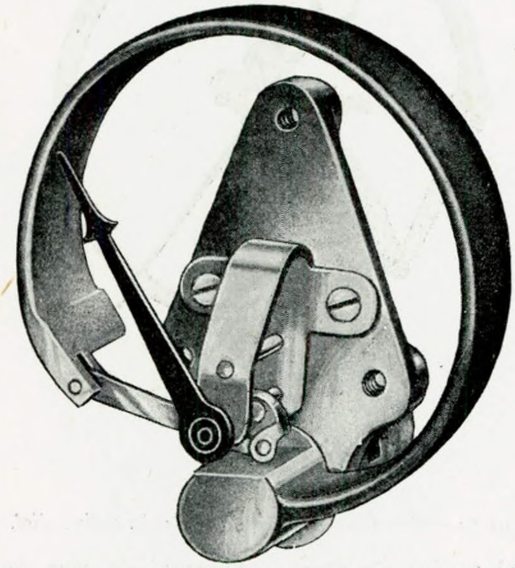


FIG. 6C.—*Mounting block with pointer not centrally located.*

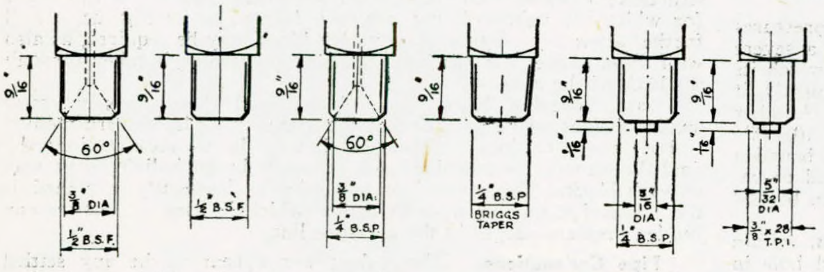


FIG. 7.—*Pipe connections for mounting blocks.*

(Valves, gauges and fittings for land boilers) and 1123 (Valves, gauges and fittings for air receivers and compressed air installations) make some general recommendations, it is not unusual to find gauges of the same type fitted with a variety of connections such as those shown in Fig. 7. Not only does the thread size vary, but also the diameter and the shape of the union. It is suggested that some action might be taken by engineers and the specifying societies to initiate such standardisation. The author would be pleased to co-operate in this matter.

Scale. The markings on the scale must depend upon the pressure response of the bourdon tube and movement in the angular deflection which it produces upon the pointer.

The linear law between angular pointer deflection and the measured pressure, can only be obtained by restricting the actual movement of the bourdon tube to a minimum. In seeking to compromise between tube movement, gear ratio, accuracy and linearity, it has become usual to specify the largest possible dial size and to limit the maximum useful angular movement of the pointer to 270°. In fact, to avoid overstraining the tube and to eliminate hysteresis lag effects—it is customary to use the gauge only up to about two-thirds of the maximum scale reading (B.S. Specifications 759 and 1123 recommend one-half up to a working pressure of 500 lb./sq. in. and two-thirds above). Thus, above 500lb./sq. in., the maximum reading on the scale represents the maximum pressure for which the gauge should be used for safety; from zero to two-thirds the maximum scale reading represents the range of pressure over which the gauge should consistently indicate accurately throughout its working life. The scale is, of course, marked at as great a radius as the dial size will permit in order that the distance between adjacent marks shall be as great as possible, consistent with accuracy.

The markings on the scale should not be too numerous or the scale may become confusing to read. So many different designs are necessary for varying purposes that it would be difficult to produce a general design, but invariably the smallest divisions should be no less than 1/20th of the maximum reading. Thus, with a gauge reading up to 600lb./sq. in. (note: working range 0 to 400lb./sq. in.) the divisions should not represent pressures of less than 30lb./sq. in.; in fact, such a scale might be designed with increments of 50lb./sq. in. Generally, a pressure gauge should be limited to a total of 50 or 60 divisions.

For highly accurate gauges, the scale is marked off by hand at the position indicated by the pointer for each pressure. With mass-produced gauges (which are more commonly used by engineers) the scale is printed on to an enamelled metal plate. There are many methods of printing the dials of mass-produced gauges, varying from the use of copper plates to extremely expensive steel dies, photo-engraved; both the transfer method and the offset type of printing are at present popular. One printing process is very similar to that employed for the printing of transfers in so far as a metal block is produced (made by photo-engravure from the original scale) bearing all the necessary markings for the dial and the particulars of the gauge; the block is heated and then pressed upon the blank enamelled plate with a special transfer paper superimposed between the two. This enables a black or coloured scale to be printed upon the enamelled metal plate.

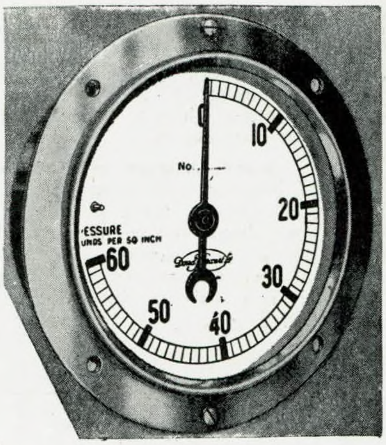
Luminous dials are etched or stamped and then filled-in by hand in chemical etching; the material may be undercut and so help to key the metal into the groove. The material used, and known as "radium" paint, is a mixture of phosphorescent zinc sulphide and radium (or mesothorium, roddon or some other such radio-active substance). Great care is required in the application of this material since any consumption of it by the operator can lead to serious physical complications. Many Board of Trade safety rules have been drafted limiting the time during which operators may be employed on this work, precautions to be taken in the work room and clothing which must be worn, etc.

Pointers. The form of each pointer is stamped out on thin metal sheets in a press with suitably shaped punching dies. Then, in another operation, the pintle bearing is expanded into the hole punched into the centre of the pointer blank. The whole assembly may afterwards be enamelled.

The shape of a pointer does not generally call for any particular comment; all the designs are made to indicate with a long sharp arm counter-balanced by a wide short arm on the opposite side of the central axis. Some pointers may even be "balanced" if the pressure is likely to vary rapidly and the gauge be required to follow these variations. When such a balance is required, the weight of the counter-balance is adjusted until the centre of gravity of the pointer is at the axis of the spindle. Several makers possess distinctive shapes to identify their pointers and gauges.

Case. Several different designs of case are used with commercial gauges; thus, they may have a flange back or flange front, or else plain ends, as shown in Figs. 8a and 8b. The final selection of any particular case depends upon the actual use to which it will be placed and the method of securing the gauge in position.

(*a*) *Flange back.*



(*b*) *Flange front.*

FIG. 8.—*Gauges with back and front flanges.*

Cases are usually pressed out under hydraulic presses and are therefore made from a material suitable for this purpose. A brass of high copper content is usually most suitable for this work, since it has excellent cold drawing properties and the pressing operation hardens it up by cold working the metal. Where the metal is deep drawn, or otherwise much worked, it is essential for the pressing to be normalised; i.e. lightly annealed to take out internal stresses, otherwise season cracking occurs very rapidly. Castings and hot brass pressings are also extensively used for gauge cases, particularly those of the rear flange type.

In many cases the dial is secured rigidly to the front to act as a baffle should any leakage take place in the tube connections; a "blow-out" back can also be fitted which will release the pressure. This blow-out is nothing more than a sheet of thin metal riveted at only two points with the "flapping" parts placed over large holes in the case back; any pressure build-up in the instrument is released by blowing out through these holes without the thin metal cover plate causing any obstruction. Other safety devices of this nature have been fitted, but the blow-out back is a simple and effective method.

Types of Pressure Gauge. Again the diversity of uses for which pressure gauges are applied precludes any generalisation of the subject.

Most gauges are of the common indicating type with a central pointer and geared movement. Sometimes a simple movement without any gearing may be used, as in Fig. 6c, which gives a sector or eccentric dial reading. With this type of gauge the multiplication ratio between the movement of the tube and pointer is less than that of the geared movement; it is not usually a very accurate gauge owing to the small scale size, but owing to the low sensitivity of the movement such a gauge is ideal for indicating the mean pressure in systems with slight pressure fluctuations. With vacuum gauges, the difference in pressure between atmospheric and that inside the bourdon tube (or diaphragm, if used) causes the movement to be actuated in the reverse direction to that which occurs when pressure is applied.

Among the special forms of pressure measuring instrument may be included the recording pressure gauge shown in Fig. 9, in which the movement actuates a pencil in such a manner that the position of the pencil corresponds to a certain pressure; this is marked on a circular chart mounted on a spindle and rotated at a steady constant speed. Similarly, a pressure controlling gauge may be used which affects or controls certain mechanisms at various pressures. This is achieved by pre-setting certain electrical contacts or mechanical trip gear to be upset at a pre-determined pressure and so actuate the controlled mechanism. Duplex gauges which involve a dual pressure responsive element utilise two pressure connections and pointers over a common scale marked off for either vacuum or pressure, or a combination of the two; one such compound gauge is shown in Fig. 10a. An example of a gauge which is claimed to be superior to the ordinary bourdon tube gauge because of the advantage its construction provides in giving a long scale vacuum reading and a short scale positive pressure reading, is the Harcourt diaphragm compound gauge (Fig. 10b). This was primarily designed and constructed for use on pumping units and patented in 1938. The vacuum graduations of 30in. of mercury is marked red on a long scale, and the pressure graduation in black on a short scale.

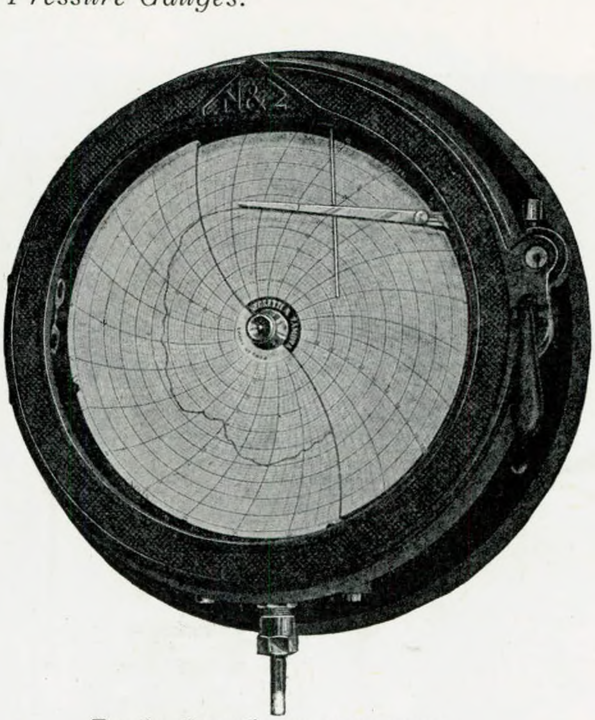


FIG. 9.—*Recording pressure gauge.*

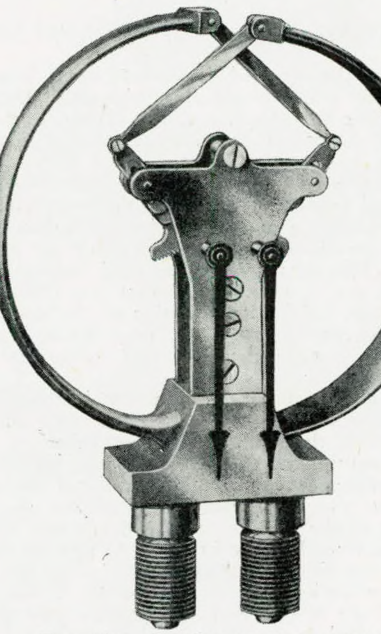


FIG. 10A.—*Duplex vacuum gauge.*

The pressure responsive element of this gauge is a non-ferrous metal diaphragm, working on the principle that a large area diaphragm is more flexible than one of small area (provided the thickness is the same in both cases).

Instead of using two diaphragm plates of different areas, this gauge employs only one, and provides the required dial reading by an arrangement of two different areas, into which the diaphragm flexes.

The diaphragm is circular in shape and has annular ribs or corrugations to ensure flexibility. It is secured at its periphery between two brass plates known as the front and rear housings. The

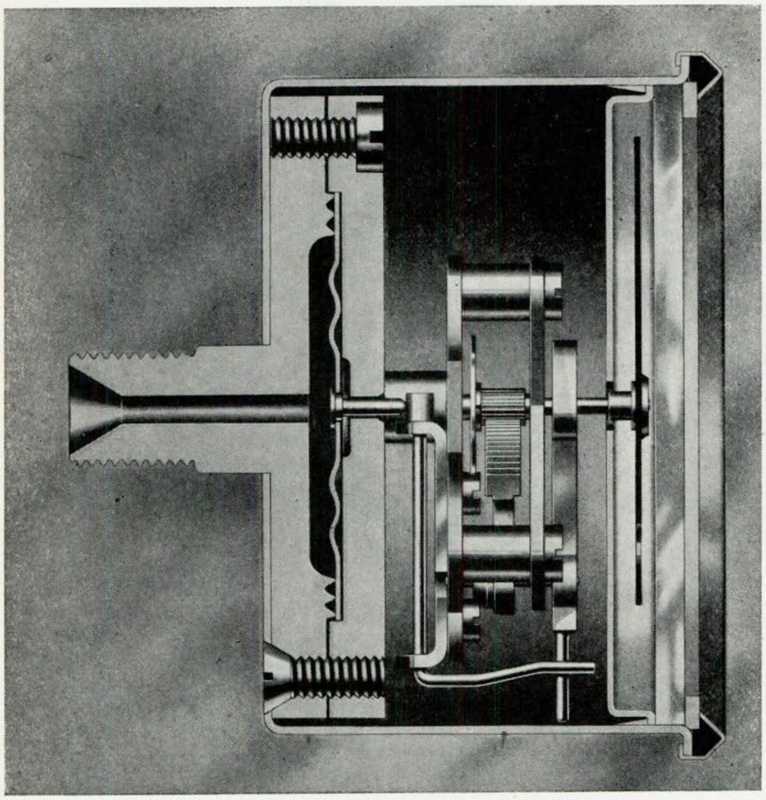


FIG. 10B.—*Harcourt diaphragm-type compound gauge.*

rear housing, carrying the screwed connection, has a large diameter cavity which allows the whole of the exposed area of the diaphragm to deflect when negative pressure is applied. When neither negative nor positive pressure is applied, the diaphragm lightly rests against the front housing.

Upon the application of positive pressure, the deflection of the diaphragm is restricted to the small cavity in the front housing. Thus, for negative pressures, a large area of diaphragm is deflected, and for positive pressures a small area is deflected. For an application of negative pressure of 30in. of mercury, the total deflection is approximately .025in., and for a positive pressure of 150lb./sq. in. the deflection is only .008in. This small motion of the diaphragm gives it long life as an excessive movement may strain it beyond the elastic limit, causing a permanent set and consequent inaccurate readings.

Attached to the centre of the diaphragm and protruding through the front housing is a stud or peg, which transmits the motion of the diaphragm through the multiplying mechanism to the pointer of the gauge. The multiplying mechanism is very similar to that of the bourdon tube gauge, except for the additional means of transmitting motion from the horizontal thrust of the diaphragm peg to the vertical plane of the stabiliser. The movement is mounted to, but raised from, the front housing in order to provide room for the rocker bar, which transmits the motion.

One end of the rocker bar has fitted to it an eccentrically mounted pad, whilst the reverse end is in contact with the stabiliser, which is in turn attached to the quadrant through its axle or spindle. When positive pressure is applied to the diaphragm it bellows forward, forcing the peg against the rocker bar pad, causing the reverse end of the rocker bar to swing the stabiliser and quadrant on the axle.

As the quadrant is geared up to the pinion (as in a bourdon tube gauge), the pointer which is mounted on the pinion indicates on the dial the pressure applied to the diaphragm. When negative pressure is applied the reverse happens, the rocker pad following the peg and the diaphragm.

The stabiliser is a piece of shaped metal so arranged that its weight is sufficient to ensure a constant connection of the rocker pad with the diaphragm peg. A hair spring mounted on the pinion ensures constant facet engagement between the teeth of the broad section or heavy-duty quadrant and the pinion. This gauge is of great service where pulsations are present and it is superior to the bourdon tube gauge for pumping units by virtue of its design and construction.

By combining two pressure responsive elements with two pressure connections on the same mounting block, it is possible to obtain a range of very interesting and useful instruments. If two bourdon tubes are suitably linked to a single movement, the resulting pointer deflection can be made to indicate the difference between two pressures, which by placing two tubes together and again linking their movement to a common point, is conveniently converted into a summation gauge, a device which is covered by the Barnet Instrument Co., in Patent No. 564159.

Other diverse forms of pressure gauge exist to meet special requirements.

Standardisation of Pressure Gauge. For the ordinary types of bourdon tube gauges used with steam, water or air up to, say, 500lb./sq. in., there is no real reason why a standardised range of sizes should not be specified. This would simplify manufacture and the issue of spares.

In their attempt to produce "standard" gauges within the limits given in Table I, the makers recommend the sizes in Tables II, III and IV.

TABLE II.

STANDARD SIZES.

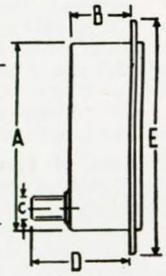
A Diameter of Bezel	B Overall Depth	C Size of Connection	D Centre of Connection to rear	E Diameter of Flange
$1\frac{5}{8}''$	$1\frac{1}{16}''$	$\frac{1}{8}''$ gas	$\frac{11}{32}''$	$2\frac{1}{4}''$
$2''$	$1\frac{1}{8}''$	$\frac{1}{8}''$ gas	$\frac{7}{16}''$	$2\frac{5}{8}''$
$2\frac{1}{2}''$	$1\frac{1}{8}''$	$\frac{1}{4}''$ gas	$\frac{7}{16}''$	$3\frac{3}{8}''$
$3''$	$1\frac{5}{8}''$	$\frac{1}{4}''$ gas	$\frac{11}{16}''$	$4''$
$4''$	$1\frac{3}{4}''$	$\frac{3}{8}''$ gas	$\frac{11}{16}''$	$5''$
$5''$	$1\frac{3}{4}''$	$\frac{3}{8}''$ gas	$\frac{11}{16}''$	$6''$
$6''$	$2''$	$\frac{3}{8}''$ gas	$\frac{3}{4}''$	$7''$
$7''$	$2''$	$\frac{3}{8}''$ gas	$\frac{3}{4}''$	$8''$
$8''$	$2\frac{3}{16}''$	$\frac{3}{8}''$ gas	$\frac{13}{16}''$	$9''$
$9''$	$2\frac{3}{16}''$	$\frac{1}{2}''$ gas	$\frac{13}{16}''$	$10\frac{1}{4}''$

Pressure, Vacuum and Compound Gauge with rear mounting flange.

TABLE III.

STANDARD SIZES.

A Approx. Diam. of Case	B Depth of Case	C Size of Connection	D End of Connection to Flange	E Diameter of Flange
$2''$	$1\frac{1}{16}''$	$\frac{1}{8}''$ gas	$1\frac{11}{16}''$	$3''$
$2\frac{1}{2}''$	$1\frac{1}{16}''$	$\frac{1}{8}''$ gas	$1\frac{11}{16}''$	$3\frac{3}{8}''$
$3''$	$1\frac{5}{16}''$	$\frac{1}{8}''$ gas	$2\frac{1}{8}''$	$3\frac{11}{16}''$
$4''$	$1\frac{5}{16}''$	$\frac{1}{4}''$ gas	$2\frac{1}{8}''$	$5''$
$5''$	$1\frac{7}{16}''$	$\frac{1}{4}''$ gas	$2\frac{1}{4}''$	$6''$
$6''$	$1\frac{3}{4}''$	$\frac{1}{4}''$ gas	$2\frac{3}{4}''$	$7''$



Pressure, Vacuum and Compound Gauge with front mounting flange and flush (panel) fittings.

Although these dimensions should not be accepted as mandatory for all gauges, it would represent a definite advance if some form of standardisation such as that referred to above could be undertaken. The author would be pleased to receive suggestions on this subject from interested engineers.

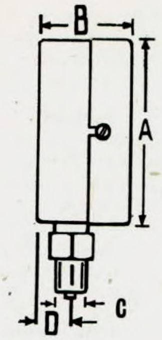
Testing of Pressure Gauges. Pressure gauges require to be tested for consistent accuracy over their working range under working conditions.

Temperature is generally the first consideration which must be taken into account. For ordinary use in the British Isles, temperatures between 10 and 20°C. are regarded as suitable. The gauge may then be tested in an ordinary test room. For low temperature testing, a cold cabinet such as that shown in Fig. 11 may be used. To test the instrument for robustness, it is placed on a "vibrating table" (Fig. 12) and vibrated for a predetermined period. This should reveal any constructional defects in the whole gauge. Other devices may be erected to test the gauge under specific conditions.

TABLE IV.

STANDARD SIZES.

A Diameter of Bezel	B Overall Depth	C Size of Connection	D Centre of Connection to rear
1 5/8″	1 1/8″	1/8″ gas	9/32″
2″	1 1/8″	1/8″ gas	3/8″
2 5/8″	1 1/4″	1/4″ gas	7/16″
3″	1 1/2″	1/4″ gas	9/16″
4″	1 1/2″	3/8″ gas	5/8″
5″	1 11/16″	3/8″ gas	5/8″
6″	1 3/4″	3/8″ gas	3/4″
7″	1 3/4″	3/8″ gas	3/4″
8″	2 3/16″	3/8″ gas	13/16″
9″	2 3/16″	1/2″ gas	13/16″



Pressure, Vacuum and Compound Gauge with Cotton mounting connection.

In testing these gauges for calibration a predetermined pressure is applied to them. The apparatus used for this purpose may consist of a weight-and-plunger arrangement (Fig. 13), a mercury column rig or a master comparator gauge rig.

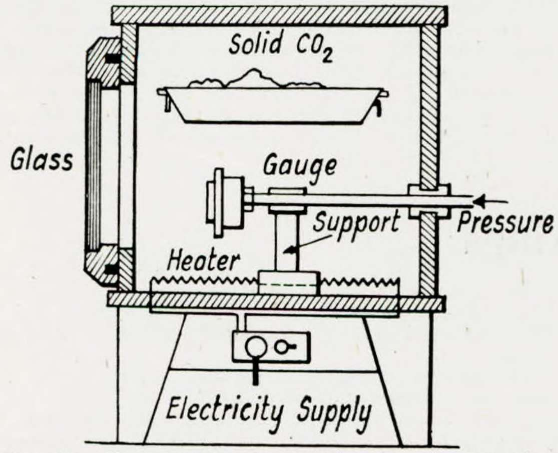


FIG. 11.—*Temperature chamber for functional testing.*

The weight-and-plunger tester (frequently referred to as the "dead-weight tester") is generally designed to produce and measure any pressure between 25 and 2,000lb./sq. in. according to the weights supplied. The pressure is applied by means of the screw press or intensifier and is balanced by a number of weights on the plunger. A similar method is used with the master gauge. The mercury column testing rig is used for pressure gauges graduated below 30lb./sq. in. Pressure (or vacuum if need be) is applied to the rig by means of a small pump.

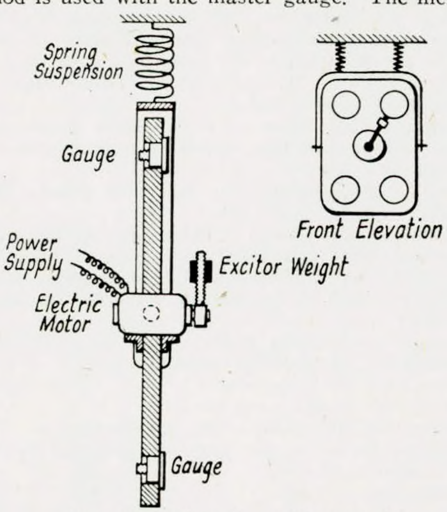


FIG. 12.—*Vibrating table test rig.*

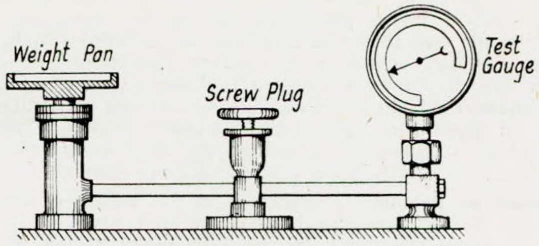


FIG. 13.—*Deadweight calibrating rig.*

These methods possess obvious limitations although an accuracy of ±1 per cent. can easily be achieved with them. Gauges are usually tested on the application of increasing and decreasing pressures, and must possess the requisite degree of accuracy on both loadings. A "smoothed" curve relating the observed to the true pressure for a normal gauge may be somewhat as in Fig. 14.

Among the other tests to which pressure gauges may be subjected are included those for fluid tightness, a blow-out test for the back and an "overload" test. This overload test is usually only applied to a small percentage of the gauges; it is a test of the general strength of the whole gauge and since it may strain the mechanism (although it should not), is only applied to a minimum number of gauges in any one batch.

Accuracy of Pressure Gauges. The degree of accuracy to which any commercial instrument can be guaranteed is dependent (a) upon its own accuracy, (b) upon the accuracy of the measuring apparatus. It has been stated previously that the accuracy of the measuring apparatus is usually within ±1 per cent.

The accuracy of the instrument itself depends upon several factors in its construction, including the printing of the dial, thickness (and distance in front of the dial—for parallax effects) of the pointer, back lash and other inaccuracies of the movement, and variations in the bending characteristics of the bourdon tube. The defects have a progressive effect, as the pressure is increased so that the accuracy is probably lower at high than at low pressures. In general, an accuracy of ±2 per cent. of the maximum scale reading can be produced in a mass-produced gauge if required.

Gauges can thus be manufactured to an accuracy within ±3 per cent. of the maximum scale reading. This means that a gauge with a maximum scale reading of 300lb./sq. in. to work at 200lb./sq. in.) would have an accuracy at all pressures well within ±9lb./sq. in.

In general, the accuracy of pressure gauges only decreases with use due to either wear of the pinion teeth in the movement, or to ageing of the bourdon tubes, principally the former. Experience shows that with a gauge such as the boiler steam gauge, working

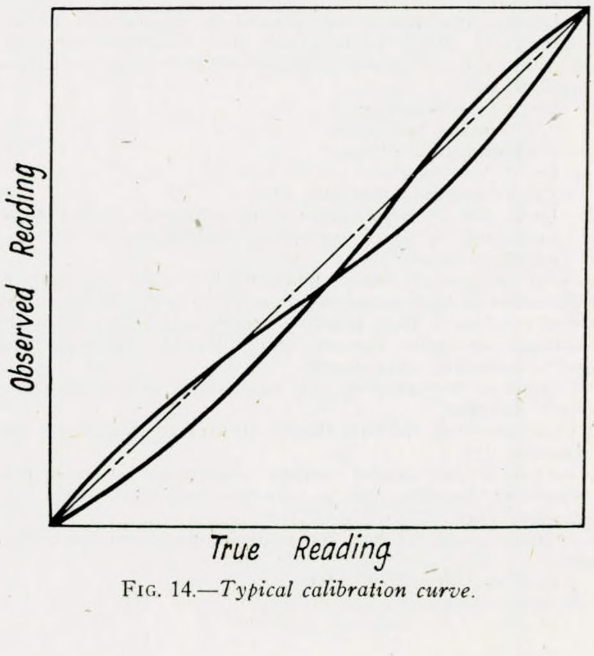


FIG. 14.—*Typical calibration curve.*

continuously between, say, 90 and 110lb./sq. in., the continual slight movement affects just a few teeth, perhaps no more than 2 or 3, with the result that these readings are not accurately indicated for the quite obvious reason that working conditions influence the characteristics very considerably; it is difficult to assess the amount of deterioration which is permissible within any particular gauge, although in general the production accuracy should be maintained over a whole (continuous) working year and be not lower than ±5 per cent. maximum scale reading before renewal.

Renewal or Repair? Experience in the repair of gauges indicates that the following headings cover all types:—

1. Negligent structural damage—somebody having intended to hit something with a hammer, hit the gauge instead. This quite often leaves the pressure indicating mechanism unharmed, in which case, to send the gauge back to the actual manufacturer would probably be cheaper than buying a new one, as a decently made pressure gauge would have interchangeable parts.
2. An overload may have been applied to the gauge, as a result of which the tube is distorted beyond its elastic limits, or bursts.
3. The pressure gauge gearing may have worn out due to considerable fluctuations of pressure or external vibration. In this case, if the gauge has not been in service for some time no amount of repairing or renewal will effect a cure, and it will be necessary to damp down pressure fluctuations and put the gauge where it is not subject to fluctuating mechanical vibrations; or to fit a special heavy duty movement on the actual cause of failure.

The movement of a gauge becomes useless after some time and needs to be scrapped. Thus, if any repairs are required the only effective parts are likely to be the pointer, scale, case and mounting block. Such parts can generally be produced very cheaply, the major expenses arising from the high cost of skilled labour doing an individual job compared with lower priced labour mass producing new gauges. It is, therefore, not usual for the repair of a gauge to be more economical than its complete renewal, except for precision master gauges and gauges fitted with special devices. Normal gauges are certainly outside the range of repairable equipment.

Packing. Finally, a word may be added regarding the packing of pressure gauges. Each gauge should be supplied in a separate carton wedged in with corrugated paper and paper waste, or other resilient material. It is found that by this means the instrument will be safe from most damage due to normal handling. The inlet should be capped to prevent the ingress of foreign matter.

Most commercial gauges are sufficiently robust to withstand ordinary transport hazards and should retain their accuracy with normal care.

Conclusions. These note have been prepared as the result of the author's observations on gauges fitted to equipment for which he has been responsible. While it is confessed that the information provided is far from complete, the author hopes that it gives some idea of the factors involved in the design, manufacture and selection of suitable gauges.

Acknowledgments. The author wishes to record his appreciation of the assistance rendered to him in the preparation of this paper by Mr. A. J. Mann, A.M.I.Mech.E., of Messrs. David Harcourt, Ltd., Mr. C. R. A. Grant, M.I.Mar.E., of Messrs. Barnet Instruments, Ltd., and to the Advisory Bureau for Research, 70, Victoria Street, London, S.W.1. Grateful acknowledgment is made to Mr. J. R. S. Fawcett, B.Sc., A.M.I.Mech.E. of the Budenberg Gauge Co. Ltd., and to the proprietors of "The Mechanical World and Engineering Record" for permission to use illustrations appearing in the issue of that journal dated December 24th, 1943 (Figs. 3, 5a and 5b); also to Messrs. David Harcourt, Ltd. for permission to reproduce from their publications Figs. 6a, 6b, 6c, 8, 10a, 10b, and the figures in Tables I, II and III, and to Messrs. Negretti & Zambra for Fig. 9.

B. C. H. Bearings.

B.C.H. bearings come under the generic term of "plastic" materials and are manufactured by the impregnation of selected fabrics with synthetic resin. After impregnation the fabric is subjected to heat and pressure, forming a material very resistant to wear, and having a specific gravity of 1.37 as compared with 2.56 for aluminium.

This type of material has been progressively developed during the past eighteen years especially for bearing purposes, resulting in particular specifications being available to meet widely divergent mechanical requirements. The original purpose was the manufacture of roll neck bearings for rolling mills. This application subjects the bearing to heavy loads and, in many cases, considerable shock loading. The majority of these bearings are lubricated by water or emulsions of soluble oil and water, and in a few special cases, by grease or light machine oil.

As a bearing material it has proved so satisfactory under the arduous conditions of the rolling mills that it is now entering the field of marine engineering, and is at present in use for the following marine applications:

- Stern tube bearings.
- "A" bracket bearings.
- Rudder post bearings.
- Davit bearings.
- Pump bearings and eye rings.
- Rings for the water ends of reciprocating feed pumps.
- Surfacing of slides for cross head slippers.
- Lantern rings.

The craft on which these applications are in use vary from harbour launches to high speed motor torpedo and gun boats, and in the world of commerce, tugs, coasting vessels and other similar types.

In comparison with lignum vitae, B.C.H. bearing material possesses the following advantages:

(1) Consistent homogeneity and mechanical characteristics with each delivery.
(2) Freedom from splitting during storage or should the bearing become dry.
(3) No need for special storage conditions. Spares can be stored in the same way as non-corroding metal parts.
(4) Longer life.

As compared with rubber, the material possesses the following advantages:

(1) Unaffected by oil or grease.
(2) Freedom from galvanic action.
(3) Does not grow on to the shaft.
(4) Does not deteriorate if allowed to become dry.
(5) Does not deteriorate by reason of storage or weather conditions.
(6) Will withstand working temperatures up to 90° C.
(7) Does not generate static electricity.

Bearings are made of this material in many different forms. They are manufactured as sleeves, split journals or bearings consisting of strips dove-tailed into slots in the housing, also as strips presenting a continuous surface of bearing material and locked together by means of the angle on the strips and keepers. A recent development has been the manufacture of roller bearings. These are now made with parallel rollers for journal loads, taper rollers for thrust loads, taper rollers for combined journal and thrust, also barrel type rollers giving a self-aligning bearing. These roller bearings have no metal in their construction and so can be run under water or in the presence of chemicals.

B.C.H. rings for water ends of reciprocating feed pumps are supplied machined to their correct size and split. The rings are sprung on to the pump bucket in the same way as a steel piston ring is fitted to the piston of a Diesel engine. These rings require no soaking or treatment before fitting.

The bearing material, when made in certain forms, has a grain structure and for this reason two values of compression strength are shown in the attached table.

With water as the lubricant the following can be taken as an approximate guide for bearing loads:

The load should not exceed 3,000lb. per sq. in. with rubbing speed between 2,000 and 200ft. per min. Under these conditions the coefficient of friction should be between .003 and .02.

There are many uses of the bearing material awaiting development, such as for:

- bearings on dredging gear;
- bearings for control rods on tankers;
- bearings for deck machinery;
- bearings for steering equipment;
- bearings for cofferdam slides and mechanism.

The physical properties of the material are as follows:—

Maximum thickness of strip	4in.
„ diameter of tube	4ft.
Compression strength through the grain	34,000lb. per sq. in.
„ „ with „ „	15,000lb. per sq. in.

Percentage yield at 10,000lb. per sq. in.	2.6
Modulus of elasticity (compression)	390,000
Coefficient of expansion per inch per degree Centigrade	.000055
Specific gravity	1.37
Coefficient of friction, water lubricated	.003/.02
„ „ „ , oil „	.04/.08

B.C.H. bearing material can be machined in a similar manner to aluminium. It can be turned, drilled, tapped, milled, planed and sawn. The cutting speeds are high, being of the order of 800ft. per min. for turning. The tools must be kept sharp and must have considerable clearance. Lubricant is not generally used.

Tools tipped with widia or similar tungsten carbide tips should be used when possible. Tools of this type have much longer life and provide better finish.

In the case of stern tube bearings of the strip type, any fitting that may be necessary can be carried out by hand tools as used for hard wood, except that a hand plane would not be practicable and any shaping would have to be done by means of a file or rasp. Boring can be carried out by the accepted methods using a boring bar, and holes can be finished by hand reaming in the same way as a bronze bearing would be handled. Bearings can be scraped with an engineer's scraper in a similar manner to white metal bearings.

ADDITIONS TO THE LIBRARY.

Purchased.

International Load Lines. By E. W. Blocksidge, M.Inst.N.A. Published by Charles Birchall & Sons, Ltd., 17, James Street, Liverpool, 155pp., +appendix 73pp., illus., price £2 2s. net.

Presented by the Publishers.

Fuel Efficiency Bulletin No. 39. Water Treatment. (F.E.C. 313). Ministry of Fuel and Power, 2, Little Smith Street, Westminster, London, S.W.1. Obtainable free on application to the above address or from the Ministry's Regional Offices.

Spinning and Panel-beating of Aluminium Alloys. Information Bulletin No. 9, published by the Wrought Light Alloys Development Association, Union Chambers, 63, Temple Row, Birmingham, 2, 32pp., illus., price 1s.

The Ship's Manual of 1944. Edited and published by John C. Broderick, New York, 85pp.. illus.

This publication contains a reprint of 16 articles which form part of a series of similar articles originally published in "The Nautical Gazette". They concern the operation and maintenance of the propelling machinery of certain standard type vessels of the U.S. Maritime Commission, among the items dealt with being watertube boilers of the Babcock & Wilcox type, steam turbines and gears, triple expansion engines and marine Diesel engines.

The authors of the articles are, in almost every instance, senior members of the technical staffs of the various manufacturers concerned, and their aim appears to have been the compilation of clear and concise instructions for the users of their particular products.

Although no attempt has been made to explain the design and construction of the various items of machinery and equipment in the text, their functions, operation and maintenance are dealt with in an admirable manner, whilst the quality of the accompanying diagrams, sectional drawings and half-tone illustrations is of a very high order.

A Short History of the Royal Navy, 1805 to 1918. By Christopher Lloyd. Methuen & Co. Ltd., London, 1944, 134pp., six illus., 5s. net.

This little book deals with the activities of the Royal Navy in war and peace from the death of Nelson to the end of the first world war. The first five chapters constitute a very brief survey of the various warlike operations in which ships of the Royal Navy were engaged during the years between 1805 and 1914, whilst the last six chapters are devoted to the war of 1914-18, which is dealt with at somewhat greater length, some of the events described being illustrated with full page diagrams. Only one chapter (VI) of 11 pages is reserved for a somewhat perfunctory attempt to deal with the revolutionary changes in the design and construction of warships and Naval armaments during the period covered by the book.

Quin's Metal Handbook and Statistics, 1944. Compiled by F. B. Rice-Oxley, M.A. Published by Metal Information Bureau, Ltd., Princes House, 39, Jermyn St., London, S.W.1, 332pp., 6in. by 4in., cloth, 10s.

The gradual relaxation of the official ban on the publication of metal statistics in the United Kingdom and other countries has enabled a good deal of new statistical material to be incorporated in the new edition of this international and authoritative reference book on ores, metals, scrap and iron and steel. The book is arranged for easy alphabetical reference, but in the new edition the light metals have been grouped together.

The first section is purely statistical, giving prices, imports, exports, production and consumption figures of metallic ores, major and minor non-ferrous metals, precious metals, iron and steel and scrap metals. The continued absence of official statistics of production lends additional interest to the detailed estimates of world production in 1943 of aluminium, copper, tin, lead and zinc compiled by the "Metal Bulletin".

The second section consists of reference notes on such subjects as the properties, uses and commercial grades of non-ferrous ores; similar particulars of the minor metals; notes on specifications and uses of copper and copper alloys; a brief summary (with diagrams) of the methods of producing steel; diaries of events in the copper, tin, lead, zinc, iron and steel and scrap markets; a survey of aluminium and magnesium and their alloys giving properties, uses, fabrication methods, etc., together with reference tables of weights, sizes, gauges and physical constants of metals and metal products. New features in this section are notes on the manufacture of tinplates and galvanised sheets.

Machine Drawing. By Thomas Jones, M.I.Mech.E. and T. Gilbert Jones, M.Sc. (Manchester), Wh.Sc., revised edition, 140pp., illus., 6s. 6d.

This book in its dark red limp cloth cover must be very familiar to many thousands of students; certainly it has earned a well-deserved popularity. The specially pleasing feature of the work is the number of explanatory, well-executed isometric drawings which accompany the text. These pictorial views are extremely helpful to the beginner when models are not available. The present edition, reduced slightly in size to 8in. by 11in., is practically a reproduction of the original Machine Drawing Book 1. One or two of the isometric views have been improved, some six new drawing plates have been added, including a rather unusual one of a roller chain wheel and pinion, and a corresponding number of plates originally in Book 1 withdrawn. There are some 69 plates in all, which for the most part involve examples of the heavier type of machine.

The book provides accurate scale drawings, executed in a clear and good style, and in working most of the exercises the student is required to supply additional views, thereby preventing the subject becoming one of purely mechanical copying. The object of the book is to train the student so that he acquires a good style of draughtsmanship, a knowledge of the construction of mechanical engineering details, and an orderly imagination; a careful study of this book should greatly assist him in obtaining these essential qualifications.

British Pleasure Steamers. By Geoffrey Grimshaw. Richard Tilling, 106, Great Dover Street, London, S.E.1. 8¾in. by 5½in., 366pp., price 15s.

In the two decades between the World Wars, there have been very considerable changes in the character of the pleasure steamer fleets in British waters, and in the concerns owning them. Particularly in the South of England, the owner operating trips based on a coastal resort, or even working a regular service between the Metropolis and the Thames Estuary, did not enjoy prosperity, partly as a result of changing habits and tastes, particularly in connection with the increasing use of road transport. Competition between fleets almost disappeared and the survivors developed to a noteworthy extent the added attraction of a cross-channel excursion from the Thames and Medway. Though this book deals with so recent a chapter of shipping history, the author says that he has been hampered by a lack of reliable data, which is not surprising when some of the kaleidoscopic changes of ownership are borne in mind. Nevertheless, painstaking work has done much to repair the deficiency, and the author has the satisfaction of a job well done, though we fear that artistic triumph and personal pride in achievement will have to provide compensation for inadequate financial return for the labour expended.

We have mentioned first the purely pleasure vessels in the South, but this volume also includes details of the more important, and only partly pleasure, fleets of the Clyde, Western Highlands, and Irish Channel, though strictly utilitarian services are left outside its scope. The work is based on the individual vessel, every one of which has its separate entry, giving brief details of history. The groups of ships are prefaced by notes on ownership. Here we would make one typographical criticism, for the general notes are so arranged in some places as to appear to be remarks about the previous vessel—dividing rules or asterisks would have facilitated reading and made for clarity.

Appendix I gives fleet lists, with principal particulars, and Appendix II a tabulation of pleasure steamers in commission during the 1939 season. There are also a ship index and a list of illustrations. The author has earned the gratitude of ship lovers for his work, which is a noteworthy piece of compilation.

Steel Ships: Their Construction and Maintenance. A manual for Shipbuilders, Ship Superinendents, Students and Marine Engineers. By Thomas Walton. Revised by John Baird, B.Sc., M.I.N.A. Chas. Griffin & Co., Ltd., London, 1944, 8th edition, fully revised, 275pp., 146 illus., including 22 folding diagrams reduced from working drawings, price 30s.

One can think of no more difficult task than that of writing a text-book on modern "Steel Ships", yet Mr. Baird has done this with a considerable measure of success.

In the main it has been wise to follow the pattern of the original author, but perhaps it would have been better to place Chapter VI, dealing with types of ships, after Chapters V, VII, VIII and IX, all of which deal with structural details. Such an arrangement would have afforded greater continuity and would prove helpful to the student. In his preface Mr. Baird expresses his regret at having to omit some of the folding plates of the earlier editions. This, however, is all to the good. Folding plates are always difficult to find in relation to the text, and furthermore are apt to become seriously mutilated in a well used book. The first three chapters deal with the materials used in shipbuilding, the tests to which they are subjected, and the calculations relative to the strength of the hull structure. The work is concise and clearly set out. There is, however, one difficulty which every writer experiences when inserting a chapter on theory into an essentially practical book. The extent to which one feels justified in going is not sufficient to satisfy the needs of a serious student, but may be more than that which is likely to be understood by a purely practical man. Mr. Baird has partially solved this conundrum—for such it is—in his efforts to deal with Moments of Inertia and Strength Calculations, but not wholly. The reviewer would, however, offer him both sympathy and congratulations.

The material on "Types of Ships" is generously portrayed, and in fact one is inclined to regard this chapter as the clearest and most adequate treatment of the subject in the literature of shipbuilding.

Perhaps when the paper shortage is not so acute the author will expand his chapter on Shipyard Practice to include detailed descriptions of some of the more important operations carried out on the slipway, for example "Taking account of, preparing and subsequently erecting the sternframe", "The horning and plumbing of frames", "Preparation and erection of shellplates", to mention only a few of these jobs. There are many shipbuilding apprentices in repair yards who know very little of what goes on on the slipway, and would welcome some authoritative literature on the subject.

The section on welding in ship construction is very lucid and informative, but like "Oliver Twist" we again ask for more—and hope to get it.

Finally, the book is extremely well produced, the sketches are good and workmanlike, the book is useful in almost every line and is very readable.

Reinforced Concrete Design. By John Berry, B.Sc. Hutchinson & Co. (Publishers) Ltd., 10s. 6d. net.

Reinforced concrete is a comparatively new material, but one which has already been widely and successfully applied in the fields of engineering and architecture. It is quite safe to prophesy that this material will be used to a far greater extent during the coming years and that it will be adapted to many new and diverse requirements.

It behoves every student of engineering or achitecture, therefore, to be acquainted with the elementary theory, at least, of reinforced concrete designing.

In this book the author has clearly set out the essential parts of the subject, a thorough knowledge of which is necessary for a complete understanding of the potentialities and the more advanced treatment of reinforced concrete. Fortunately the subject is one which can be studied with the minimum of mathematical ability, only a working knowledge of arithmetic and algebra being essential in the preliminary stage of study.

Part I of the book deals with the physical properties of concrete and its constituents and also the main details of the actual constructional work.

In Part II the basic principles of design, together with the present trend of designing methods, are stated and discussed in order that the student may be fully aware of the assumptions that have to be made in the actual design of structures.

The standard theory of reinforced concrete design is dealt with in Part III, beginning with elementary stress conditions in individual members and developing the theory from first principles. The actual process of designing various members is clearly illustrated by numerous worked examples. The practical limitations of the theory are stressed, and the accepted standards as regards mathematically indeterminate quantities are stated so that the student can appreciate the necessary blending of theory and practice.

The structure as a whole is treated in Part IV, particularly the effect of continuity in the members and reciprocal reactions, while in Part V examples are given of actual design methods as used in the drawing office.

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Transfer from Associate Member to Member.
George Whyte Cowie.

Transfer from Associate to Member.
William Grieve, C.E.R.A., R.N.
Peter Johnston.
Hunter Thomson McMichael.

Transfer from Graduate to Associate Member.
Ronald Magill, B.Sc.

Transfer from Student to Graduate.
Michael Bedell Dodson, 2nd Lieut., R.E.M.E.

PERSONAL.

Sir Percy E. Bates, Bart., G.B.E. (Past President) has been re-elected to represent the Liverpool Steam Ship Owners' Association on the council of the Liverpool Chamber of Commerce.

Dr. L. C. Burrill (Member) has been appointed Professor of Naval Architecture at King's College, Newcastle-upon-Tyne.

Mr. H. M. Harte (Member) of Messrs. Harte, Lindley & Co., London, has been nominated President of the Society of Consulting Marine Engineers and Ship Surveyors for the ensuing year, in succession to Mr. H. E. J. Camps, who vacates the office at the next annual meeting.

Elections to the Council of the North-East Coast Institution of Engineers and Shipbuilders include those of Sir Summers Hunter (Vice-President I.Mar.E.) as President, the following Members of the Institute as Ordinary Members of Council: Dr. L. C. Burrill, Messrs. W. Nithsdale and W. H. Purdie, and Mr. W. H. Pilmour as Honorary Treasurer.