LABORATORY AND WORKSHOP NOTES

A Selection reprinted from the Journal of Scientific Instruments

COMPILED AND EDITED BY
RUTH LANG, PH.D., A.INST.P.
FOR
THE INSTITUTE OF PHYSICS

LONDON
EDWARD ARNOLD & CO.

First published 1949
Reprinted 1950

Printed in Great Britain by
Butler & Tanner Ltd., Frome and London

FOREWORD

The Laboratory and Workshop Notes published during the past twenty-five years in the *Journal of Scientific Instruments* represent a fund of practical knowledge which is not readily accessible in many laboratories and workshops. The Board of the Institute of Physics, which is responsible for the production of the *Journal*, believes that these simple, elegant and time-saving solutions of problems should be made more widely known. The authors have co-operated by giving their willing consent to the reproduction of their Notes in this book, and the Board wishes to record its thanks for their kindness in allowing the royalties from its sale to be placed to the credit of the Institute's Benevolent Fund.

With the present severe paper restrictions the number of Notes which it has been possible to reproduce is less than half those selected for publication in the *Journal*. The Board invited Dr. Ruth Lang to make the selection on the basis of general usefulness, and highly appreciates her enthusiastic response to its invitation. It will be realised that the selection has necessarily been somewhat arbitrary, and therefore inclusion of a Note in the book must not be taken to imply its superiority over those omitted. Indeed, when circumstances make it possible, subject to the favourable reception of the present volume, the Board hopes that it will be able to present a further volume of these Notes.

PREFACE

This book is not intended to cover the complete range of laboratory and workshop practice, or even the main features of it, and indeed, by its method of compilation this is not possible. The placing in sections is somewhat arbitrary, and is only to be taken as a rough guide. A full index has, however, been included, and it is hoped that this will be freely consulted in the first place. With the object of including as much useful information as possible some Notes have been slightly condensed by omitting introductory paragraphs, acknowledgements, and so forth. It was considered inadvisable to retain those names and addresses of particular makers or suppliers of materials mentioned in the original Notes.

While every endeavour has been made to trace the authors to obtain their permission to reprint these Notes, this has been unsuccessful in a few cases; it is sincerely hoped that these authors will readily join with the others in agreeing to make their work more widely known by inclusion in this volume.

RUTH LANG.

CONTENTS

SECTION 2. Clamps, Supports and Agitators

SECTION 3. Soldering, Brazing and Welding

SECTION 7. **Optical Devices and Techniques**

SECTION 8. Devices for Liquids and Gases

SECTION 1. LABORATORY AND WORKSHOP TOOLS, PROCESSES AND DEVICES

1. Some Mechanics' Own Tools

By R. S. CLAY, D.Sc., F.Inst.P.

J. Sci. Instrum. **18**, p. 109 (1941)

Most of the older skilled mechanics in a factory have accumulated a number of special tools that they have made for themselves from time to time, some for a particular job and some for general use, and these are frequently interesting to other mechanics. A few are described below.

Countersink. A simple hand countersink (Fig. 1) with its shank turned down to a diameter of about $\frac{1}{16}$ in. to enable it to be used under a projection. It is made from $\frac{1}{4}$-in. silver steel. The countersink was turned to a cone and the teeth filed by hand. It could also have been made in two pieces, the countersink and stem of steel, and the handle

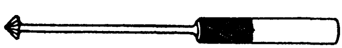


FIG. 1.—Hand countersink.

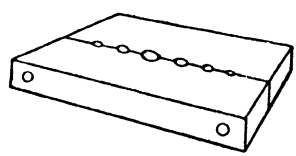


FIG. 2.—Screwholder.

of brass or Erinoid. The handle should be knurled at its lower end, but it should be left smooth and rounded at the top where it is pressed against the palm of the hand in use.

Screwholder. A pair of rectangular strips of brass (Fig. 2), held together edgewise by pins passing through their ends ; the pins are tight in one piece and a sliding fit in the other. Along the central line are a number of holes of different sizes, countersunk on one side. This gadget is intended to hold a screw when it is desired to file it to shorten it or to square up its end and remove any burr from the thread.

Bent screwdriver. A bent screwdriver (Fig. 3), for use when a screw has to be inserted underneath some part which prevents the use of a straight tool. For a short distance the ends are bent at right angles to the length, one end has its blade at right angles to the length of the tool, and the other blade is in the plane containing the long axis of the tool. The ends are used alternately.

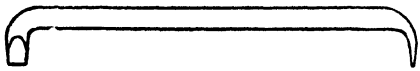


FIG. 3.—Bent screwdriver.

Spanner. A tool for turning a nut which is operated by a pair of holes (such as are frequently found on the trunnions of a microscope) is shown in Fig. 4. These holes are at different distances apart in different instruments, and this tool has sufficient spring to enable it to be used whatever this distance. It is made of a length of about

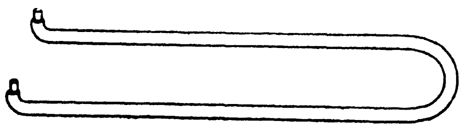


FIG. 4.—Tool for turning a nut.

8 in. of $\frac{1}{8}$-in. silver steel. About an eighth of an inch of each end was turned down to a diameter of $\frac{1}{16}$ in.; then the ends were heated, bent at right angles to the length and parallel to each other, hardened and tempered to a blue. A central bend was made in the rod, cold, to a half circle of a radius of about $\frac{1}{2}$ in., in a plane at right angles to the bent ends.

Spring hook. A small tool like a tiny button hook, made similarly of silver steel. It is used for hooking on a small spring to its attachments, especially in a confined space.

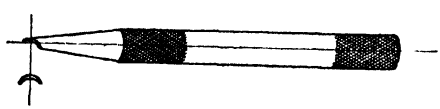


FIG. 5.—Half-moon punch.

Half-moon punch. This tool (Fig. 5) is a steel chisel with its end in the shape of a part of a circle. It is used to fix a ball-bearing in its parallel housing. The bearing is arranged just to bed below the surface of the outer cylindrical housing in which it is carried; then the edge of the housing is hit with the punch at three equidistant points round its edge, thus burring it in at these places; the tool produces a firmer fixing than would be obtained by the more usually employed centre-punch.

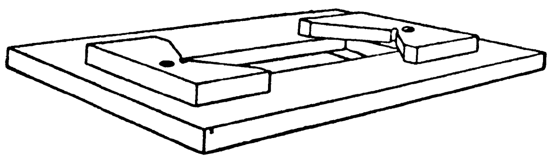
Tweezers. A pair of tweezers made of two old smooth files. The files were softened; filed at one end to reduce the thickness to allow sufficient give; then they were riveted together at that end. The other end was filed almost to a point, but without reducing the thickness until near the end, so as to maintain the stiffness up to the end. This end was hardened and tempered. Such tweezers are much stronger and stiffer than the usual ones.

Chisel. A chisel made of $\frac{1}{4}$-in. silver steel. The last inch is filed to a blade $\frac{1}{16}$ in. thick and sharpened at its end. It is hardened and tempered to a light straw colour.

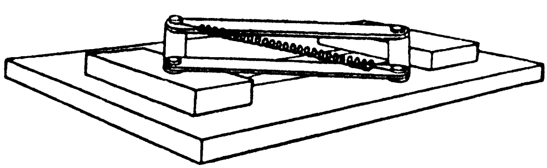
Scraper. A scraper with a curved blade with a radius of about $\frac{1}{2}$ in. This had the blade flat on the outside of the curve and the bevel on the inside of the curve. It was used to scrape out a hollow in a special job.

Snap-punch. A snap-punch for finishing the head of a rivet. It has its end hollow in the form of a part of a sphere.

Other small tools. Other useful tools were a bent scriber and a bent "tommy-bar".



(*a*)



(*b*)

FIG. 6.—Metal holder for thin metal.

Metal holder. A tool (Fig. 6) for holding a flat piece of metal of irregular shape while its surface is being filed. It consists of a rectangular piece of steel, $4\frac{3}{4}$ in. by $3\frac{1}{4}$ in. by $\frac{3}{16}$ in., in which is a central slot about $3\frac{3}{4}$ in. by $\frac{1}{2}$ in. In this slot are two blocks which slide freely in the slot; these carry on the upper side, pieces of hardened steel, held down by screws let into their thickness on which they can turn freely as seen in Fig. 6 (*a*). On the under side, Fig. 6 (*b*), the blocks are connected by four equal strips of mild steel forming a parallelogram in a horizontal plane; the other diagonal of the parallelogram is joined by a spiral spring. The screws holding the front plates and the back strips go into the same holes in the sliding blocks, and are cut just to meet, so as to lock one another. In use, the sliding blocks are held in the vice, the pressure acting along the direction of the length of the slot. To enable the blocks to slide easily, they should be left a trifle " proud ".

Metal vice. Another somewhat more elaborate vice is shown in Fig. 7; it is also for holding a flat piece of metal to be filed, but this one can be adjusted to hold pieces of any thickness. This also is built on a rectangular piece of steel, 4 in. by $3\frac{1}{4}$ in. by $\frac{3}{16}$ in., with a slot 3 in. by $\frac{1}{2}$ in. Fixed to its under side at one end of the slot is a steel block *A*, 2 in. by 2 in. by $\frac{1}{2}$ in. This block has a slot in which a 2 B.A. steel

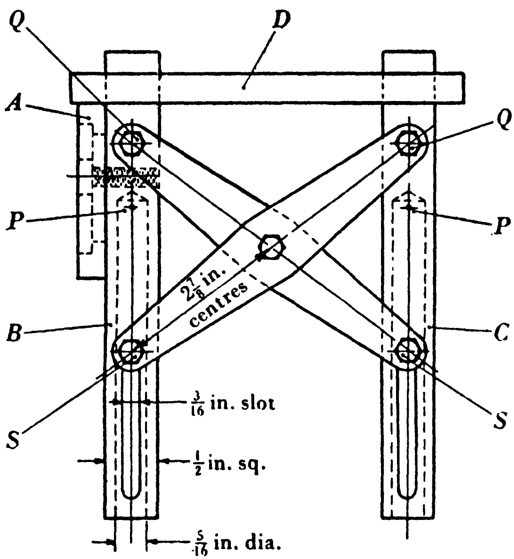


FIG. 7.—Another metal vice for thin metal.

cheese-head screw can travel about $\frac{1}{2}$ in. The screw clamps the square steel bar *B* against the block, and the slot enables any length of this bar up to $\frac{1}{2}$ in. to project above the plate *D*. The two bars *B* and *C* are similar; they are made of tool steel and have the top surfaces hardened and tempered. They are $\frac{1}{2}$ in. square and 5 in. long. A $\frac{5}{16}$-in. hole is drilled up each of them to a distance of 3 in., and a $\frac{3}{16}$-in. slot is cut through them, from about $\frac{1}{4}$ in. from the bottom for a length of 2 in. The bars are connected both front and back by pairs of cross strips of steel $\frac{1}{16}$ in. thick pivoted together at their centres, carried on 4 B.A. screws passing right through, with lock-nuts. There are washers under the upper strips on each side. The holes *S* and *Q* in these strips are $2\frac{7}{8}$ in. apart. Finally, there are springs in the holes in the bars *B* and *C*, connected between the screws *S*, *S*, working in the slots, and the pins *P*, *P*. This tool also is held in the vice, with the pressure acting along the length of the slot.

Tool for bending up end of a spring. A useful tool (Fig. 8) for use

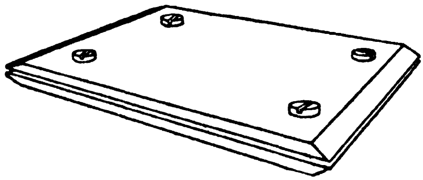


FIG. 8.—Tool for bending up end of a spring.

in bending up the half of the last turn of a spiral spring by which half-turn such a spring is usually connected to the working part. It consists simply of a pair of steel plates about 2 in. by $\frac{3}{4}$ in. by $\frac{1}{16}$ in., filed at their ends to a bevel and held together by two screws near each end. At one end the bevel comes almost to a sharp edge and at the other is left rather blunt. The plates are hardened and tempered to a blue.

Centre-punch. A centre-punch for use to centre a hole inside a hole already bored in thin metal. This has to be made of the size of the hole that has to be centred. It consists of a short piece of silver steel that fits the hole. It is hollowed at the end between the edge and the centre, leaving a somewhat sharp edge and a central pip, the pip projecting slightly beyond the plane of the edge. The end is hardened and tempered.

Trepanning tool. A trepanning (or perhaps more correctly *trephining*) tool (Fig. 9) for making a side hole in a thin tube is used instead of the usual pin-bit; the pin-bit works all right at first, but when the hole is nearly cut through there is a great danger that it will catch in the projecting parts of the last piece of the edge, not only spoiling the job but possibly injuring the workman. To avoid this, the tool is made somewhat like the centre-punch described above, i.e. it has a hollow cut in a cylindrical steel rod, leaving the edge and a central cylindrical pin. The pin can be made into a small "diamond" drill so that it makes its own guiding hole. Teeth are cut round the edge; then the whole end is hardened and tempered.

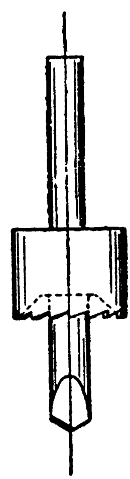


FIG. 9.—Trepanning tool.

Clamps. A clamp made out of an ordinary steel hexagon nut is shown in Fig. 10. One corner of the nut is cut away, the hole is filed to a square of which two sides are parallel to two of the sides of the hexagon, and a steel screw is inserted in one of the parallel sides. The workman had a number made from hexagon nuts of various sizes.

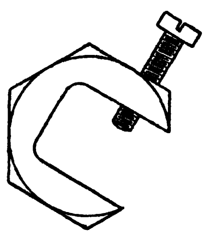


FIG. 10.—Clamp from hexagon nut.

Tool for locating a hole. A tool for use when a hole has to be located at a definite distance from the edge of a plate has been called a "wobbler". It is mounted in the drilling machine and is run at a high speed while the table on which the plate is mounted is gradually approached until the edge of the plate touches the tongue of the wobbler. The contact first sets this tongue concentric with the axis of rotation, then the edge is brought still further, and when it has moved about half a thousandth of an inch beyond the point of true contact the tongue suddenly is violently deflected. The point of contact is in this way determined with accuracy; the axis is then distant from the edge half of the diameter of the tongue (within the half-thousandth).

The construction of the wobbler can be seen from Fig. 11. The tongue terminates at the top in a ball which is held between the cone *A* and a housing of phosphor-bronze *B*, which is pressed down by a light spring *C*. The piece *A* is coned both above and below, to allow of the freest possible movement of the tongue. The tongue is somewhat barrel-shaped at its lower end where it comes into contact with the edge. It will be noticed that the upper end *D* is drilled up for a little distance to accommodate the spring. When screwed together, the phosphor-bronze housing nearly touches the shoulder of *D*. The instrument depends for its success upon the nice adjustment of the pressure of the spring; it must, of course, be carefully made. It will locate the edge equally accurately even if the upper part of the tool is not running quite true.

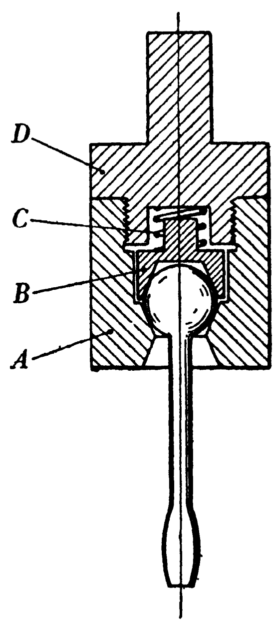


FIG. 11.—"Wobbler" for locating a hole.

Use of round bar with holding vice. I noticed one man had placed a round steel bar between the moving jaw in the holding vice of a shaper and the work he was clamping. He explained that however well the sliding jaw was fitted, there was bound to be a slight tilt of the jaw in the final clamping of the work, and this would raise that side of the work. The insertion of the roller made it easy to tap the work down after the vice had been tightened. Thus, if it were desired to obtain parallelism between the upper and lower surface of the work, this cylinder was a great help. It obviously must not be used if the cut has a tendency to lift the work on the roller side, e.g. if a cut was to be taken on a side face of the work. Sometimes it is better to use a ball for a similar purpose, if the work has not a straight parallel edge.

Forceps for pivot wires. A pair of forceps made of phosphor-bronze to avoid possible magnetization of the forceps were noticed in one workshop. To hold the fine wires for which they had been made, the mechanic had cut a fine longitudinal groove on the inner surface.

Ball countersink. This tool (Fig. 12) is used to make a spherical seating for a ball. It is made by uniting a ball of the diameter of the ball for which the seating is required to the end of a short length

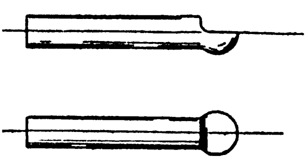


Fig. 12.—Ball countersink.

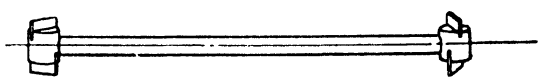


Fig. 13.—Special screwdriver.

of silver steel. The ball is softened and drilled a short way in. The stem is made a tight fit in the hole and silver-soldered on. Then half the ball is filed away and the ball is hardened and tempered. It is finished by grinding the flat face.

Another special screwdriver. I was told of an extension of the idea of the bent screwdriver (Fig. 3). That screwdriver, by using the ends alternately, could screw up a screw if the handle could be turned through 90°; but there may not sometimes be room for this turn. This one (Fig. 13) only requires room for a 45° turn. It consists of a short cylinder at each end of the handle, each cylinder having a blade inset in both upper and lower faces (four blades in all). Two of these blades make angles of $22\frac{1}{2}°$ with the handle, and the other two make angles of $67\frac{1}{2}°$ with the handle. The four blades are used in rotation, each turning the screw through 45°.

It was also pointed out in this connexion, that the handle of the ordinary hexagon spanner should make an angle of 45° with one of the sides of the hexagon. Then the spanner can, by turning it over, be put in a variety of ways on to the nut; whereas if the handle is at 30° with a face of the hexagon, changing it over does not give similar flexibility.

Dividers for marking from holes. A tool is shown (Fig. 14) that can be considered to be made from a draughtsman's dividers (with the well-known *C*-spring joint) by inserting in one limb a needle carrying a ball and in the other a gramophone needle. A No. 50 drill makes

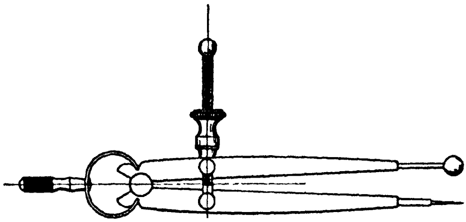


FIG. 14.—Dividers for marking from holes.

a hole that is a tight fit for the standard needle. The tool is used for marking a hole at some required distance from a hole already drilled. The ball is located in the drilled hole and the point marks the new hole. The mechanic who showed me this had a number of balls of different sizes to suit varying size holes.

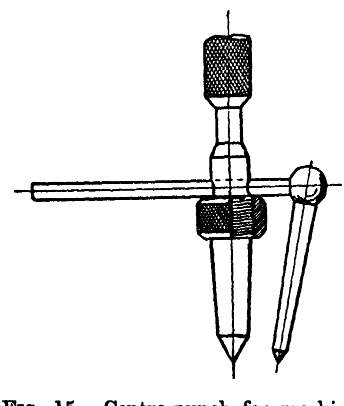


FIG. 15.—Centre-punch for marking holes.

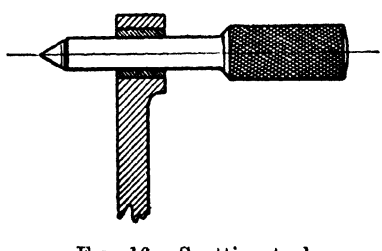


FIG. 16.—Spotting tool.

Special centre-punch. A centre-punch for marking holes at a definite separation is shown in Fig. 15. An automatic (spring) punch was used, but the punch had a bar carrying a second punch, which can be set at any distance from the central punch and clamped by tightening the knurled nut shown in the figure; this second punch is located in the hole already punched.

Spotting tool. Fig. 16 shows a spotting tool which is used in the lathe for marking such a thing as the pitch circle on which a set of holes are to be drilled. It consists of a cylindrical cutter mounted in a true hole. The cutter is hardened and ground to an exact size (this one is exactly ¼ in. in diameter). It fits in a hardened and honed steel bush which is a tight fit in a bar that can be clamped in the slide rest. The end of the cutter is pointed at about 60° and has exactly half ground away, so that the point forms a cutting point and can either be used to mark out a circle (by rotating the mandrel once while the cutter is touching the work) or can be used to dot the holes for drilling if the mandrel has a divided head, by rotating the cutter by its knurled end. If the diameter of the work is known, the cylindrical part of the cutter can be brought up to touch the edge of the work (the cutter being pushed forward through its bush), the reading of the cross-slide is noted, and it is moved forward by the scale on the slide to the required diameter; the amount of the necessary movement is easily found, knowing the diameter of the work and that of the cutter.

[*See Notes 2 and 3.*]

2. A Few More Mechanics' Tools

By R. S. CLAY, D.Sc., F.Inst.P.

J. Sci. Instrum. **19**, p. 101 (1942)

An adjustable boring tool. For this tool (Fig. 17), a 5-in. length of tool steel, ¾ in. × ⅝ in., was mounted between centres to rotate parallel to its axis, but about a line equidistant from three of the faces as shown in the end-view, and one end was turned down to a diameter of 9/16 in. for about 2½ in. Then a 3/16-in. hole was drilled along this turned part

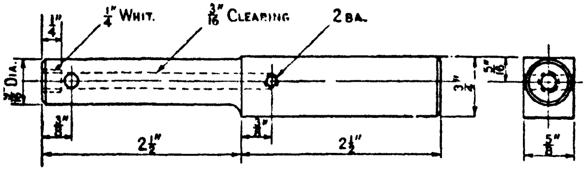


FIG. 17.—Boring tool-holder.

and for about another ⅜ in. into the rectangular portion. Near its inner end a cross-hole was drilled and tapped to take a 2 B.A. screw. Another cross-hole, 3/16 in. in diameter, was drilled through the turned part, about ⅜ in. from its end, to take the cutter. A rod was cut from a piece of 3/16-in. silver steel and its end turned to a 90° cone. A 2 B.A.

screw was also made from cast steel and its end turned to a 90° cone. The length of the rod was such that it exactly reached from the point of the screw to the cutter. Both rod and screw had their ends hardened and tempered. The rod should not be too tight a fit in its hole, to allow for any slight distortion in the hardening. (If the rod can be finished by grinding, it can of course be a good fit in the hole.) The head of the screw has a slot that will admit of the entry of the edge of a halfpenny, so that this can be used for tightening the cutter. For the sake of appearance, the mouth of the long hole was tapped to ¼ in. Whitworth, and a piece of rod was screwed in; this was then cut off and filed flush with the end face.

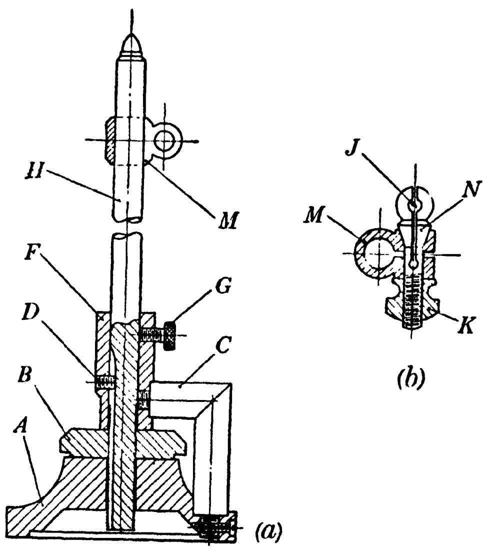


FIG. 18.—Scribing block, (*a*) vertical section, (*b*) horizontal section, through the scriber-holder that fits on main vertical rod.

A scribing block that can be made almost entirely with the lathe. This tool is shown in vertical section in Fig. 18 (*a*) and a horizontal section through the scriber-holder, that fits on the main vertical rod, is shown in Fig. 18 (*b*). The base *A* is an iron casting which is turned on its outer surface. Its greatest diameter is about 2¼ in. *H* is a cylindrical bar, $\frac{5}{16}$ in. in diameter and 6 in. long, the lower inch of which has a thread cut in it of 40 to the inch. This threaded part is made a sliding fit in the central hole in the base *A*. The bar *H* is further supported by the sleeve *F*, which is itself fixed by the bent rod *C* to the base *A*. The rod *C* is actually made in two pieces; one piece is screwed into a shouldered hole in the base *A*, the other piece is similarly screwed into a shouldered hole in the sleeve *F*; the two pieces are then filed to the correct bevels, and the joint brazed. Between the sleeve *F* and the base *A* is a nut *B*, fitting on the screw on *H*; the nut has a bevel turned on it and is divided into 25 parts; thus each division will read a thousandth of an inch. A flat is filed on one side of the sleeve on which is scribed a vertical line against which the divisions on the nut are read. In this same face there is a grub-screw *D*, which engages in a vertical groove 1½ in. long cut (through the teeth of the screw) in the bar *H* to prevent the bar from rotating on its axis as the nut is turned. Through the sleeve there is also a 4 B.A. clamping screw *G* acting on a loose plate (omitted from the drawing) which bears on the bar *H*.

The scribing rod is mounted in the well-known way by which a single knurled head clamps all the motions. The head *K* (Fig. 18 (*b*)) draws the split cone *N* into its conical collar and so closes the hole *J* upon the scriber (not shown), while at the same time the pressure of the nut tightens the split ring *M* upon the bar *H*.

A toolmaker's clamp with an extra jaw. This is shown in perspective in Fig. 19 (*a*), while Fig. 19 (*b*) is a cross-section through the nearer jaw. The main support *A* is milled out of the solid. It is 3⅜ in. long by ⅞ in. wide and 1⅛ in. high. It has a groove cut lengthways from end to end, which is $\frac{3}{16}$ in. wide in its narrow part and ⅜ in. wide below. The block *B* is 1⅛ in. long and is held down by the strip of steel *D* (1 in. long) which is fixed to *B* by two screws. All this is usual practice. The special feature of this clamp is the extra jaw *C*; this is shown upside down in perspective in Fig. 19 (*c*) and in inverted plan in Fig. 19 (*d*). This shows the method by which it can be removed from the clamp. The projecting piece by which it is clamped is $\frac{3}{16}$ in. wide with a head which is ⅜ in. long. Both the stem and the head have two opposite corners removed to form parts of cylinders $\frac{3}{16}$ in. and ⅜ in. in diameter respectively, the other corners being left square. It will be seen that this enables the head to be inserted through the narrow $\frac{3}{16}$-in. groove, and then by turning it through a right angle it becomes held. This extra jaw enables a metal piece which is not quite parallel or has an unusual shape to be held by inserting it between the movable and one of the other jaws, a cylinder being placed between the movable jaw and the other fixed one.

A die adapter. This is a very simple but useful tool, enabling one standard size die-holder to take either size die. It is made from mild steel, but the screws should be case-hardened. Fig. 20 gives the dimensions and requires no further explanation.

Another depth gauge. This depth gauge (Fig. 21) is made from a piece of square ¼ in. bar, about 2½ in. long. Passing vertically through the centre of it is a short length of silver steel, say $\frac{1}{16}$ in. diameter, of which the lower end is flat. This is clamped by a 10 B.A. screw

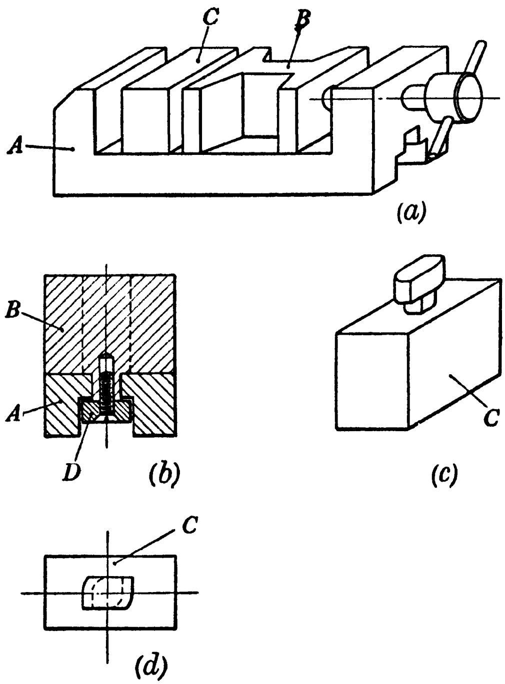


Fig. 19.—Toolmaker's clamp with extra jaw: (a) perspective, (b) cross-section through nearer jaw.

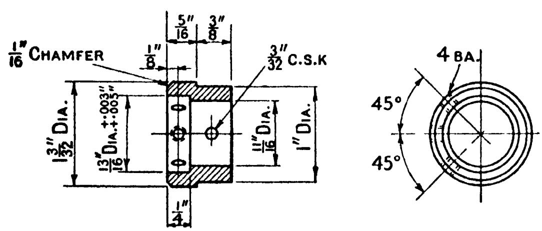


Fig. 20.—Die adapter.

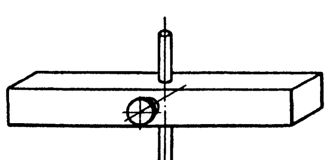


Fig. 21.—Depth gauge.

with a small knurled head. With the aid of short tubes that fit over the rod this tool can be used to measure a depth, if an ordinary inch micrometer is available. For it is obvious that the distance the rod projects below the surface of the bar can be found by subtracting the combined thickness of bar and tube from the over-all distance from the top of the tube to the end of the rod (it is assumed that the top of the rod is lower than the top of the tube). To make the subtraction easy, the combined thicknesses of bar and tube should be made exact distances, say exactly ½ in. and exactly ¾ in.

An easily made scribing block which can be made for use when one of the more elaborate ones is not at hand.

The stem (Fig. 22) consists of a length of square-section silver steel, an eighth or three-sixteenths square, mounted on a flat base of any size, from the scrap-box. (Many seem unaware that silver steel of square section is a commercial article.) On the steel slides a square tube which fits it, some 2 in. long. The tube is split at both ends, and bent inwards to form a spring grip on the steel. At the upper end the tube is surrounded by a brass clamping piece; this also is split and is tightened on the tube by a 6 B.A. screw. At its opposite end, this clamping piece is split horizontally to take the scriber and is similarly tightened by a second screw. It will be found that the split tube slides very smoothly on the steel, so that the height of the scriber can be adjusted fairly exactly without much trouble.

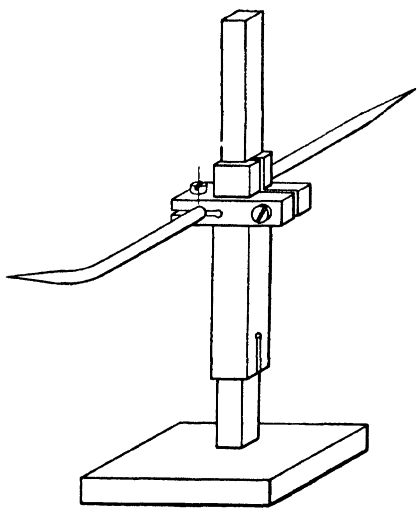


FIG. 22.—Easily made scribing block.

It is obvious that a round rod and round tube can be used instead of the square ones, but the square ones have the advantage that the tube slides without turning, making the setting a little easier.

A copper-fibre-hammer. Each end of the head of the hammer, *A* (Fig. 23), is furnished with a thread on which screws a short ring, *B* or *C*. The ring is recessed on its inner face, and by means of this recess the ring at one end clamps a copper block, *D*, which has a collar left on it fitting the recess in the ring. The ring at the opposite end similarly clamps a fibre block, E, against the face of the hammer. This enables new blocks to be substituted when they become too damaged by wear, or a lead block can be substituted at any time if desired. The hammer may be made of any size; for instrument work a head about 2 in. in length by $\frac{5}{8}$ in. in diameter is convenient.

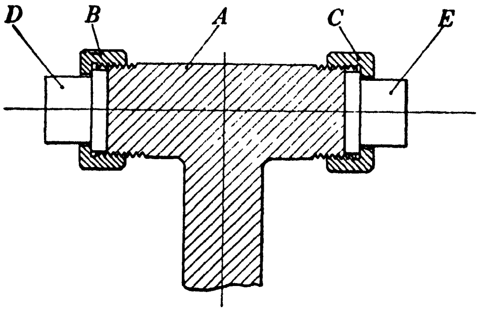


FIG. 23.—Copper-fibre-hammer.

A tool for turning a spherical hollow. On the upper surface of a piece of steel of a size that fits the slide-rest of the lathe is mounted the cutter, which is a strip of steel about $\frac{1}{2}$ in. by $\frac{1}{8}$ in. and 3 or 4 in. long, as shown in Fig. 24. This strip is held down by a spring washer and nut. The shorter end is made with its cutting point at a distance

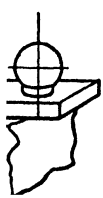


FIG. 24.—Tool for turning a spherical hollow.

from the axis round which it turns equal to the radius of the hollow required. At the opposite end there is fixed a small knob on the upper side of the strip, by which it is rotated to feed the cut. Strips of various lengths from axis to point, interchangeable with one another, are used for cutting hollows of various radii.

Tools for turning spheres. Failing a spherical turning-rest, there are two easily made tools. The simplest is made by drilling a hole in an old file (Fig. 25 (*a*)); countersink it nearly through from the back if it is to turn a brass sphere as shown in the sectional view (Fig. 25 (*b*)), or right through for steel. Cut it through a diameter, and harden and temper it. Similar tools are useful for cutting a bead; for such a use it is sometimes well to trim off part of the side as shown in Fig. 25 (*c*). The tool can be sharpened by grinding it with carborundum on a conical copper lap. A single such lap can be used for tools of all radii up to its greatest diameter.

The second tool depends upon the fact that every plane section of a sphere is a circle. It is made by turning a cylindrical hollow in the end of a bar of tool steel, forming the end section to a cutting edge, as shown in section in Fig. 25 (*d*) and as an end view in Fig. 25 (*e*). When hardened and tempered, this can be used to turn a sphere of any size (greater than its own diameter). It is easiest to rough out the sphere with an ordinary turning tool. The tool is rocked to and fro over the surface of the sphere. Instead of making a steel tool

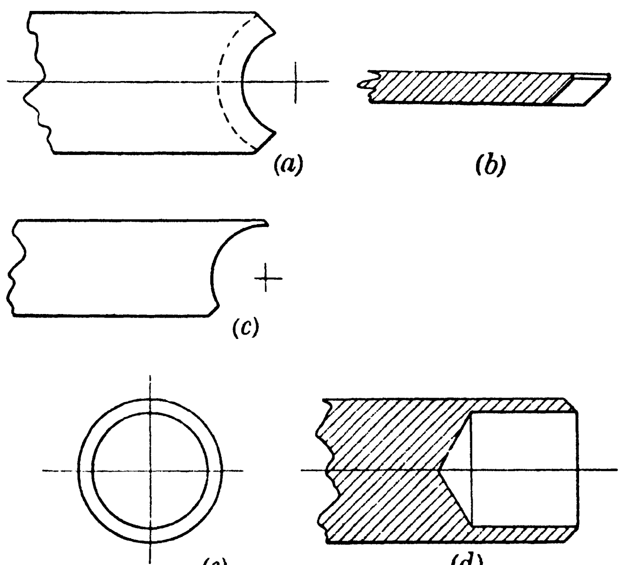


FIG. 25.—Tools for turning spheres: (*a*) hole drilled in file, (*b*) sectional view showing countersink, (*c*) modified for cutting a bead, (*d*) section of tool made from bar, (*e*) end-view of (*d*).

actually to turn the surface, a brass tube of which the end has been turned true to the axis can be used to show where the sphere is high, being pressed against the work as it rotates and rocked to and fro. Then the high parts are turned off with a hand tool.

These methods have the advantage that the cylinders do not need to have the diameter of the sphere, so that the one cylinder is sufficient for spheres of different radii.

A countersink. This is used to produce spherical hollows (e.g. the oil-holes for a clock pivot). A hardoned steel wheel with sharp square edges is mounted in a holder similar to that usually made to carry a knurling tool, except that the stem is cylindrical and is used in the drilling machine or lathe.

Tool for turning a nut which has a slot, when the screw on which it works projects above the nut. This was made out of a broken pair of scissors. Flats to fit nuts of two ranges of size were ground, one on the stumps of the blades, and one on the handles after the loops had been cut away. A short rod was pivoted on the handle on one side, and it was clamped by a screw and nut on the other handle. This enabled the width to be set and made the tool easier to use.

An eccentric cutter holder for boring holes of any given size. This is an exceedingly valuable tool for obtaining a hole of an accurate size. The main part of the tool is made from a steel bar, 1 in. × $\frac{7}{8}$ in. and about 4 in. in length. About 3 in. is turned down either to a cylinder *A*, $\frac{1}{2}$ in. in diameter (if the tool is to be used in a drilling machine), or to a Morse taper (if, as is preferable, it is to be used in a miller). At the opposite end a dovetail groove is milled across the face, and below this is drilled a $\frac{3}{8}$-in. hole parallel to the dovetail as seen in the end view (Fig. 26 (*b*)). Then the block is slit through the middle of the dovetail and hole to a depth of $\frac{3}{4}$ in.

Fitting in the dovetail is a block *B*, which is also an inch long and $\frac{7}{8}$ in. wide; this has a turned extension, *C*, with a cylindrical hole $\frac{5}{16}$ in. in diameter, to carry the boring tool. On the inner face of this second block, beyond the dovetail, is a nut, *D*, in which works a $\frac{3}{16}$-in. screw, *H*, to move the block along in the dovetail. To keep the screw from end motion, it has a collar in which is turned a square groove; two halves of a split plate, *E*, fit in this groove and the halves are screwed on the side face of the main block. The screw has 40 threads to the inch, and the outer side of the collar, *F*, is turned to a bevel and divided into 25 parts, each of which therefore indicates a thousandth of an inch.

To tighten the main block upon the dovetail, there are two 4 B.A. screws, *G*, passing transversely through it; with these the dovetail may be adjusted to a close fit, and after setting it, it can be definitely clamped. The heads of these screws, of the traversing screw, *H*, and of the screw, *K*, that clamps the tool in the $\frac{5}{16}$-in. hole, are all made square and fit one and the same adjusting key.

A one-tooth milling cutter-holder. This tool is shown in perspective in Fig. 27 (*a*); Fig. 27 (*b*) is an end view, and Figs. 27 (*c*) and 27 (*d*) are side elevations at right angles to each other. It is intended to be used as an end mill and to be carried on a milling machine, but it can also be used in a lathe, the work being mounted on the slide-rest. Its great advantage is the ease with which the cutting tool is mounted and sharpened. The cutter is carried in the holder with its cutting face across a diametral plane. The end face of the holder is milled at a slant of about 75° to the axis. For ordinary work the tool is simply ground to a slant and the front face hollowed out as shown in Fig. 27 (*b*). It cuts round in a circle lying in the plane normal to the axis as indicated in Figs. 27 (*b*) and 27 (*c*) by the dotted lines. Thus it will mill a plane surface if the work is traversed across its face, while the tool is rotating.

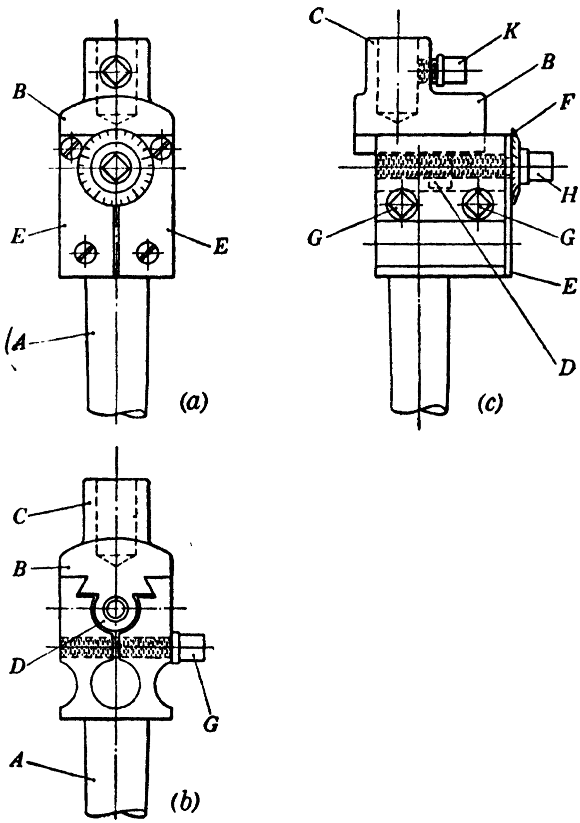


FIG. 26.—Eccentric cutter holder for boring holes of any given size.

The construction is so obvious from the drawings that little description is necessary. It is made from mild steel and the shank is turned to the Morse taper; the flats shown at the back of the holder are to facilitate its removal from the miller. The cutter can be $\frac{5}{16}$-in. Armstrong steel. A convenient diameter for the holder head is about $1\frac{1}{2}$ in. The slot should be of such a width that the cutter resting against its face shall have its cutting edge in the diametral plane as already

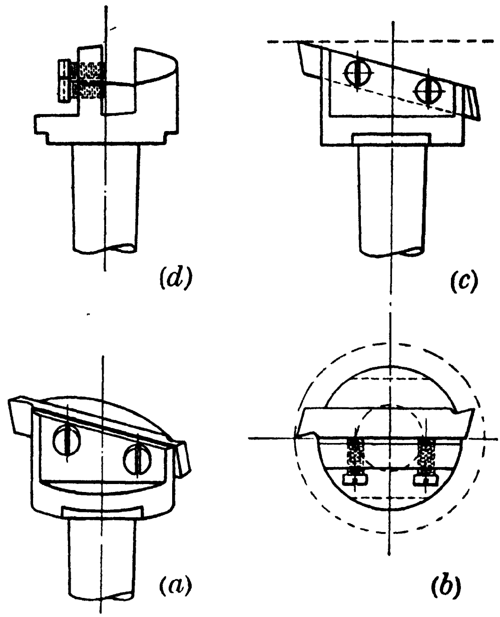


FIG. 27.—One-tooth milling cutter-holder: (*a*) perspective, (*b*) end-view, (*c*) and (*d*) side elevations at right angles to each other.

mentioned. It will be noticed that then the pressure of the cut is taken by the solid part of the head, the screws serving only to hold the cutter against that surface. It may be well to point out the cutter lies along the line of maximum slope.

[*See Notes 1 and 3.*]

3. Some More Mechanics' Own Tools

By S. MUNDAY

J. Sci. Instrum. **18**, p. 223 (1941)

A variation, and what appears to be a more convenient form of screwholder than that described in the previous Note by Clay is a steel plate, in one piece, in which holes are tapped. This prevents any damage to screw threads. Saw cuts are made along the centre line of the tapped holes and the screws are firmly held when the plate is nipped edge on in the vice. The saw-cuts run into large holes to give more spring to the plate, In addition to the tapped holes, countersunk clearance holes are also drilled. These are used to round the ends of countersunk screws which are awkward to hold in the lathe. The plate is held vertical in the vice and the screw is rotated in its appropriate hole by a screwdriver, whilst a file, its safe edge on top of the vice, is moved backwards and forwards and, at the same time, given a slight rotative movement which rounds the screw end. The plate, illustrated in Fig. 28, is 3 in. × 1 in. × ⅛ in. and is case-hardened.

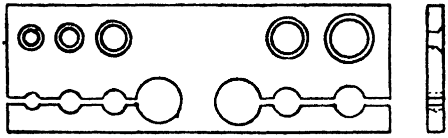


FIG. 28.—Tapped screw holder.

Trammels, shown in Fig. 29, are made from a pair of spring dividers. One leg of the dividers is cut off about half-way up and silver-soldered into a $\frac{5}{16}$ in. round steel bar which has a flat machined along its entire length. This flat locates the sliding point. An extension bar doubles the range of the trammel and the maximum radius is about 20 in.

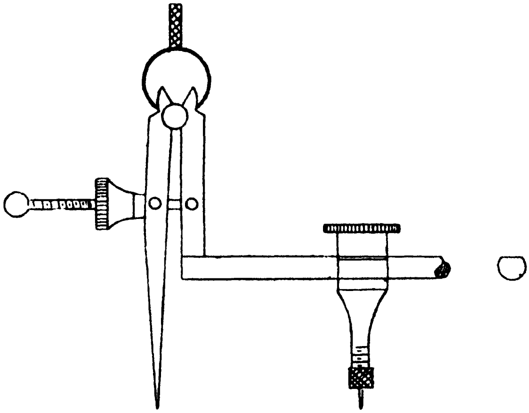


FIG. 29.—Trammels made from spring dividers.

Fig. 30 shows a depth gauge for measuring shallow grooves or recesses. It consists of a ground and lapped steel block, tapped to take a 6 B.A. grub screw. The block is split to take up backlash on the screw. The length of the screw must be the same as, or less than, the depth of the block. In use the screw is adjusted until it touches the bottom of the groove or recess, and the overall distance from the top of the block to the screw end is measured with a micrometer. The depth of the block is subtracted from this reading and the result is the depth of groove, etc.

In Fig. 31 is shown a very convenient boring-tool holder. A rect-

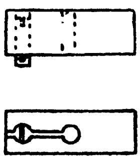


FIG. 30.—Depth gauge for shallow grooves or recesses.

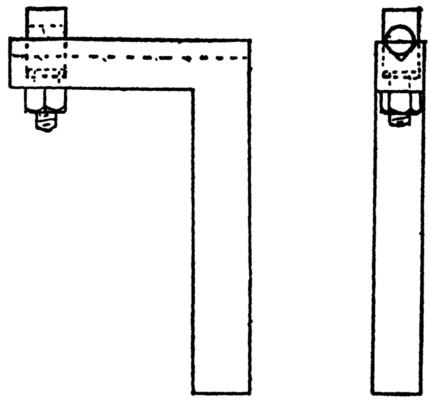


FIG. 31.—Boring-tool holder.

angular steel bar bent at right angles has a V-groove cut on the outer face of the shorter leg. A hole is also drilled to take the clamping

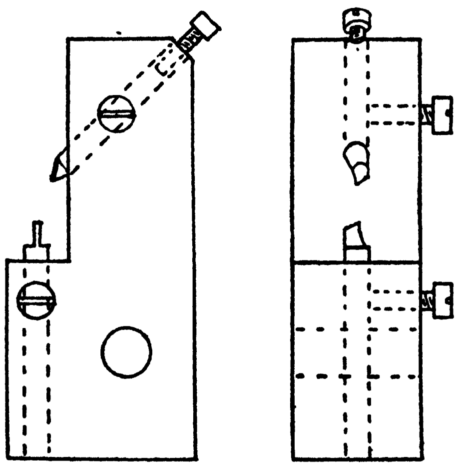


FIG. 32.—Tool holder for making tube washers.

bolt for the tool shanks. Tools are made from round rod. The writer has two of these holders; one for a small precision lathe, the other for a 6½-in. centre lathe. In the latter holder provision has been made, by using three sizes of clamping bolts, for tools, the shanks of which are $\frac{3}{16}$-, $\frac{1}{4}$- and $\frac{5}{16}$-in. diameter respectively.

In order to make a large number of tube washers, e.g. spacing washers for condenser vanes, the tool holder shown in Fig. 32 was constructed. It is bolted on the lathe slide rest in place of the ordinary tool holder. There are two tools, one for parting off, the other for facing. The facing tool is upside down as it cuts on the back side and is set at an angle of about 45° to the lathe axis. It is adjusted by a 4 B.A. screw and held firmly in position by a similar screw. Once adjustment is correct, washers can be parted off to within very fine limits. Each washer should have a slight skim taken by the facing tool before being parted off.

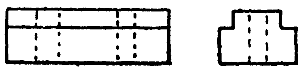


FIG. 33.—Tongue pieces to fit T-slots in machine tables.

Tongue pieces illustrated in Fig. 33 to fit T-slots in machine tables are very convenient. Smaller ones have 0 and 2 B.A. tapped holes, larger ones $\frac{5}{16}$ and $\frac{3}{8}$ B.S.F. Screwed sleeves to fit the latter holes with 4 and 2 B.A. tapped holes in the centre are often helpful to hold light work on a heavy machine.

[*See Notes 1 and 2.*]

4. The Use of Ball-Bearing Balls as a Convenient Series of Equal Weights

By E. C. WADLOW, Ph.D.

J. Sci. Instrum. **12**, p. 23 (1935)

A quick cheap way of obtaining a series of equal weights is to employ sets of ordinary steel balls which are stocked by most workshops in a wide range of sizes. The data given below have been supplied by the manufacturers.

A ball-bearing company employ a mean density of 7·76 gm./cm.^{3} for calculation purposes, and find a variation of from 7·724 to 7·888 gm./cm.^{3}. Another company state that the density of various samples measured varied between 7·762 and 7·768 gm./cm.^{3}, but they expect that wider variations than this do occur. Density measurements by the writer have given figures between 7·737 and 7·778 gm./cm.^{3}. Different makers use different steels and heat treatments ; composition and heat treatment are also governed by the size of ball. The standard limits for sphericity and diameter are $\pm$ 0·0001 in. on the nominal size.

For the present purpose it is proposed to adopt a mean value of 7·76 gm./cm.^{3}, and the limiting values suggested by the first company. For nominal sizes, and a density of 7·76, the weights of ordinary steel balls are given by the following equations:

$$\text{Weight (gm.)} = 66{\cdot}58d^3 \text{ (in.)} \quad (1)$$
$$\text{Weight (gm.)} = 4{\cdot}06 \times 10^{-3}d^3 \text{ (mm.)} \quad (2)$$
$$\text{Weight (lb.)} = 0{\cdot}1467d^3 \text{ (in.)} \quad (3)$$
$$\text{Weight (lb.)} = 8{\cdot}956 \times 10^{-6}d^3 \text{ (mm.)} \quad (4)$$

It is assumed that the balls are spherical and that diameter variations account for the dimensional limits allowed. Then, on a $\frac{1}{16}$-in. diameter ball, the possible maximum variation in weight due to a $\pm$ 0·0001-in. diameter limit is $\pm$ 0·48 per cent. The possible maximum variations for other sizes are inversely proportional to the diameters, and can therefore be readily obtained from the above figure. On 1-mm. diameter, the possible maximum variation in weight will be $\pm$ 0·76 per cent and the variation possible for other sizes is again inversely proportional to the diameter. The limits suggested by the first company correspond to possible maximum variations in weight, for nominal sizes of ball, of + 1·649 and − 0·4639 per cent respectively. These variations are independent of the size of the ball. The combined weight variation due to dimensional and density variations is equal to the sum of the possible maximum weight variations due to density and dimensional limits, respectively. If the diameter is greater than about $\frac{1}{4}$ in., or about 6 mm., the possible weight variation due to dimensional limits may be considered negligible in comparison with the possible variation due to density limits.

If extreme accuracy is desired, it will be necessary to check the weight of each ball by weighing. For many purposes, however, this is not necessary, as the accuracy of other measurements made during the loading tests will not be sufficient to justify the extra labour involved. It is also probable that balls bought from the same batch will all have the same density, and therefore will have more nearly equal weights.

It is often convenient to use small balls so that several go to make each increment of load. Balls are obtainable in all sizes in non-corrodible steel, brass, gunmetal, and phosphor-bronze, but as these are not used in industry to nearly the same extent as ordinary steel balls, they are not generally stocked, and have to be obtained specially from the makers. They do not, therefore, offer the same advantages in the present connexion as do ordinary steel balls. Balls of these special materials have the advantage of being more resistant to corrosion, but against this, the guaranteed dimensional limits of the non-ferrous ones are five times as great as those of standard ball-bearing balls. Greater variations in density are also likely.

5. Steel Balls as Pivots

By E. A. Baker, D.Sc.

J. Sci. Instrum. **15**, p. 304 (1938)

Where one piece of metal has to pivot upon another a steel ball makes a simple joint. A hole of suitable size is made in each piece of metal at the position of the pivot and a steel ball about half as large again as the holes is inserted between them. The two pieces may be held together and the ball thus retained by mechanical pressure, springs or gravity according to circumstances.

The same form of pivot, applied twice to the same pair of parts, makes a very precise and effective hinge. Two forms of this hinge are especially useful. In the first, which has the holes co-axial, one

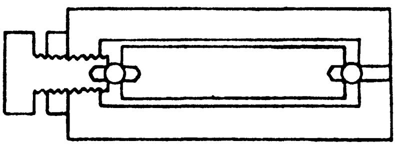


Fig. 34.—Hinged joint with ball pivots, holes co-axial.

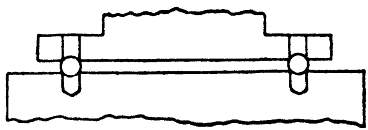


Fig. 35.—Hinged joint with ball pivots, holes parallel.

part has the form of a frame or fork in which the other part is held. Fig. 34 shows one method of applying the necessary pressure in this case. The second type of hinge (Fig. 35) has the two pairs of holes parallel. The parts to be hinged are clamped together in position while the holes are bored through them, with the result that the precise fit required for this non-geometric form of joint is automatically obtained.

By the use of three parallel holes bored in a similar way a detachable part may be mounted rigidly, in such a way that it may be removed and replaced in perfect register.

6. A Precision Test for Squareness

By J. W. Drinkwater, Ph.D., A.M.I.Mech.E., F.Inst.P.

J. Sci. Instrum. **18**, p. 115 (1941)

In the construction of end-measuring machines and tools it is essential that the measuring surfaces be parallel to each other for all positions in which they will have to operate. Consider the case of a micrometer. Since the measuring face of the spindle rotates, it must be square to the shank. To check this point is the object of the simple test to be described.

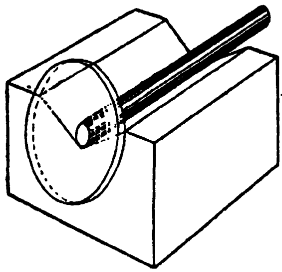


FIG. 36.—Precision test for squareness.

Wring an optical flat to the end face of a true, lapped, V-block. Then lay the spindle in the V and lightly press it against the flat, observing the interference fringes between the flat and the measuring face of the spindle. If the fringes do not move when the spindle is rotated, the spindle face must be square with the shank to within 2·5 millionths of an inch over the diameter of the face, assuming a mean wave-length of 2×10^{-5} in. and that a displacement of half a fringe is the least that can be observed.

If the V-block is not true, and a dead square spindle face is tested, a set of straight line fringes will be formed, their distance apart being determined by the error in squareness of the V-block. The test may still be applied, however, since the criterion is not the shape of the fringes, but the change of shape that occurs on rotating the spindle.

7. A Marking Tool for Tubes

By E. A. BAKER, D.Sc.

J. Sci. Instrum. **7**, p. 107 (1930)

Where one tube is to be fixed into another at an angle, the part of the larger tube which has to be cut away to admit the smaller may be marked off by the easily improvised tool shown in Fig. 37. The points on the larger tube through which the axis of the smaller one is to pass are first marked and drilled with a $\frac{1}{8}$-in. drill, and the holes drifted slightly to allow a straight piece of $\frac{1}{8}$-in. steel rod to slide through them. The marking tool is made by driving two lengths of this rod, one long, the other short and pointed, into parallel holes in a piece of square-section brass rod, at a distance apart equal to the radius of the smaller tube. A similar tool of more general application may be made by inserting the longer rod in place of one of the points of a pair of dividers.

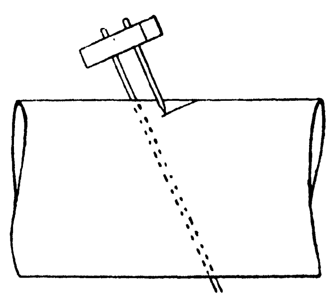


FIG. 37.—Marking tool for tubes.

8. Cutting Holes in the Side of a Tube

By R. Harries

J. Sci. Instrum. **12**, p. 234 (1935)

In constructing some large shunts it was necessary to drill several holes about $1\frac{1}{2}$ in. diameter in the side of a brass tube some 8 in. diameter. The ordinary expansion-drill circle-cutter was unsuitable for the job owing to the fact that the blade of the cutter catches in the work when partly through, so the cutter shown (Fig. 38) was made up and worked very satisfactorily. The body of the cutter is turned from mild steel, making the shank about $\frac{3}{8}$ in. diameter, the pilot $\frac{1}{4}$ in. diameter and the dimensions A $1\frac{1}{2}$ in. less twice thickness of saw blade less about $\frac{1}{16}$ in. to allow for set of teeth.

The cutter proper is a fairly coarse-tooth hacksaw blade which has been softened by heating to red heat and bent round, to fit the body

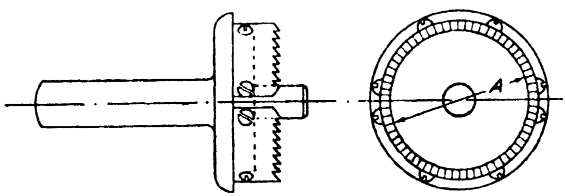


Fig. 38.—A tool for cutting holes in the side of a tube.

to which it is attached with screws, care being taken that the teeth point in the right direction. Where the two ends of the blade meet the teeth should be ground away at a slant as shown in the figure in order to prevent them catching and possibly breaking the saw. The blade should be hardened on the body by heating to a cherry red and plunging into oil. No tempering seems necessary. By keeping the blade on the body during hardening the tips of the teeth come out harder than the back of the blade which is desirable, also it has been found that hardening the blade separately and then screwing it to the body part almost always leads to fracture of the blade. The cutter is of course used in the drilling machine after drilling the appropriate size pilot hole.

9. A Tool for Cutting Circular Washers or Bobbin Cheeks

By G. W. Drury

J. Sci. Instrum. **21**, p. 125 (1944)

This is a simple and robust improved design of a well-known tool. As will be seen from Fig. 39, the cutter bar is made from a piece of silver steel, bent at right angles and then has a flat machined or filed along its upper side. The cutter is clamped by a nut with a fine thread, below which is a washer. The pilot pin is removable, to enable a drill to be substituted if the work permits the drilling and trepanning to be done simultaneously. The cutter can be sharpened either to leave

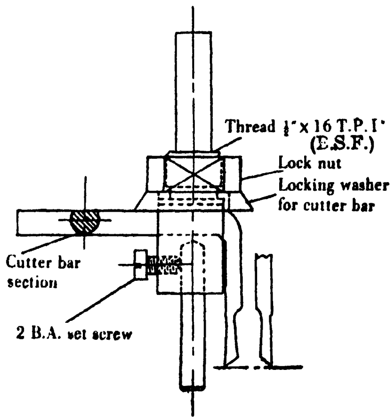


Fig. 39.—A tool for cutting circular washers or bobbin cheeks.

the hole true, e.g. instrument holes in panels, or to cut a washer with a square edge, as may be desired. The diameter of the cut can be adjusted between 1 in. and 4 in. A wide range of materials varying in thickness from $\frac{1}{16}$ in. to $\frac{1}{4}$ in. have been successfully cut with this tool. It was found that with a drill in place of the pilot pin chattering was liable to take place if the speed was too high at the larger diameters. In such cases it is better first to drill a $\frac{1}{4}$-in. diameter hole to take the pilot pin.

10. A Simple Saw for Hard Materials

By W. A. Wooster, Ph.D., F.Inst.P.

J. Sci. Instrum. **23**, p. 131 (1946)

Mineralogists commonly employ for cutting slices of rocks a saw which consists of a soft iron disc about 12 in. in diameter and $\frac{1}{16}$ in. thick, armed with diamond dust which is hammered into the periphery of the disc. This disc is rotated at a speed of 200–400 r.p.m., and the rock specimen is pressed against the side of the disc. In the cutting of hard uniform materials such as sapphire, use is often made of a phosphor-bronze disc of about 4 in. diameter and approximately $\frac{10}{1000}$ in. thick, rotating at a speed of some 5,000 r.p.m. It has been found that discs of this kind but somewhat thinner can be used very conveniently on a laboratory scale for cutting pieces of sapphire, quartz,

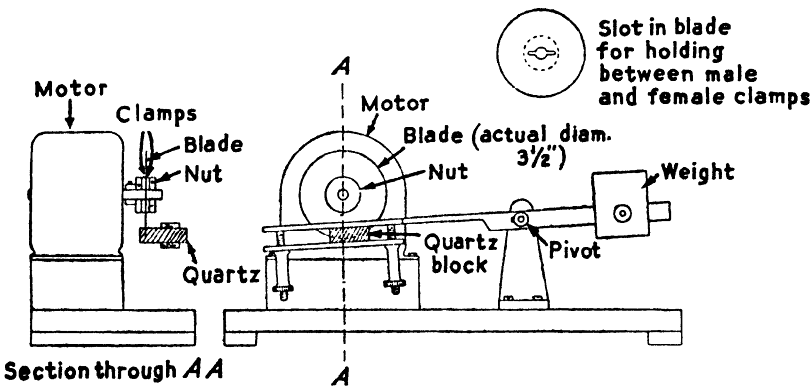


Fig. 40.—Schematic diagram of quartz saw.

glass and similar materials. The general arrangement of the parts of this cutting machine are shown in Fig. 40. The disc is mounted on the axle of a $\frac{1}{10}$-h.p. motor, rotating at approximately 1,500 r.p.m. Before starting to use the saw it is necessary to true its periphery by holding a cutting tool against it. The specimen to be cut is mounted in the clamp, which can pivot about a horizontal axis and is counterbalanced by the weight which can be moved along the supporting bar. In starting the cut, the edge of the disc is moistened with a little cedarwood oil in which the diamond dust is mixed, and the specimen is carefully raised until an edge just comes into contact with the rotating disc. The disc quickly makes an incision, and then the full force due to the weight can be allowed to press the specimen against the disc.

The cut obtained in this way is very little wider than the thickness of the slitting disc, and over an area of at least 1 sq. cm. the cut surface is flat. Over larger surfaces the saw is liable to wander, though a surface several square centimetres in area can be cut through by starting from two or more sides of the specimen.

The advantages of this arrangement over that normally employed by mineralogists are: (1) no lubricating liquid is used apart from the cedarwood oil which is the carrier of the diamond dust; (2) the machine is so small that it can be put into use on any desk or bench; (3) the cut is so narrow that even crystals only a few millimetres long can be fashioned.

11. Making Small Drills

From The Taylor-Hobson Research Laboratory

J. Sci. Instrum. **6**, p. 140 (1929)

Very good drills for small holes can be made from ordinary sewing needles. The needle should be broken off where it is thickest, just below the eye, and then a flat ground at this end, down to the axis, so that the end is of half-round section. The end may be ground conically, as engraving cutters are formed, with clearance to the cutting edge, or may be ground not quite squarely across the end, in the manner of the old " Woolwich bit ". Such a drill is a great deal more satisfactory than the ordinary fluted or flat drill with two cutting edges, as its edge extends right to the axis, and there is no part, such as is inevitable between the two lips of the ordinary drill, which must somehow worry its way through the material without cutting.

For ease in chucking, these small needle drills are best mounted in little brass shanks—a piece of, say, $\frac{3}{16}$ in. brass wire would be chucked in a lathe, faced up and just centred with a hand graver. It would then be drilled axially, using the needle drill itself held in a hand vice. The hole having been drilled to sufficient depth, the needle would be soft-soldered into it with its business end projecting.

12. The Drilling of Deep Holes

From The Taylor-Hobson Research Laboratory

J. Sci. Instrum. **6**, p. 331 (1929)

It is generally realized amongst mechanics that holes are more accurately drilled in the lathe where the drill is fixed and the work revolves than in the drilling machine with a revolving drill, and the general practice when drilling long holes such as the holes through gun-barrels, lathe mandrels, etc., is to revolve the work and feed through a stationary drill.

Figs. 41 and 42 illustrate the two conditions. The explanation generally given is that when with a rotating drill the drill gets out of line, as shown in Fig. 41, the pressure of the surface *A–B* tends to

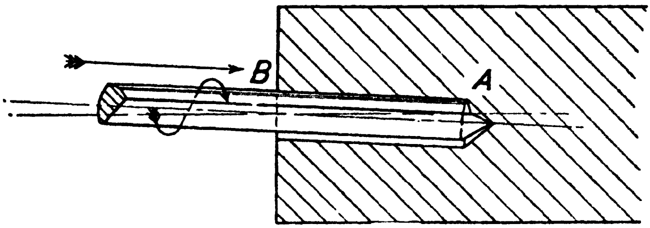


Fig. 41.—Revolving drill, work stationary.

make it deviate still farther from its course. When the work is revolving, as in Fig. 42, the point of the drill will be carried round in a circle of radius *R* about the axis of rotation, and the stiffness of the drill will tend to force it into the axis of rotation, with the result that a straight hole is produced.

This explanation will hardly stand a close examination. As long

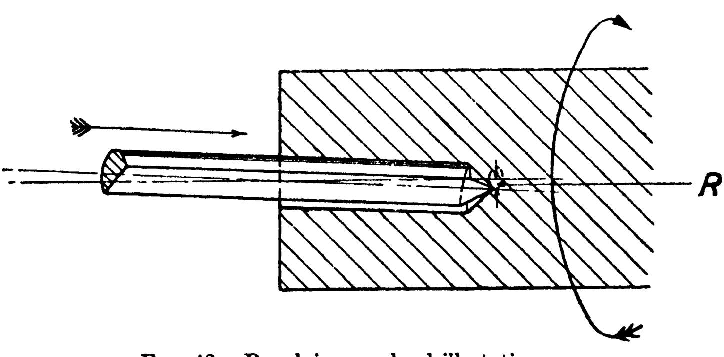


Fig. 42.—Revolving work, drill stationary.

as the initial axes of the drill and the work are in line there can be no geometrical difference between the two conditions, the relative motion of drill and work being the same, whichever it is that rotates. If the axes do not coincide the drill will, on account of its stiffness, tend to act as a boring tool if the work is revolving, and to make a hole concentric with the axis of the work, but with such slender drills as must necessarily be used for drilling deep holes this would not appear to make very much difference, and the advantage of rotating the work would seem to lie simply in the greater precision with which it is possible to start the hole. In the case of deep hole drilling machinery an important advantage of the fixed drill is the ease with which arrangements can be made for pumping lubricant through this, as is the usual practice, both to lubricate the cutting edges and to wash away the chips.

13. Riveting into a Blind Hole

From The Taylor-Hobson Research Laboratory

J. Sci. Instrum. **5**, p. 230 (1928)

The illustration (Fig. 43) shows an ingenious method of upsetting a pin into the bottom of a hole. The pin is drilled at the bottom slightly smaller in diameter than the ball. This is an ordinary steel bearing ball, which, when the pin is driven down, expands it, upsetting

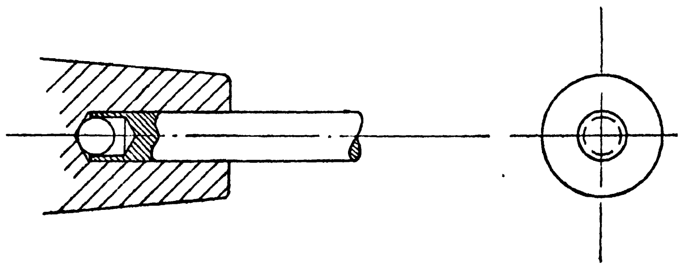


Fig. 43.—Riveting into a blind hole.

it into the hole. If the bottom of the hole is first chambered, using a wobble drill, an even securer job can be made Not only does this method make a simpler and cheaper job than screwing, but the pin will be true in the hole and will never come loose.

14. The Punching of Holes

By A. F. Dufton, M.A.

J. Sci. Instrum. **9**, p. 392 (1932)

Thin steel strip is an exceedingly useful material but is somewhat uncompromising to deal with. When used in instrument work it generally requires perforation in order that it may be screwed or bolted into position. A satisfactory method of making a hole is to insert the strip into a saw-cut in a brass block and to drive a punch of the required size through a hole drilled in the block at right angles to this cut. This method, which gives a clean hole without damaging the material, is probably very old. It may not be generally known, however, that the method is suitable for perforating soft materials such as cotton tape or wash-leather. The writer was interested to see recently a very satisfactory instrument, of unknown date and origin, in the form of a pair of pliers, one jaw of which was provided with a hole and a transverse cut and the other with a punch working into the hole. One advantage of inserting the material in such a cut is that as the punch is withdrawn the material is stripped from it.

15. Riveting Thin Wire through Aluminium Plate

By S. MUNDAY

J. Sci. Instrum. **6**, p. 105 (1929)

A method of fixing fine steel wires through aluminium or duralumin plates, where soldering is impossible, is shown in Fig. 44. The steel wires, 0·01 in. diameter, are held taut by clamping the ends across the forks of a U-shaped spring. The middle part of the wire is tinned and a close coil of fine copper wire wound on and soldered.

If the ends of the copper wire are nipped off close and surplus solder

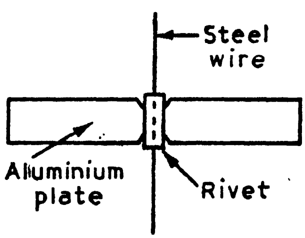


FIG. 44.—Riveting thin wire through aluminium plate.

removed with an iron, a fairly uniform cylinder of wire and solder is the result. This forms a rivet. The coil should be slightly longer than the thickness of the plate so that, the wire being passed through the plate, the rivet will project on either side. The projecting ends are riveted up by a hollow punch which should be a fairly good fit on the steel wire.

16. A Light Tool for Pulley or Gear Removing

By A. H. Cox

J. Sci. Instrum. **19**, p. 140 (1942)

Fig. 45 shows a gear being removed from its spindle. The tool was made from ½-in. square mild steel bar, slotted on either side with a fine threaded hole in the centre, also a series of holes across the slots. L-shaped jaws with a series of holes are inserted into the slots and held at their convenient width and length by knurl-headed spring dowels. To prevent the jaws slipping when pressure is applied by

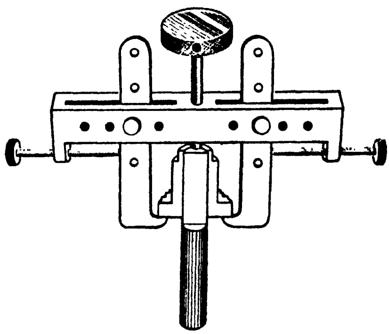


FIG. 45.—A light tool for pulley or gear removing.

the centre knurl-headed screw a small plate was fixed at each end of the bar, having an adjustable thumb-screw bearing against its respective jaw. The jaws being properly adjusted for diameter and length a few turns of the centre screw will remove the gear or pulley without damage to either piece, since the strain will be evenly distributed.

The tool only weighs 8 oz., and is thus very convenient to manipulate for light engineering work up to 3 in. in diameter.

17. Stop-Clock Key Retainer

By S. MUNDAY

J. Sci. Instrum. **18**, p. 243 (1941)

In order to obviate the loss of keys which operate the minute hands of stop-clocks, it was decided to fit a retaining device (Fig. 46) which would prevent the keys from being pulled from their spindles, subsequently mislaid and lost. The keys as fitted by the makers pass through a hole in the back of the clock case and are a spring fit on the minute-hand arbor.

On the few existing keys a piece of brass tubing, *A*, was soldered, in such a position that its upper edge was flush with, or a little below,

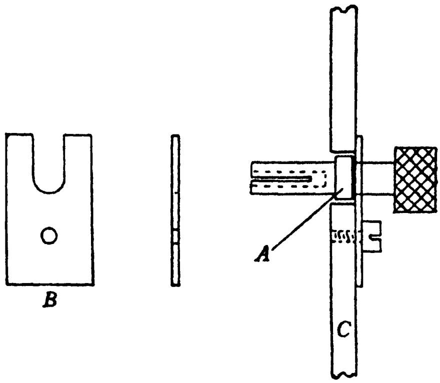


FIG. 46.—Stop-clock key retainer.

the clock case. A forked washer, *B*, was fastened to the back of the case, *C*, with a small screw.

The fork fits over the shank of the key, and the collar on the latter prevents the key from being withdrawn from the clock. Keys which were made to replace lost ones had the collar turned from the solid rod.

18. Locking Screwed Members

FROM THE TAYLOR-HOBSON RESEARCH LABORATORY

J. Sci. Instrum. **4**, p. 426 (1927)

The case frequently arises in instrument design where one member has to screw into another without risk of its slacking out again. The simplest method of ensuring that the two will lock together is to provide a shoulder on the one which will screw down on to a corresponding facing on the other when the two members are assembled, the two jamming together when screwed up tightly.

Whether they can be locked in this way or not depends on the diameter of the shoulder, the form and helix angle of the thread, and the coefficient of friction. Experience with threads of the ordinary

Whitworth form shows that, roughly, the condition that the two members will jam together is given by the formula

$$\text{Diam. in inches} \times \text{Turns per inch} > 72.$$

For example, if the threaded members are 3 in. diameter and are screwed 30 turns per inch, they can be jammed by screwing them together tightly: if, however, they are screwed 18 turns per inch, they cannot be locked, however tightly they may be screwed up.

19. V-Pulleys

By G. R. Myers

J. Sci. Instrum. **10**, p. 90 (1933)

Brass discs of various sizes and thicknesses can be bought by the pound and are useful stock for an experimental workshop. The illustration shows how a V-pulley can be made from a suitable size of disc

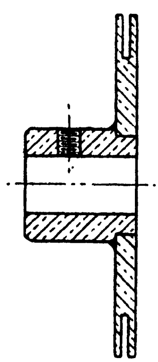


Fig. 47.—V-pulleys.

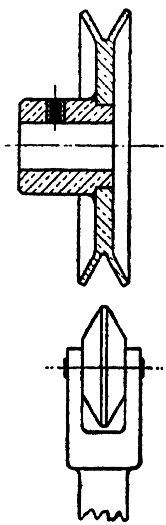


Fig. 48.—V-pulleys.

by turning a deep groove with a parting tool (Fig. 47) and by spreading the two flanges to form the V with a conical roller held in the slide rest as shown in Fig. 48.

20. A Flexible and Non-Extensible Driving Band

By J. M. Waldram, B.Sc., F.I.E.S., F.Inst.P.

J. Sci. Instrum. **10**, p. 395 (1933)

In taking a band drive from a small "toy" motor to a rather heavy glass disc, some difficulty was experienced in obtaining a suitable driving band. It was required that the band should be very flexible, but it was undesirable that it should be extensible, or torsional oscillations of the disc resulted. The pulleys were small (about 1 in. diameter), so that the joint in the belt had to be imperceptible, otherwise the disc was retarded whenever a joint ran over one of the pulleys.

The problem was finally solved by the use of ordinary sewing cotton, the driving band being built up around the pulleys. The cotton was taken about twenty times around the pulleys to form a kind of parallel strand "rope", and the ends knotted. The knot was, of course, imperceptible in relation to the rest of the cotton. In winding this part of the "rope", sufficient tension should be used to ensure a good drive. To prevent a tangle in case one strand should break or get off the pulley, the rope was lashed with cotton by taking one turn around it about every eighth of an inch with a length of cotton wound on a small bobbin. This made a very flexible band, and the lashings added considerably to the friction between the band and the pulleys.

21. The Mounting and Preparation of Fine Wire Specimens for Photo-Micrography

By H. Gollop, B.Sc., F.R.I.C., A.M.I.Chem.E.

J. Sci. Instrum. **4**, p. 492 (1927)

The preparation (grinding and buffing) of sections of very fine wires or other small objects whose microstructure is to be examined and photographed is frequently difficult. The difficulty is increased when the sample is resistant to most etching reagents, for in that case the use of a low-melting alloy as embedding agent, to facilitate handling, is generally objectionable.

A simple, convenient method of mounting and preparing such samples is as follows. A small wooden cube is treated on one roughened face with a thick layer of Formite syrup (the liquid form of Bakelite compound) and the wire is dropped into this mass. The whole is then heated in an oven at 110° C. for at least 4 hrs. On removal from the oven and cooling the Formite has set to a hard amber-like mass, which adheres closely to the wood. This mass can be buffed down to the sample.

The fact that the compound is unattacked by most reagents enables the sample to be etched very conveniently. Electrolytic etching of the sample is facilitated by the fact that the compound is an excellent insulator. The method readily permits of the preparation of sections of such objects as corroded or encrusted wires, whose brittle outer layers can often be examined in position.

22. A Simple "Trip" Mechanism

By O. W. Gill

J. Sci. Instrum. **13**, p. 24 (1936)

It frequently happens during the design of special machines and mechanisms that, in order to carry out a certain operation, a shaft is required to turn at either regular or irregular intervals through one

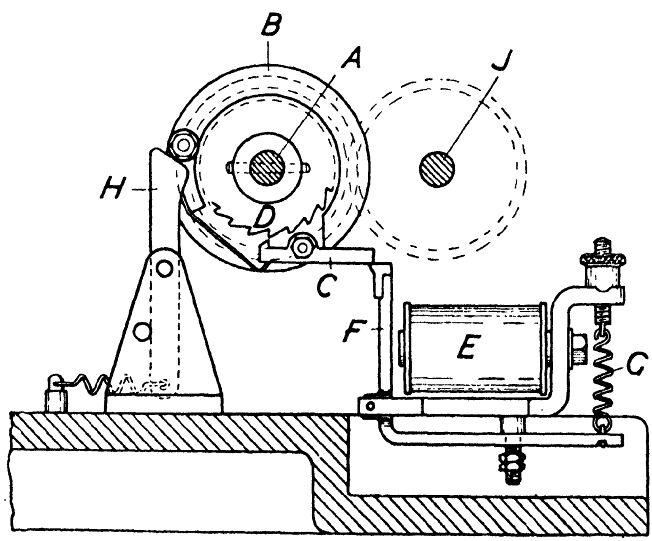


Fig. 49.—"Trip" mechanism.

revolution and then stop in its original position. A simple and effective method of achieving this end is illustrated in Fig. 49, where the shaft *A* is being driven continuously at some suitable speed. A sleeve *B* mounted on ball bearings is free to rotate on the shaft *A* and carries a pawl *C* which engages, under spring pressure, with the ratchet wheel *D*, the latter being keyed or pinned to the shaft. An electromagnet *E* carries a pivoted armature *F* having a hardened tip which engages the extended end of the pawl *C* preventing rotation of the sleeve *B*. On closing the magnet circuit momentarily, the armature is withdrawn from the pawl *C* which falls into engagement with the ratchet wheel. On completion of one revolution the pawl strikes the armature tip, which has been returned by the spring *G* to its original position, and again frees the sleeve from the ratchet wheel. A spring-loaded pressure pad *H* engages a roller on the sleeve at the completion of the revolution and holds the pawl in contact with the armature tip. A second shaft *J* may be connected to the sleeve by suitable gearing, the number of revolutions of the second shaft, per impulse of the magnet, being determined by the ratio of the gears.

23. The "Chain" and "Screw-Cord" Movements as Substitutes for the Rack and Pinion

By E. A. Baker, D.Sc.

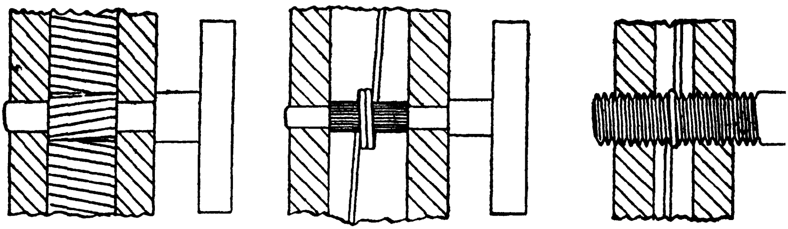
J. Sci. Instrum. **12**, p. 165 (1935)

Certain microscopes made about seventy years ago were fitted with a "chain" coarse motion. The chain, of the type still used in the fuzee of a chronometer, was wound once or twice round a ribbed axle which replaced the usual pinion, and was then stretched tightly along the body of the microscope in the position normally occupied by the rack. The motion so obtained is definitely smoother than that given by a diagonal rack and pinion, and since also its smooth working does not depend on precise adjustment its complete disappearance is surprising.

A simpler and cheaper substitute for the rack and pinion and one which works as smoothly as the chain is what the writer calls a "screw-cord" movement. It resembles the chain movement, but uses a cord in place of a chain and a screw in place of a ribbed axle, the difference here being that while the ribbed axle rotates in plain bearings the screw, of a standard size, works in tapped holes which are readily made and require no loose parts. The fact that the screw moves to and fro as it is rotated is actually an advantage. In the chain motion the chain traverses the axle as this is rotated, consequently the chain has to be set out of parallel to the body and space allowed for its motion between the axle bearings. In the screw-cord motion the cord, being wrapped round in the thread of the screw, does not move along it, and the mechanism becomes stronger and at the same time more compact.

Owing to the manner in which the screw thread grips the cord a single turn round the screw is sufficient—the possibility of slip between cord and screw is frequently a desirable safeguard.

Fig. 50 shows the three types of motion on a comparable scale, each giving the same movement for one turn of the head. The superior



(*a*) (*b*) (*c*)

FIG. 50.—(*a*) Diagonal rack and pinion; (*b*) chain motion; (*c*) screw-cord motion. The motion for one turn of the head is the same in each case.

strength of the screw-cord motion is apparent, especially in view of the figures given below for the possible load on a suitable cord.

In the chain movement one end of the chain was fixed to the body while the other was supported from it by a screw for adjusting the tension. A similar tension adjustment can be used for the cord of the screw-cord motion; but it is simpler to use a short spiral spring.

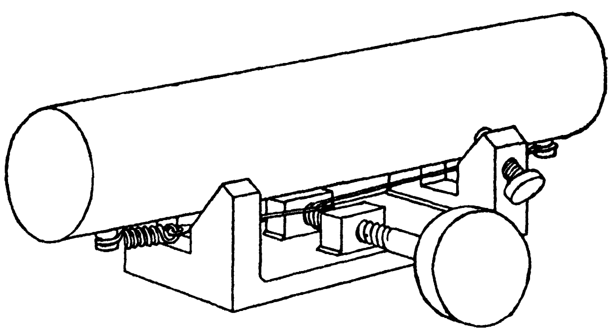


FIG. 51.—Application of screw-cord motion to reading microscope.

The fact that the spring may change its length slightly without greatly affecting the tension extends the applications of the screw-cord motion to geometric designs in which a rack and pinion would be inapplicable. Fig. 51 shows a simple instance in which the screw-cord is applied to move a cylinder (e.g. the body of a reading microscope) in the direction of its axis and at the same time to hold it against a four-point support, two of the points being adjustable.

Of the various materials tried as cords the most suitable is undoubtedly a strand of a steel-wire rope. If this type of cord is used, as in Fig. 50 (*b*), on a ribbed axle, strains are set up which speedily cause the wire to fray. Used, however, as in Fig. 50 (*c*), in a screw thread of appropriate form, it has an extremely long life. For light instruments a strand, consisting of nineteen steel wires each 0·004 in. in diameter, has been found very useful. It can be used on a screw as small as No. 0 B.A. or on standard brass thread from ¼ in. upwards and withstands a tension of some 70 lb., though only one-tenth of this would normally be used. For temporary apparatus, or where the need for occasional replacement is no objection, gut or silk cord (e.g. silk violin string) is satisfactory. For heavy duty, steel wire strands are available in great variety.

Certain applications of the "screw-cord" motion are the subject of a British Patent No. 434,289 by Baker and Renoulf entitled "Improvements in Gearing Applicable to Focussing Movements or other Adjustments of Optical Projection Apparatus, Philosophical Instruments or the like".

24. Self-Locking Winding Gear

By O. KANTOROWICZ, Dr.Phil., F.Inst.P.

J. Sci. Instrum. **14**, p. 346 (1937)

It is customary to lock the drum of a winding gear either by a pawl and ratchet or by friction brakes. A new method of locking is here

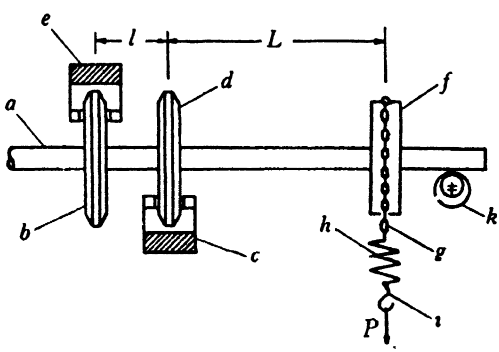
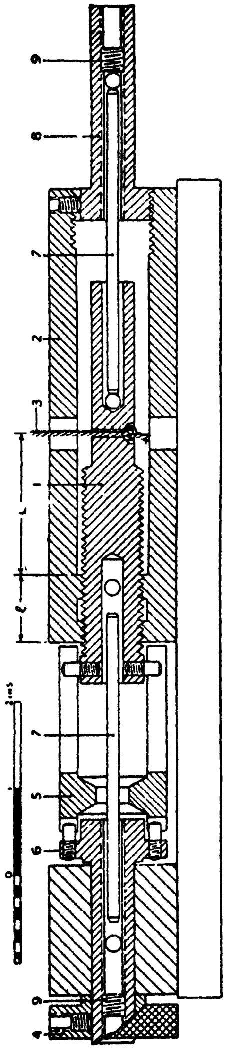


FIG. 52.—Principle of self-locking winding gear.

described, which seems especially appropriate to instruments. The advantages of this method are its cheapness and simplicity of construction and its ability to stop the drum by indefinitely fine steps whilst at the same time making the locking force proportional to the torque upon the drum. The action of the locking device is shown in Fig. 52. Fixed on the spindle a are two friction discs b and d, having radii r_b and r_d, their respective centres being l units apart. Each of these discs has a rim in the form of a double cone, the angles included between the faces of the cones being α_b and α_d respectively. Fixed L units from the centre of the disc d is the chain pulley f with the radius r_f over which a chain g is put carrying at its end a spring h and a hook i on which the pull P is acting.



Drawing No. 1709
Reproduced from the Science Museum Handbook "Very Low Temperatures, Book II" with the permission of the Controller of H.M. Stationery Office

FIG. 53.—Self-locking winding gear.

The friction disc is supported by the brake block c, the centre part of which is machined away so that the friction disc contacts on two small areas, each fitting against the conical sides of the discs. These areas have a mean angular separation of β_c measured at the axis of the spindle. Similarly, the friction disc b is held down by the brake block e which is constructed in an analogous way, the angular separation this time being β_e. The two brake blocks are rigidly fixed. In order to prevent the spindle rotating under the influence of the pull P the following relation must hold:

$$P.r_f \leq \mu.p\left(\frac{r_d.\dfrac{l}{L+l}}{\sin \alpha_d/2.\sin \beta_c/2} + \frac{r_b.\dfrac{l}{L}}{\sin \alpha_b/2.\sin \beta_e/2}\right),$$

where μ is the coefficient of friction of the surfaces of contact of the brake blocks and the friction discs. In order to deduce the relation, the moving system may be regarded as a lever turning about the line that joins the supporting areas on the brake block c. There is then a force acting downwards on c and one acting upwards on e. These forces are the resultants of two forces, the sum of which is $1/(\sin\beta/2)$ times greater than the resultant, acting on the areas of the brake blocks, and these forces again are the resultants of two forces acting normal on to the V-groove faces, the sum of these forces being $1/(\sin\alpha/2)$ times bigger than the resultant in consequence of the wedge action. The minimum tangential forces necessary to make the friction discs slip in the V-grooves are given by multiplying these normal pressures by the coefficient of friction μ. The system will be at rest when the moment $P.r_f$ about the axis is resisted by the bigger sum of the moments which are the products of the frictional forces multiplied by the radii at which they act. It follows from the equation that the equilibrium depends only on the geometrical dimensions and the coefficient of friction, but not on the pull. For moving metallic faces, μ may become as low as 6 per cent if the lubrication is as good as obtainable. Winding gears for which μ might have been as small as 10 per cent have been found to be self-locking when at rest but to have a tendency to slip when moving. This only happened, however, after the friction surfaces had become polished by long service.

25. A Silent Worm Drive

By M. C. Marsh, Ph.D., F.Inst.P.

J. Sci. Instrum. 7, p. 171 (1930)

For laboratory-made apparatus, a Meccano worm drive is a very convenient form of speed reduction gear. When the speed of the driving shaft is high, this gear, however, is apt to be very noisy. The noise has been greatly reduced by employing an ebonite worm constructed as follows.

A cylinder of ebonite was bored to fit a screwed shaft and gripped between two nuts. It was then turned down on the shaft to 0·56 in. diameter and the worm formed by cutting a screw thread of $\frac{1}{12}$ in. pitch at an angle of about 45°. By causing the driven wheel to dip into water ample lubrication is provided and the gear has been in operation for some hundreds of hours without serious wear.

This method reverses the usual practice of a brass worm driving a fibre wheel, but in the average workshop the worm can be made sufficiently accurate for most experimental work, much more easily than the wheel.

26. A Simple Reduction Gear and Clutch

By J. M. WALDRAM, B.Sc., F.I.E.S., F.Inst.P. and
J. M. SANDFORD

J. Sci. Instrum. **11**, p. 26 (1934)

In the course of an experiment on the switching of lamps, a commutator was driven at a constant speed from an electric gramophone motor. In the preliminary experiments the commutator was mounted directly on the motor spindle and rotated at 80 r.p.m., but later experiments demanded a speed of one-half or one-quarter the motor speed. To have the apparatus redesigned and gears cut would have involved undue delay, and a friction gear was devised which has shown itself to be useful as a simple gear and clutch. Several ratios can be used

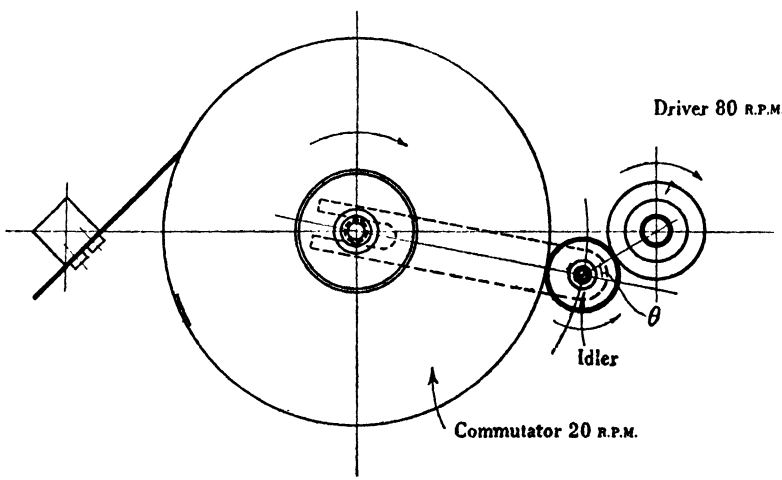


FIG. 54.—Diagram of reduction gear and clutch.

and changed without altering the centres, and the drive can be instantly engaged or disengaged at any point. At the same time the drive is positive and free from slip.

The arrangement is shown in Figs. 54 and 55. The commutator is mounted on a vertical spindle, and an ebonite disc, the diameter of which bears the required ratio to that of the commutator, is mounted on the gramophone motor spindle. A loose idler pulley, the surface of which is rubber covered, is arranged to connect the two in the manner shown. It is mounted on a radial arm free to turn about the axis of the commutator and arranged on a slot to have a certain amount of freedom in the radial direction in addition, so as to permit it to take up its own position in relation to the other two wheels. It will be seen that the effect of load on the commutator is to tend to pull the idler in between the other two wheels and to increase the friction. If the commutator is held stationary, the friction is sufficient to stall the motor and to pull the rubber tyre off the idler.

To change the ratio, a disc of different size is substituted on the motor spindle, and the idler takes up a suitable position without altering the position of the commutator or motor axes. It might be necessary if the ratio is changed by a considerable amount to use a different size of idler, which can, however, be changed in a moment. The limiting condition is that the angle θ in Fig. 54 should not exceed twice the angle of friction between the tyre on the idler and the discs.

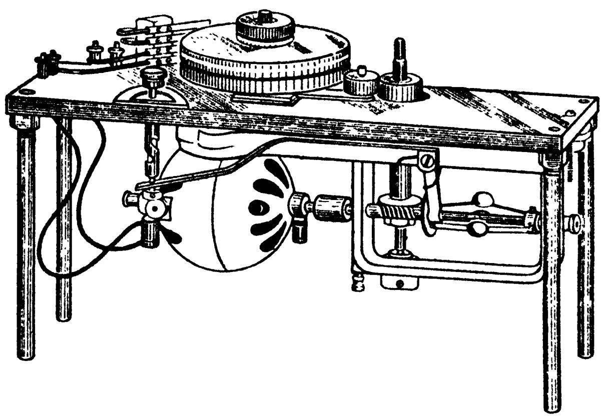


FIG. 55.—Reduction gear and clutch.

If the idler is withdrawn from between the other two wheels, the drive is instantaneously disconnected, and when it is brought lightly into contact with them, it is immediately re-established. This characteristic might make the drive suitable for certain types of mechanical relay, for the force necessary to move the idler is very small, especially when establishing contact. If the load is heavy, rather more force is required to separate the wheels. The drive can be re-established at any point, and is not limited by the position of gear teeth; it is also completely silent.

The rubber tyre should be thin and smooth. The tyre used was made by cutting ordinary electrician's V.I.R. tape to size, with the paper backing still in position to prevent stretching. The paper was removed and the tape applied to the idler, to which it adhered without further adhesive. The ends stuck together to make a good and invisible butt joint.

The gear can obviously be developed to form other devices such as a free-wheel gear, a gear driving in both directions (using two idlers), a step-cone change-speed gear or a mechanical relay.

[*See following Note.*]

27. A Simple Variable-Speed Gear

By J. DE GRAAFF HUNTER, C.I.E., Sc.D., F.Inst.P., F.R.S.

J. Sci. Instrum. **11**, p. 127 (1934)

For this device which has been described previously * two cones of wood of length about 12 in. and tapering from diameter 5 to 0·5 in. were made. These were mounted on parallel spindles, the large end of one opposite to the small end of the other as shown in the horizontal plan (Fig. 56). Connexion was made by placing an ordinary solid rubber playing ball between the two cones. The diameter of the ball was some 30 per cent greater than the least separation of the cones;

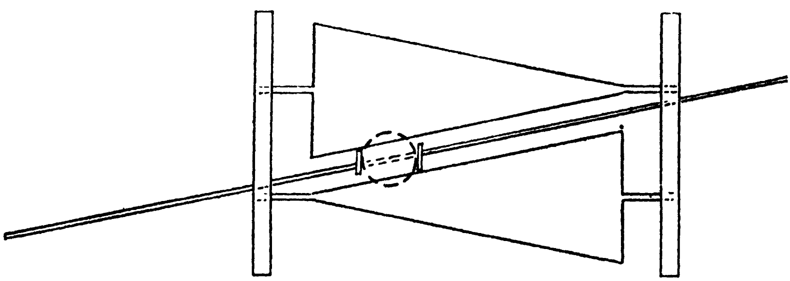


FIG. 56.—A variable-speed gear.

so that the ball rode somewhat above the plane through the spindles. Its position longitudinally was controlled as required by a rod which could be slid parallel to the most adjacent generating lines of the cones; the rod bore two parallel guide plates at right angles to the spindles and these plates were separated by an amount just greater than the diameter of the ball.

By traversing the ball from end to end it was easy to obtain any desired relative speed of the two spindles between 7 to 1 and 1 to 7 or a little more—a fiftyfold variation. Just as in the arrangement described in Note 26, the two cones and ball constituted a free wheel gear and clutch, and drive could be established at any point; but in addition the speed ratio could be varied by amounts large or small.

* de Graaff Hunter, *Trans. Op. Soc.* 8, p. 1 (1906).

When considerable power was to be transmitted the ball soon showed signs of wear.

For small power transmission—such work as rotating some physical apparatus—it proved very suitable.

[*See previous Note.*]

28. Calculation of Gear Wheels to Obtain the Best Approximation to a Given Ratio

By R. S. Clay, D.Sc., F.Inst.P.

J. Sci. Instrum. **18**, p. 66 (1941)

Occasionally the problem arises of finding a train of wheels to give some arbitrary ratio. For instance, it may be asked what train will convert centimetres into English inches ? We will assume this ratio to be 2·539954 ; then what set of wheels will give this ratio approximately ? The method to be adopted is actually well known, but not as a rule by instrument makers. It consists in converting the decimal fraction into a continued fraction, and taking a convergent that gives a sufficiently near approximation.

To do this, begin by doing a similar calculation to the method of finding the least common multiple of two numbers of our old arithmetic days, thus :

	1	2·539954	
	·	2	2
1	·539954	539954	
	460046	460046	1
5	399540	79908	
	60506	60506	1
3	58206	19402	
	2300	18400	8
2	2004	1002	
	296	888	3
2	228	114	
	68	68	1
1	46	46	
	22	44	2

The quotients are : 2, 1, 1, 5, 1, 3, 8, 2, 3, 2, 1, 1, 2, 11.

From these quotients the successive numerators and denominators of the continued fractions are made by a simple rule which is most easily explained by setting them out.

Quotients	2	1	1	5	1	3	8	2	3	2
Fractions	$\frac{1}{0}$	$\frac{2}{1}$	$\frac{3}{1}$	$\frac{5}{2}$	$\frac{28}{11}$	$\frac{33}{13}$	$\frac{127}{50}$	$\frac{1049}{413}$	$\frac{2225}{876}$	$\frac{7724}{3041}$

Rule. Take any one of the quotients and use it as a multiplier of the numerator and denominator of the fraction under it, and add the respective numerator and denominator of the preceding fraction: e.g. $5 \times 5 + 3 = 28$, and $5 \times 2 + 1 = 11$. Or again: $8 \times 127 + 33 = 1049$, and $8 \times 50 + 13 = 413$. Obviously the first convergent is 2 and to apply the rule we prefix a fraction $\frac{1}{0}$ which makes the rule consistent. The successive values of the fractions above are 2, 3·0, 2·5, 2·5454, 2·5384, 2·54, 2·539951, 2·5399543, 2·53995396. It will be seen that they are getting progressively nearer to the desired value, being alternately larger and smaller than the final value.

Now it is necessary to find a fraction that can be split up into suitable fractions. Neither 1049 nor 413 can be split up, but the next fraction can be broken up into $\frac{25 \times 89}{12 \times 73}$ giving a result correct to about one part in ten million.

If it should happen that neither of the fractions will break up into convenient numbers, it is sometimes possible to get a pair of figures by combining two of the fractions, without a very great loss of accuracy. For instance, if we add the numerators and denominators of the fifth and tenth fractions we get a new fraction $\frac{7752}{3052}$ and this breaks up into $\frac{24 \times 17 \times 19}{4 \times 7 \times 107}$. The value is 2·53997 and is therefore a little high.

A nearer result would have been obtained by using a later (and therefore nearer) fraction than the fifth. Or the fractions can be subtracted instead of added.

It should be noted that the convergents are always in their lowest terms, but this does not necessarily hold for the combinations of convergents.

The British Association for the Advancement of Science has published a volume giving the factors of all numbers up to 100,000 (*Mathematical Tables*, vol. 5, or vol. 8 can be used for any number up to 10,000. Anyone who has many of these gear-trains to compute will find these books most helpful.

[*For further discussion of this subject, see* Baker, E. A., *J. Sci. Instrum.* **18**, p. 169 (1941), and Sutcliffe, R., and Clay, R. S., *J. Sci. Instrum.* **18**, p. 243 (1941).]

29. The Simple Construction of Accurate Division Plates

By D. C. GALL, M.I.E.E., F.Inst.P.

J. Sci. Instrum. **20**, p. 77 (1943)

For many years my instrument shop has constructed accurate division plates by a very simple method. These plates are used for gear cutting, scale dividing and for any kind of light accurate index milling or boring. The principle used is very simple and any number of divisions can be made with a very high degree of angular accuracy. Each division is composed of a steel ball-bearing which can be obtained in selected batches uniform to 0·0001 in. These balls are pressed into a groove turned in the face of a brass or gun-metal disc, and this disc, when mounted on the dividing head, becomes the division plate. Registration is made in the V between the faces of adjacent balls by means of a chisel-pointed locking pin. A number of different divisions can be mounted in the same plate and up to 500 divisions have been used.

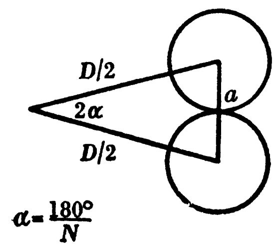


FIG. 57.—Showing mean diameter of groove required.

The disc must be accurately prepared in the following way. Mounted in the lathe, a central hole is bored to fit the particular dividing head with which it is to be used. At the same setting the groove for balls is turned in the face of the disc. The depth of the groove should be made about three-quarters the diameter of the balls and rectangular in section. The diameter of the groove must be accurately calculated as follows: if d is the diameter of the balls chosen, then it is easy to see (Fig. 57) that for any required number of divisions N, the mean diameter of the groove will be

$$D = d \operatorname{cosec} 180°/N.$$

The groove must be made slightly narrower than the diameter of the balls, and about 0·002 in. is a reasonable allowance for small balls. Thus, for example, to construct a division plate of 100 divisions, using balls of 0·2 in. diameter, we have:

The mean diameter D of the groove $= 0{\cdot}2 \operatorname{cosec} 1{\cdot}8° = 6{\cdot}3672$ in.

The inside diameter would therefore be made smaller by 0·198 in., i.e. 6·169 in.

The outside diameter would be made larger by the same amount, i.e. 6·565 in., giving a groove width of 0·198 in.

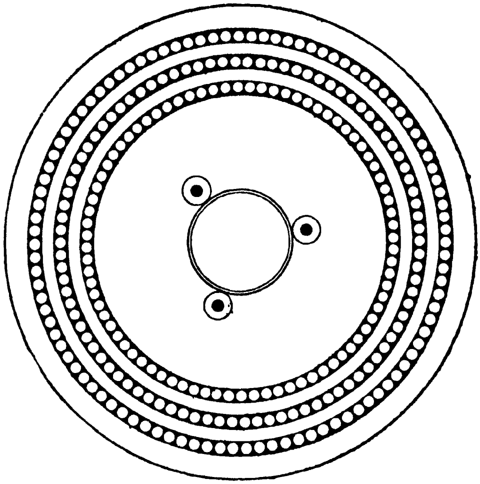


Fig. 58.—Typical division plate, employing ball bearings. The number of balls in the three grooves is 80, 90 and 100.

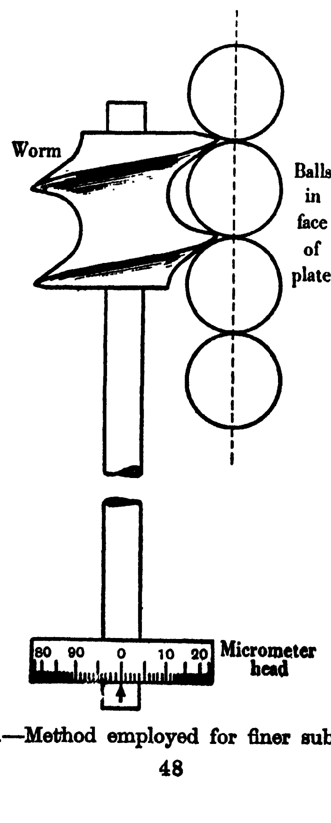


Fig. 59.—Method employed for finer subdivision.

Having turned the groove to these dimensions and 0·15 in. deep, the plate should be removed from the lathe (after any other turning required has been done) and laid flat on a small surface plate. After carefully cleaning everything, the balls should be laid round the groove just touching each other. Tapping will shake them down into place, but they will not go right home because of the groove being too narrow. A second surface plate should now be placed on top and then pressed down. Great force is not required, but a hand press is usually employed to force the balls home to the bottom of the groove. When there they are extremely secure and none has ever fallen out in use. If removed, they are found to be embedded in perfectly regular indentations in the softer metal of the plate, and they take a lot of prising out.

It is easy to see that if the differences of diameter of the balls do not exceed 0·0001 in. and if the errors are randomly dispersed, then the probable error in angle, if concentrically mounted, would theoretically not exceed 20″. A typical plate is shown in Fig. 58. It is usual to choose a size of ball which will give a mean diameter of about 6 in. as grooves of this size can be turned with a high degree of precision. Finer subdivision can be obtained by engaging the balls with a worm with a suitably shaped thread so that a micrometer tangent screw adjustment can be made. This has not found much use but has interesting possibilities for some purposes; the scheme is shown in Fig. 59.

30. A Simple Method of Dividing Instrument Scales

By W. E. Williams, B.Sc.

J. Sci. Instrum. **14**, p. 384 (1937)

The problem of dividing scales for electrical instruments, rheostats, potentiometers, and similar apparatus is one which is constantly arising in an electrical laboratory, and it is by no means easy to mark out a scale which shall be both accurate and neat.

The following method, which does not require any elaborate apparatus, has been found to be both quick and accurate. It makes use of a standard Amsler planimeter, the division being carried out by means of the graduated roller of the planimeter, advantage being taken of the fact that by varying the position of the roller on the bar the angular value of a division may be varied to suit the required scale. A fitting *A* (Fig. 60) is made to clamp on the planimeter bar and carries two small straight edges of celluloid to guide the marking pen. It is convenient for the guide to be situated about $\frac{1}{8}$ in. above the scale since the plates which have to be divided vary in thickness, hence two straight edges one about $\frac{1}{2}$ in. above the other are used in order to ensure that the drawing pen shall be vertical.

Taking first the case of a circular scale which is to be divided uniformly: the scale plate is set up on a drawing board, the circles for the scales are drawn, and the terminal marks put in. The tracing point of the planimeter is fixed at the centre O of the circles and the marking edge adjusted to be over the scale. The other point B which is normally the fixed point is put in a small piece of cork so as to move

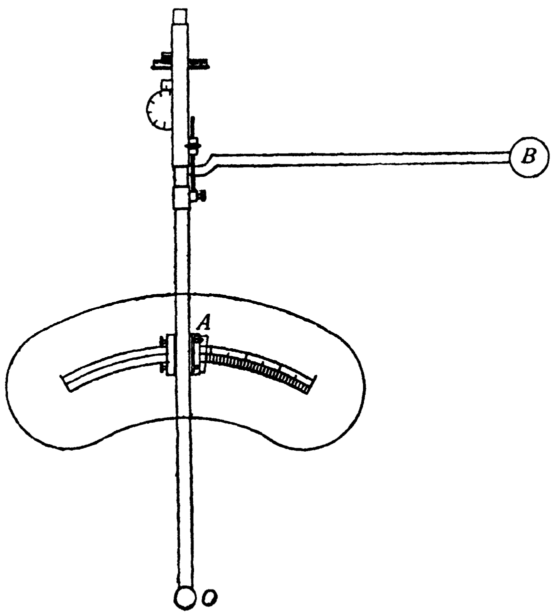


Fig. 60.—Dividing a scale with a planimeter.

freely over the board. The celluloid edges have a slight lateral adjustment so that they can be set radially. The planimeter is now traversed between the two end marks of the scale and the position of the roller on the bar is altered until the total reading between the marks is some multiple of the required number of scale divisions. The screw adjustment on the bar enables this to be done with great accuracy. Each scale division will now correspond to some simple number (preferably 5 or 10) of roller divisions, and the scale is readily marked off.

Similarly if the scale is to be marked according to a given function such as a square or log law, the readings for which are to be obtained from a table of the function, the position of the roller is adjusted so that the roller readings shall be some simple multiple of the tabular values. Should the scale be given by calibration marks which do not fit any known function, the positions of the given marks are read off with the roller, these are then plotted on square or logarithmic paper and a smooth curve drawn through them ; finally, divisions for a suitable scale are read off from the graph and marked from the roller scale as before.

31. Ruling Verniers and Scales on a Lathe

By P. Kirkpatrick

J. Sci. Instrum. 8, p. 330 (1931)

Verniers and short scales of very good quality may be ruled (on flat surfaces) with the aid of an ordinary lathe. The method here suggested does not employ the lead screw, so that neither the calibration nor in fact the existence of this part is required. The machine should, however, be furnished with a cross-feed screw with micrometer collar.

The work is clamped to the tool post in such a position that the surface to be ruled is horizontal and uppermost, and so oriented that the desired rulings shall lie parallel to the lathe bedways. A lathe tool for cutting female threads or a specially ground boring tool will be found convenient for executing the rulings. This tool is clamped by its larger end in the lathe chuck in a radial and horizontal position, so that its cutting end extends toward the operator, swinging on a radius of 4 or 5 in. The bit of the tool is so turned that it meets the work to be ruled in a proper manner when the carriage is advanced to the correct position. The tool is pressed down against the work with the proper force by the torque of a loaded horizontal rod or arm, which may be secured to the chuck by thrusting an end into one of the chuck wrench holes. The constant pressure against the work which is obtained in this way will be found to produce more uniform rulings than will result from any rigid method of setting the tool. The rulings are inscribed by moving the carriage through the desired range. Clamps may be attached to the lathe bed to limit this motion and to ensure uniformity in the lengths of the lines.

The important matter of the correct spacing of the rulings is readily controlled by means of the cross-feed screw with its micrometer collar. Since this collar is ordinarily graduated to thousandths of an inch, either English, metric, or any odd scale whatever may be accurately and precisely executed.

32. A Laboratory Ruling Device

By V. H. L. SEARLE

J. Sci. Instrum. 2, p. 268 (1925)

In an attempt to devise a means of producing short millimetre scales of sufficient accuracy for use as objects in the measurement of focal lengths and nodal distances of thick lenses, for the testing of the scales of travelling microscopes, and for the calibration of micrometer eyepieces, the writer was led to the construction of the arrangement shown in Fig. 61. It has the advantage of being easily made from parts which are usually available in any physical laboratory and gives fairly fine rulings which are spaced with an accuracy of about one hundredth of a millimetre. The basis of the method is the employment of a spherometer *S* to advance the plate *PP* beneath the ruling point *R* whose distance from the spherometer is fixed. A hardwood base *AB* carries the spherometer which is rigidly affixed to the base by having two of its outside legs forced into the edge of the wood. The moments of the forces tending to displace the spherometer are so

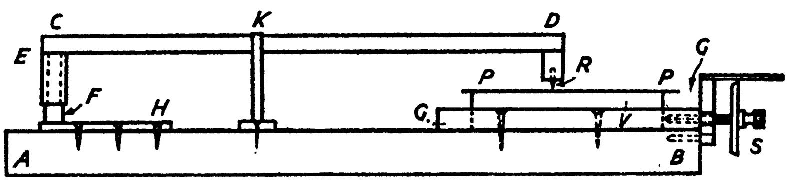


FIG. 61.—A laboratory ruling device.

small that no other clamp is required. The baseboard also carries two parallel straight brass guides *GG* between which a rectangular block of glass *V* slides, freely but without shake, in the direction of advance of the spherometer leg. The photographic plate *PP* is fixed, film side upward, to the glass block by four spots of soft wax. The plate has previously been greatly over-exposed and, on development, gives a dense deposit. The thin film layer is removed by the action of the ruling point, thus leaving fine transparent lines which give, on a positive, the required scale rulings as fine black lines. The length of these lines is made uniform by restricting the sideways movement of the radial arm *CD* between two stops *K* arranged symmetrically to the axis of the instrument. Gentle pressure of one hand against the edge of the glass block keeps the spherometer leg in uniform contact and effectually prevents uncertainty in the rulings. The ruling point is carried at the end of the brass bar *CD* to which is soldered, at the end *C*, a brass sleeve *E* which fits snugly on the supporting pin *F* screwed into the brass plate *H*. It was anticipated that play in this bearing would affect the accuracy of the device but, in practice, it was found a simple matter to turn the pin down to a sufficiently close fit in the sleeve. A gentle pull is exerted towards the spherometer while the point is cutting into the film. The necessity for the construction of a cutter having rigidity combined with a keen cutting edge led to the use of a small drill which was driven firmly into a slightly smaller hole drilled in a brass support also soldered to the arm *CD*. This drill was then broken off so that about 4 mm. projected. This end was then ground down to a rounded chisel point which was found to give a good cutting edge without play. If the cutting edge is not quite at right angles to *CD* then a cut in one direction, only, gives spaces which are alternately too close and too far apart. To avoid this defect a backward and forward movement of *CD* is made for each line.

The scales produced for use are positives obtained by contact prints on glass plates, and for the use of students, 1-mm., ½-mm. and ¼-mm. scales and corresponding vernier scales may be made.

The lines obtained are sharper and of a more uniform width than those obtainable by the usual Brunswick black and hydrofluoric acid method, while the process of duplication by contact printing is more convenient than the etching method. By substituting a carborundum crystal for the ruling point scratched rulings may be obtained.

33. A Drawing Instrument for Large-Radius Arcs

By E. Simeon

J. Sci. Instrum. **10**, p. 157 (1933)

To scribe arcs of large radius, say 2 or 3 ft. and upwards, one usually resorts to the pearwood " radius curve ". A full set of these is rather expensive. The instrument illustrated in Fig. 62 serves the same purpose ; it will scribe an arc of any radius from a foot up to infinity, i.e. a straight line.

It depends on a well-known proposition concerning angles drawn within a circle. The reader may recall the method of tracing out a semicircle with the aid of two pins set upright in the table, putting the square corner of a card up to them and working it round—a geometric curio which contains the germ of the idea.

There are two arms, *AA'*, hinged together ; the scribing pencil point *R* is placed where their straight edges intersect. To draw a true arc through three given points, a pin is inserted at each outer point

PP' ; the arms are adjusted to touch them while the pencil coincides with the intermediate point. The arms being then locked, the arc can now be struck, using both hands.

To scribe an arc of a particular radius on a sheet of paper, the arms are set to the appropriate scale mark on *S*, and used with a companion accessory, not shown on the drawing. This is merely a straight metal tube near each end of which is permanently set a fine point. It is obviously impossible to scale the instrument unless the distance *PP'* is fixed by some such means. The resulting arc, of course, terminates at the two points.

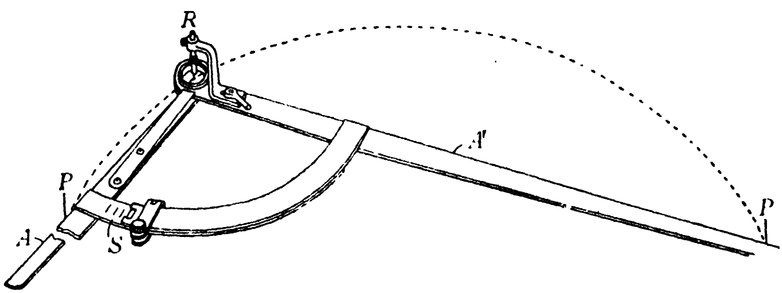


FIG. 62.—A drawing instrument for large-radius arcs.

If a given radius arc through two stated points x and y be required (the distance xy being not greater than *PP'*), the hinged arms are first locked at the scale mark indicated, and then manipulated against the accessory points somewhat as follows : one end point P is placed at x, and with the pencil at y, arm *A* is made to touch *P*, and *P'* is then swung round to touch *A'*. This case admittedly seems involved, but it is really simple enough if one has the instrument in one's fingers.

For storing purposes the arms are made to take apart easily. They should be at least 18 in. long—for large " full-sizing " work they could well be several times that length.

34. An Adjustable Curve

By H. H. MACEY, M.Sc., F.Inst.P.

J. Sci. Instrum. **16**, p. 90 (1939)

The construction of this device for drawing smooth lines of reasonable length and small curvature is very simple, and will be clear from Fig. 63. It consists of a 10-in. hacksaw blade from which the teeth have been removed and which is bowed by means of a screw. Two pieces of ½-in. brass, each ¾ in. by ⅝ in., are fastened, one to each end of the blade, by short lengths of 2 B.A. rod tapped into the brass. A strip of light brass, about 7 in. in length, is pivoted in a slot in the left-hand end-piece. To the other end of this strip is soldered a length of 4 B.A. screwed rod. This passes through a collar pivoted in the right-hand end-piece, and a terminal head provides the adjustment. Simplicity being the key-note, mention is made of the fact that the pivoted collar was at one time an alarm clock winding key of a type having a loose

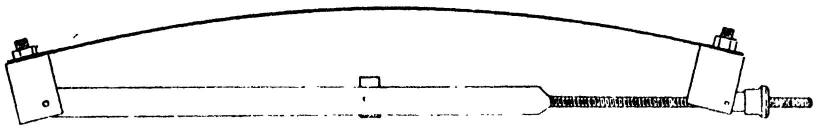


FIG. 63.—An adjustable curve.

finger-grip. A small piece of brass of the requisite thickness, soldered to the under side of the brass strip, enables the curve, once adjusted, to be firmly held with the left hand. The blade, naturally, should not touch the paper along its length.

The blade possesses a certain amount of give under the lateral pressure of the pen. With a little practice and care this can be turned to advantage.

Flat parabolas 9 in. long may be readily drawn with the device as described, but it is suggested that for particular purposes it might be found advantageous slightly to taper the blade towards one portion in order to obtain more rapidly changing curvatures.

35. A Note on the Mounting of Quartz Suspension Fibres

By D. R. BARBER, B.Sc., F.Inst.P.

J. Sci. Instrum. **7**, p. 105 (1930)

It is often necessary to mount a number of similar suspension fibres, each having the same degree of tension, but this is not an easy matter when the diameters are 10μ or less. The following method however gives satisfactory results.

A rectangular frame (Fig. 64 (*a*)) is constructed either of glass or of a metal having a fair coefficient of linear expansion, and over the horizontal limb a coil of resistance wire is wound. The actual amount of wire used is dependent upon the source of current available. The extremities of the two vertical limbs are coated with a small amount of Wood's metal, and a selected fibre is stretched at moderate tension over the frame, and secured at either end. The frame is then mounted in a suitable support (Fig. 64 (*b*)) in a horizontal plane, and a current passed through the heating coils. The frame expands, and the fibre is stretched, the final degree of tension attained being determined by an initial adjustment of the heating current.

When the requisite tension has been applied the quartz frame, on which the fibre is to be permanently mounted, may be carefully lowered

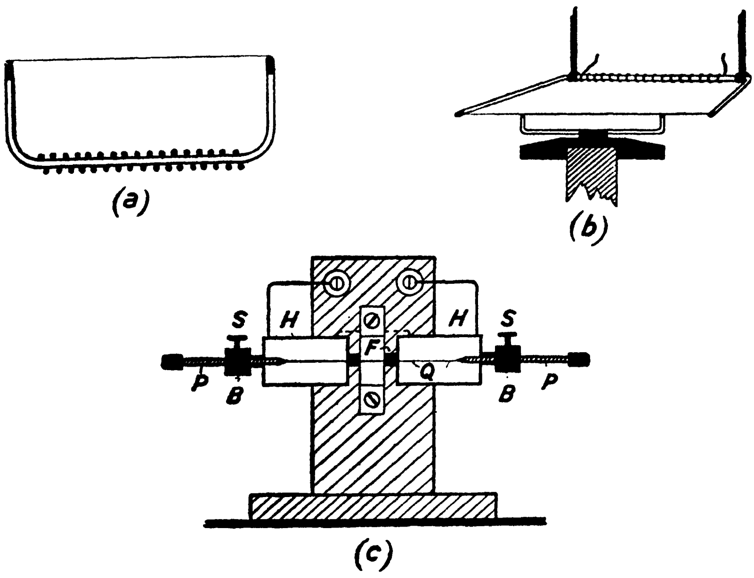


FIG. 64.—The mounting of quartz suspension fibres.

into contact, and the fibre fused thereto with either Wood's metal or shellac. The excess lengths of fibre can then be cut away at either end of the frame. A modification of the temporary frame carrying the heating coils is shown in Fig. 64 (*c*).

A metal frame *F* is wound with two nichrome heating coils *H*, series wound, and it is provided with two sliding anchor pins *P*, which are preferably glass-tipped with the object of avoiding excessive conduction of heat to the junction of fibre and support. Such an arrangement simplifies the initial attachment of the quartz thread *Q* to its temporary support, since it may be readily attached to the anchoring pins when in a lax state. The initial tension is obtained by carefully sliding the pins outwards and afterwards locking these by means of the two set-screws *S* in the blocks *B*.

This method has the additional advantage of obviating the use of any excess length of fibre over that actually required to fill the temporary frame, a condition which is not easily realized when mounting fibres in the usual manner.

36. The Construction of Molecular Models

By W. A. Wooster, Ph.D., F.Inst.P.

J. Sci. Instrum. **21**, p. 125 (1944)

For many years crystallographers have made models of crystal structures using balls drilled in appropriate directions joined together by spokes of the required length. One frequently used type of ball has twenty-six holes drilled in the directions of the thirteen axes of symmetry of the cubic system. Such balls and spokes are convenient

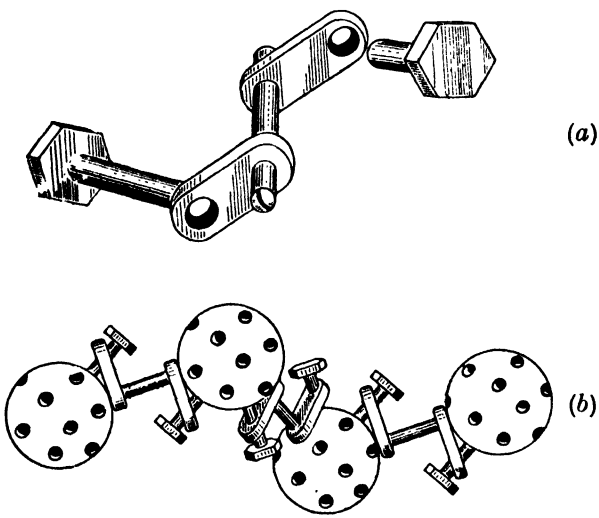


Fig. 65.—Improved device for molecular models.

for making models of molecules such as those of the ring compounds which are rigid on account of their geometry. But molecular compounds such as those of aliphatic hydrocarbons do not lend themselves to this technique, since rotation about the single bonds always tends to occur.

A simple device, illustrated in Fig. 65, has been made to overcome this difficulty. The spokes are designed to occupy two holes in the ball instead of one. The triad axis hole is normally employed for the spoke representing the C—C bond in models of organic compounds, hence the most convenient choice for the auxiliary hole is that subtending the smallest angle with the triad axis, namely, 35° on to the diad axis.

A simple arrangement for doing this is to solder to the two ends of each spoke corresponding to a single bond, a brass piece, drilled with a hole through which a brass peg may be inserted. The position and direction of the hole is such that the peg subtends the required angle of 35° to the main spoke. These components are shown in Fig. 65 (*a*); Fig. 65 (*b*) shows three balls rigidly linked together by these non-rotatable single bonds.

[*See following Note.*]

37. A Spherical Template for Drilling Balls for Crystal Structure Models

By W. A. Wooster, Ph.D., F.Inst.P. and R. Cole

J. Sci. Instrum. **22**, p. 130 (1945)

Wooden or plastic balls, an inch or three-quarters of an inch in diameter, appropriately drilled in certain radial directions, are commonly used for crystal structure models. These balls may be drilled with an accuracy of $\pm$ 1° without much difficulty on a lathe fitted with two divided circles. The ball is held in the headstock to the axis of which one divided circle is rigidly attached. The drill is held on a rotatable cross-slide fitted with the other circle. In this way a hole may be drilled with any desired orientation with respect to any other hole in the ball.

The care and time and skill required to produce accurately drilled balls may be greatly reduced by employing a template. This is essentially a hollow metal sphere (Fig. 66) containing all the required radial holes, which have been drilled in it in the lathe by the method described above. The sphere opens into two halves and a ball is enclosed in the centre, and bored through the holes by a drill whose length is such that when fully inserted the hole is the required depth.

It is, of course, essential that the inner hollow spherical surface and the outer spherical surface of the template should be accurately concentric. This is ensured by the method of manufacture, which is as follows, the dimensions given being suitable for the preparation of a template for one-inch balls.

Two metal cylinders are prepared by drilling and tapping three holes through them, one along the axis, the other two parallel to this but $\frac{5}{8}$ in. on either side of it. A groove is also cut in the end face near to the circumference. A cutting tool for making concave hemispherical surfaces is set up so that its tip is pivoted about an axis 0·5 in. from the tip. This tool is used to cut a hollow hemisphere in one end of each of the cylinders. When this has been done the cylinder is removed from the chuck and a third cylinder put in. A convex hemisphere is turned on to the end of this to fit into the hollow ones just prepared. An axial hole is bored and tapped, like those in the other cylinders. Keeping the third cylinder still in the chuck, one of the hollow hemispheres is fitted over the convex surface and screwed on to it through the axial hole. A cutting tool is then set up to turn a convex hemisphere 0·8 in. in radius on the back of the hollow hemisphere. In order to ensure that the inner and outer hemispheres are concentric, a stop

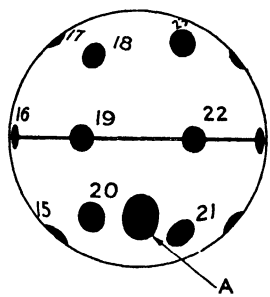


FIG. 66.—Spherical template for drilling balls for crystal structure models.

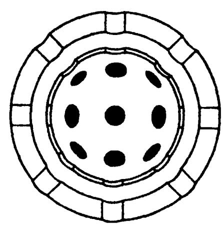


FIG. 67.—Sphere open showing enclosed ball.

is attached to the lathe-bed so that the position of the axis about which the tools used for turning both the convex hemispheres is the same. The other hollow hemisphere is then similarly treated.

The hemispheres are made to fit together by putting a cylindrical ring into the grooves mentioned earlier. One half of this ring is made slightly thicker than the other half so that it fits very tightly into one hemisphere forming a ridge, which sits in the other groove more loosely. These are shown in Fig. 67.

The two hemispheres are screwed together through the tapped holes which were made on either side of the axial holes. One of these is shown at *A*, Fig. 66. The sphere so produced is then bored with the appropriate holes in the manner described above. The illustration shows a template containing all the twenty-six directions of the cubic axes of symmetry. The holes are serially numbered, so that none are overlooked when drilling the balls.

When the screws joining the two halves are being tightened up a metal peg is inserted into one of the equatorial holes to ensure proper registration of the two halves of the template.

The wooden or plastic balls used need to be accurately spherical and of the right diameter to within a few thousandths of an inch. No commercially produced balls that we have come across come up to this specification, but it is not difficult to turn them on a lathe, a satisfactory wood being seasoned sycamore.

If the balls are properly prepared they sit snugly in the template, but balls which are somewhat small may be used if they are held in place during the drilling by pegs inserted in the first two or three holes drilled. During the drilling the template is held against a cone in the tailstock if a lathe is used. If the template is made of steel the labour involved in its manufacture is, of course, considerably greater than if brass is used, but should the template be of brass it is advisable to use a brass drill for drilling the balls, or the holes should be reinforced with steel linings.

[*See previous Note.*]

38. The Lubrication of Fine Mechanisms

J. Sci. Instrum. **3**, p. 231 (1926)

M. Paul Ditisheim has called attention to an important investigation which has been carried out by M. Paul Woog, and which has led to a very simple device for obtaining reliable lubrication of chronometers, etc. As is well known, the great difficulty in obtaining satisfactory lubrication over a long period, apart from the oxidation of the oil, is its tendency to creep over the surfaces holding the pivots and to be withdrawn from the pivot itself. In order to minimize this action various forms of oil-retaining pivots have been devised, with the object of retaining the oil in place by surface tension, but these only delay and do not prevent the creep, so that re-oiling at intervals is necessary.

M. Woog has made an exhaustive scientific study of this phenomenon by observing the movements of drops of various oils on mercury surfaces strewn with lycopodium powder, and on various metallic and non-metallic surfaces. He finds that the creeping effect depends upon the saturation of the molecules; mineral oil in which the molecules are saturated shows no tendency to creep, while olive oil, in which the molecules are chemically active, rapidly spreads over the mercury surface to form an extremely thin film, which then breaks up into minute drops.

With solid surfaces, the effect is slower and opposite. Mineral oils spread fairly rapidly over the whole surface, and mixed oils more slowly, while olive oil clings to the pivots and shows no tendency to spread. This explains why mineral oils have been found unsuitable for chronometers, in spite of their more permanent nature and their smaller tendency to solidify at low temperatures. But M. Woog has found apparently a perfect solution of this difficulty, by coating the metal parts with a thin film of stearic acid which has considerable molecular activity. The metallic surfaces to be treated are dipped in a solution made by dissolving 1 per cent of stearic acid in toluene, dried, heated in an oven to 100° C., and finally rubbed with a fine cloth which has first been dipped in the same solution and dried. On surfaces treated in this manner pure mineral oils remain in place without any tendency to creep.

The process has been applied by M. Ditisheim to three chronometers, two with steel springs and Guilleaume invar balances, and the third with elinvar spring and monometallic balance and presumably lubricated with pure mineral oil. These three chronometers have been tested at the Neuchâtel Observatory, between temperature limits 21·5° C. and 48° C., with very satisfactory results.

[*See J. Sci. Instrum.* **3**, *p. 352 (1926), for further details of the above process.*]

39. "3 in 1" Oil (for Delicate Mechanisms)

By Sir Charles Boys, F.Inst.P., F.R.S.

J. Sci. Instrum. **3**, p. 60 (1925)

It must be fifteen years or more ago that I first saw "3 in 1" oil in a friend's workshop. He found it admirable for his choice lathes, as besides being a good lubricant it did not leave any oil stain on the metal. From that time onwards I have used this oil exclusively for lathes and fine mechanism generally, including clocks and chronometers, and I have not hesitated to use it in the small jewelled pivots of carriage clocks.

40. Laboratory Cements and Waxes

By L. Walden, G.M.

J. Sci. Instrum. **13**, p. 345 (1936)

This article deals with the substances most generally useful in the laboratory, and with their manipulation. The classical source of information on waxes is Faraday's *Chemical Manipulation*. His descriptions of cementing surfaces together are typical examples of experimental ability and can still be held to describe a perfect technique of cementing and waxing practice. Fundamental constituents of well-known cements are also given, many of which have appeared in recent years under new names and dressings.

Sealing-wax. Sealing-wax has risen from its early original use to become one of the popular laboratory cements, but in order to obtain good results careful consideration should be given to the materials used in its manufacture. As in other trades, substitution of materials takes place and these are often detrimental to the cementing purpose required of the wax.

Sealing-waxes of the "Bank" class should always be chosen, the adhesive constituent being shellac of high quality (bright orange leaf shellac) and the body materials in the red colour being vermilion, or chinese red. The other constituent is Venice turpentine, this giving plasticity and greater ease of flow when melting. In the cheap or substitute class, rosin, almost to the exclusion of shellac, is added, along with such materials as plaster of Paris, gypsum, chalk, etc., known as fillers, which give rise to charring, lumpiness, and lack of finished gloss. "Bank" wax, when broken, will give a dull uniform fractured surface of clean fine grain, the poorer qualities usually exhibit air holes and coarse grain, with the filler showing unevenly and prominently. A good wax will adhere, when proper waxing conditions have been observed, to most materials, and examples of the technique of glass to glass and glass to metal cementing are given below; the same technique is suitable for many other materials.

The materials to be cemented together should be freed from grease and dirt. With such types of glass as optical, plate or window, where damage or breakage can easily occur, care must be taken that heating is gradual, for instance, by placing the glass on a thick metal plate heated from one end, and allowing the glass to warm by conduction along the plate, or by using an electric hot plate with a high series resistance or at a lower voltage than specified. While this is taking place a stick of wax should be teased out into spills, say 20 cm. long × 0·3 cm. and 0·6 cm. diameter, which give greater ease of application than the original sticks. This is done by softening the stick of wax in the hot air well above a Bunsen flame, and then pulling gently into the sizes required, and allowing to harden.

Tests are now made upon the heated glass to ascertain if the wax will wet. Sealing-wax softens at about 50–60° C., commences to wet at 100° C. and well wets at 125° C. The wetting of the material by the wax is essential, and failure to obtain this will produce imperfect adhesion. The wax is then applied by the spills, so as to cover the surfaces with a thin uniform layer, the two waxed surfaces are placed in contact and pressure applied with a slight to and fro motion. This drives out surplus wax and frees any trapped air bubbles from the wax film. The work is then allowed to cool gradually. When cold the edges and any irregularities may, if desired, be trimmed and finished with a warm knife blade, or with that very useful laboratory instrument known as a "lead-a-crack" glass tube cutting tool. This is a burner consisting of a glass tube with a small piece of platinum tube sealed in at one end, which produces a fine needle point of blue flame giving a local heating. This, when applied momentarily, makes the wax run locally and produces a finished gloss without charring the wax. Contact with a flame in any waxing process should usually be avoided as much as possible.

To take a second case, say the waxing of a glass tube into a brass sleeve, the metal is chosen so as to allow a clearance of about 0·25 mm. between walls. This gives a larger wax bearing surface than would be obtained if the glass and the brass tubing were "telescopic tube" fit. The glass and brass tubes are heated separately above a Bunsen flame at the position where waxing is to take place, keeping the tubes in slow rotation to obtain uniform and gradual heating. The sealing-wax is then applied by the spills obtaining a good wetted surface. The tubes so treated are then taken one in either hand and rotated above the flame, getting the wax in good liquid condition. They are then slid one into another to the final position, a gentle pulling apart and closing of the hands as the wax slightly cools off frees the wax film from air locks, allowing alignment to take place. Rotation of the tube as the wax sets will maintain this alignment. Should any finishing off be required, the small flame previously mentioned may be used.

White sealing wax is obtainable, which is less brittle than the ordinary wax, but unfortunately it does not possess all the good qualities of the red sticks. It usually contains fillers of magnesia, carbonate of lead, or dry white lead, which easily discolour and char.

Points to observe when cementing with sealing or similar waxes.

(1) Continued heating of the wax dries up the shellac, leaving gummy residues which are not adhesive.

(2) Temperatures higher than 150° C. produce darkening of the wax and finally charring, with consequent impairment to its physical and mechanical properties.

(3) By dissolving in methylated spirit the wax can be made into a semi-liquid mass which may be applied by brush, or other suitable methods. The mixture unfortunately does not properly dry for some days, even when warmed by a current of heated air obtained from an electric hair-dryer. After being applied in this manner the wax lacks the high insulating properties that are obtained with the original wax.

Shellac. This purified insect resin is to be found in most laboratories. Dissolved in spirit, it is used for metal protection and colouring, as an adhesive cement, and also as a bonding of granular materials, in, for instance, grinding and abrasive discs, etc. It is also the adhesive base of numerous modern cements. The resin is often used by itself, but when used alone it is brittle and tends to form hair-line cracks; it is therefore often reinforced with other materials that help to correct this failing, making the shellac more readily fusible, more adhesive, and stronger. The following recipe, which is reproduced by permission of the British Scientific Instrument Research Association, is given as an example:

Shellac	50 parts by weight
Wood creosote	5 ,,
Terpineol	2 ,,
Ammonia (0·880) . . .	1 part by weight

The ammonia, terpineol, and creosote are added to the shellac and gently heated, well stirring to obtain homogeneity of the mixture. The melted material can be poured into moulds to form rods of suitable size.

Shellac is best obtained in leaf or button form (flake or melted tablet), the last named being most convenient for handling when seals or joints are necessary. The button shellac is not considered to be of as high quality as the best leaf material. Both may be used if required in a semi-liquid, varnish consistency, by dissolving in warm spirit. It is then applied by brush.

Apiezon wax "W". The extremely low vapour pressure of this wax gives it a marked advantage for vacuum work, and its general properties are excellent. The wax is supplied in long narrow sticks which are easily pliable at room temperatures, although sudden mechanical shock will produce fracture into small pieces; but such shocks are not met with in general practice, especially as the wax is primarily employed in vacuum technique. This wax can also be put to various uses, having some chemical inertness not possessed by other waxes.

Dekhotinsky cement. This is extensively used in America as a vacuum and general-purpose cement, for wide application to electrical and vacuum work. It has some chemical stability and possesses excellent electrical insulation properties. It is a mixture of shellac and Caroline tar, and like sealing-wax can be applied to most surfaces, the resultant join or seal having none of the faults of the shellac itself. The cement will be found useful in the workshop and laboratory, and has a pleasant aroma when melted. The actual procedure of cementing is similar to that of sealing-wax, care being taken to avoid melting the cement in the heating flame. There are three grades, hard, medium, and soft, and instructions are supplied with the material.

Other cements of this nature are L.G. cement and Cenco-Sealstick. Their properties are claimed to be an advance on similar cements.

Picien cement. This black-coloured cement is extensively used abroad as a vacuum seal, but like similar materials it serves many other useful purposes in the laboratory. The cement, although hard at room temperatures, yields to gradual strain, such as may exist in the vicinity of a joint or seal, thus avoiding breakage. It is best applied to warmed surfaces by brush from a dish or container in which the cement has been melted to about 130–140° C. Under these conditions it has very good adhesive properties.

Mention may also be made here of a convenient laboratory tool for general waxing use. It consists of a triangular copper plate, side length about 3 in. with a tang which is fitted into a wooden handle. This tool is heated and the wax held in contact with the hot metal surface, where it will melt and run into any position at which the tool point is held.

Beeswax and rosin. One of the earliest references to this useful mixture is given in Faraday's *Chemical Manipulation.* It was then called " Cap Cement ", and with a red colouring body it was known later as Faraday wax (rosin 5 parts, yellow beeswax 1 part, colouring body 1 part, red ochre or Venetian red).

The rosin and wax can be mixed and used without the colouring body, in various proportions of rosin to wax to suit requirements. The wax should be melted first and the rosin gradually added, well stirring as the mixture cools. The rosin gives solidity and tenacity to the plastic beeswax. It is applied in much the same way as described for Picien or with the waxing tool and is generally favoured owing to its ease of application and adhesive properties. There are very few materials to which it will not stick and it is trouble free for most laboratory purposes. The addition of gutta-percha to the rosin and wax makes it more tenacious and less liable to fracture. The British Scientific Instrument Research Association gives the following recipe :

Beeswax	20	parts by weight
Rosin	40	,,
Gutta-percha	3	,,

The gutta-percha should be of good quality, dissolving almost completely in benzene and leaving no ash, or only a trace, on ignition.

Two recent additions to the beeswax and rosin class of cements are R.C. and R.H. cements. They are intended for vacuum pipe-line connecting seals, metal to glass joins, and for wax cementation between ground surfaces where it is impossible to use grease.

Soft red wax. Soft red wax was used by Faraday and was given the name " Soft Cement ". It then consisted of yellow beeswax mixed with its own weight of turpentine, with a little Venetian red to give it body and colour. At room temperatures the wax has the hardness of soap, but can be easily kneaded with the fingers into a tacky plastic mass. Contact with water while being kneaded usually prevents good adhesiveness, but the wax is not affected by cold water when firmly *in situ*. Slight additions of rosin, and substitution of the turpentine by suitable lower vapour pressure oils, olive-oil, etc., have added to its usefulness for various requirements. A soft red wax, made to the specification of the British Scientific Instrument Research Association, and known as " Sira " wax, is supplied for optical and laboratory purposes. It is not so adhesive as the soft red wax sold by firms dealing with laboratory apparatus and chemicals, but undoubtedly has other desirable qualities suitable for the purposes for which it was primarily produced. Wax threads of different diameters, which serve useful purposes as " fillets " for various pieces of apparatus that are to be soft sealed, may be produced by a simple tool. A screw-plunger metal car grease gun is screwed at the nozzle so that jets pierced with holes of different sizes can be easily attached. The body of the gun is filled with pieces of soft red wax and its cap screwed into position. If now it is slightly warmed and the screw plunger turned to give downward pressure the wax will be extruded in a continuous cord ready for use.

Glue and treacle. Glue is the tenacious viscid matter obtained from the boilings of animal matter, skins, hoofs, bones, etc. When applied to metal and glass surfaces, etc., it appears to give well-wetted contact, but unfortunately on drying out the glue peels and cracks away from this type of surface and, especially where glass is concerned, may take pieces of the contact surface as well. The addition of black treacle in varying proportions according to requirements will prevent this. The mixture is easily applied, is tenacious, and resists many organic solvents, which may be tried out as soon as the cement is cold. Broken pieces of glue should be soaked overnight in a little water, and then heated in a glue pot with a little more water. The treacle is added and well stirred during heating. The mixture adheres well to most surfaces and is best applied by brush. Only sufficient for immediate requirements should be made up for use as there is a tendency for the mixture to deteriorate with continued heating. This cement dries out after a considerable time leaving an extremely tough body which still remains liquid-tight.

Marine glue or Chatterton's compound. This cement is well known in the electrical trade and is made from a mixture of shellac and caoutchouc, with sometimes the addition of asphaltum. At room temperature it is a moderately hard, slightly elastic material, and possesses extremely good general insulating and waterproofing properties which make it useful in the workshop or laboratory. When melted, it becomes extremely tenacious and elastic, and it will adhere to almost any surface. It can be used in the purchased stick form, by melting above a burner and applying to the warmed material to be cemented, or it may be melted in a suitable container, applied by brush, or poured. The cement, in the last instances, should be taken well above the melting-point to obtain an easy flowing consistency. It remains rather plastic in the cooling stages and is often best left for some hours to set properly. It is invaluable for use where a certain yield in the cement is an advantage and allows for slight expansion, possible distortion, and any tendency to apparatus movement that may occur later.

Lead oxide aquaria cements. It is often desired to construct glass-sided troughs for thermostats, and other purposes, and in this connexion lead oxide base cements leave little to be desired. The materials may be obtained from most oil and colour merchants. For the framework, metal angle or channelling is most suitable, and this is obtainable from most metal warehouses.

The cement is made as follows: 75 parts by weight of red lead, and 25 parts by weight of white lead, are well mixed together with a large knife spatula on a large glass or metal sheet with about 30 c.c. of linseed oil per lb. of mixture. The oil gives slight plasticity to the cement, when finally set. When this has been well kneaded, gold size is added to give adhesiveness and easy flowing consistency. It is best to prepare a little of the cement the previous day, and apply this by a stiff brush to the edges and faces of the glass, and to the metal framework where they will be in contact. They are then left overnight to dry. This mixture dries very quickly, and rapidly becomes a plastic mass. It should be well applied, and the glass pieces placed in position and moved up and down so as to displace air bubbles that may have formed. If the trough has annealed copper lugs for holding the windows tightly against the metal they should now be bent into position. While this is being achieved the cement will have partially hardened, and may be trimmed if desired. These trimmings should have the plasticity of putty and may, if necessary, be used to fill in small fissures in the cement. The finished trough is cleaned with rag moistened with turpentine, and may, if required, be given a coating of suitable enamel.

Other lead basic mixtures. There are many lead base cements that may be used for a class of work similar to that just mentioned. Details of a few are given below.

A. Red lead and glycerine.
B. Litharge and glycerine.
C. Lead oxides and silicate of soda.
D. Lead oxides and linseed oil and rosin mixtures.

Wax or cement	Composition if known	Solvents that affect instantaneously or up to 24 hours' contact	Non-solvents up to 60 hours' contact
Red sealing-wax	Shellac, Venice turpentine, vermilion red or chinese red	Acetone, alcohol, benzene slightly, carbon disulphide slightly, chloroform, ether, turpentine, xylene slightly	Fatty substances, most oils, essential oils, water
Shellac	Insect and tree resin	Acetone bleaches, alcohol, carbon disulphide bleaches, chloroform, ether bleaches slightly	Benzene, turpentine, xylene, water, most oils
Apiezon wax " W "	—	Benzene, carbon disulphide, chloroform, ether, turpentine, xylene, oil	Acetone almost nil, alcohol almost nil, water
Dekhotinsky cement: 3 grades, soft, medium, hard	Shellac and Caroline tar	Acetone badly bleaches, alcohol, benzene very slightly, carbon disulphide, chloroform slightly bleaches, ether slightly bleaches, xylene very slightly	Petroleum, turpentine, oil
Picien wax	Hydrocarbons from rubber, shellac, bitumen	Benzene, carbon disulphide, chloroform, ether, turpentine, xylene oil, attack the wax almost at once	Acetone almost nil, alcohol almost nil, water
Beeswax and rosin Faraday wax	Rosin, 5 parts; beeswax, 1 part; red ochre or venetian red, 1 part	Acetone, alcohol, benzene, carbon disulphide, chloroform, ether, turpentine, xylene oil	Water
Soft red wax	Beeswax, turpentine, colouring material, with sometimes olive oil	As beeswax and rosin	Water
Glue and treacle	Carpenters' glue, black treacle	Water and chemical solutions in water	Acetone, alcohols, benzene, carbon disulphide, chloroform, ether, methyl iodide, turpentine, xylene oils
Marine glue or Chatterton's compound	Shellac, caoutchouc or rubber, sometimes with asphaltum	Acetone, alcohol, benzene, carbon disulphide, chloroform, ether, turpentine, xylene oil	Water

A table giving data on vapour pressures of vacuum and laboratory cements, etc., is given

Acid action	Normal solutions, potassium and sodium alkalis	Softening and wetting temperature points	General remarks
Not attacked by hydrochloric acid, attacked by nitric and sulphuric acid	Badly attacked	60–80° C., 100–125° C.	Bends or gives to slow changes; brittle when dropped. Vap. press. of the order 10^{-5} mm. at room temperature
Not attacked by hydrochloric acid, attacked by nitric and sulphuric acid	Badly attacked	As sealing-wax	Moderately tough resin. With some solvents no change in colour of the liquid is apparent, but bleaching and swelling of the material takes place. When taken from the liquid it is found that disintegration of the material has occurred, thus rendering it no longer suitable as a cement
Not attacked by hydrochloric and nitric acid, attacked by sulphuric acid	Not attacked	65° C., 100–105° C., safe max. temp. in use 80° C.	Slightly more plastic than sealing-wax. Very brittle to shock. Vap. press. 10^{-3} mm. at 180° C. Vap. press. of the order 10^{-6} mm. at room temperature
Not attacked by hydrochloric acid, attacked by nitric and sulphuric acid	Badly attacked	Soft (medium colour), 85° C., 85–150° C.; medium (light colour), 90° C., 95–150° C.; hard (dark colour), 100° C., 105–150° C.	Tough but very slightly plastic material. Gives slightly to easy pressure. As regards solvents, etc., read as shellac. Vap. press. of the order 10^{-5} mm. at room temperature
Not attacked by hydrochloric acid, slightly attacked by nitric acid, attacked by sulphuric acid	Not attacked	65° C., 80–110° C.	Soap hardness, with wax characteristics, not brittle
Not attacked by hydrochloric acid, attacked by nitric and sulphuric acid	Slight discoloration, but wax remains hard	Beeswax: 60° C., 65–75° C. Rosin: 75° C., 90–110° C.	Characteristics according to mixture desired
As beeswax and rosin	Potash solution attacks badly, sodium solution not attacked	Plastic at room temperature 55–63° C.	Slightly harder than plasticine
—	—	Applied similarly to carpenters' glue	Plasticity varying with the amount of treacle added. In most instances it is quite elastic for some time after application. In course of time the material becomes hard and tough like ordinary glue
Not attacked by hydrochloric acid, attacked by nitric and sulphuric acid	Badly attacked	65° C., 75–105° C.	Remains easily plastic for some time after setting

in an article by R. M. Zabel in the *Review of Scientific Instruments*, 4, p. 233 (1933).

A and *B*. Many of the oxides of lead are used as cements for aquaria. They are made into a plastic condition by the addition of glycerine, and applied in a way similar to that previously described. They require a longer drying-out period, but give every satisfaction in use.

C. When mixed into a sticky putty consistency with silicate of soda (water glass) they will be found useful for fixing glass tubes into metal sockets, etc., and will withstand moderately high temperatures up to 400° C. They are not waterproof.

D. Other well-known mixtures are obtained by melting rosin into heated "boiled" linseed oil, about 1–4 by weight and incorporating a mixture of equal parts by weight of litharge and red lead. Variations of the proportions can be made for different purposes, their usefulness for certain requirements may be gathered from the ingredients used in its manufacture.

Bakelite cement N.P.A. The basic material of bakelite products is a synthetic resinoid which results from the reactions of phenol and formaldehyde. These reactions are brought about by heat treatment in three stages: the first or "(*a*) stage" produces a transparent, amber-coloured solid which is fusible and soluble in various solvents; the second or "(*b*) stage" gives a product which is still fusible but not soluble; and the third or "(*c*) stage" converts the resinoid into a material which is infusible and insoluble. The finished resinoid has a hard shiny surface, is almost chemically inert, and resists water, and heat up to 140° C. It is, however, attacked by hot concentrated alkali solutions. It possesses high dielectric strength and has large surface and volume resistivity, with other valuable qualities.

Care must be taken when using the cement as a bonding between metal surfaces to choose, if possible, materials of similar coefficient of expansion, for the finished resin has so little "give" that it is likely to part company from double contact surfaces if this is not observed. A sandwich of glass between copper plates may be given as an example of an unsatisfactory join. With cementation on single surfaces little difficulty of this kind is experienced. The method of cementing is as follows: (1) Clean the surfaces from grease, dirt, etc. (2) Raise the temperature of the parts to approximately 50–60° C. The cement, purchased in its "(*a*) stage", should be warmed to a similar temperature, which allows the material to flow more readily. (3) Apply a thin coating of the cement with a clean glass rod. A slight bubbling of the material will take place, but it will settle down to a clear surface. (4) Raise to 80° C. for 1 hr. (5) Raise to 100° C. for 1 hr. Polymerization with consequent production of water about this temperature causes the bubbling already mentioned. Care should be taken to disperse these bubbles. (6) Raise to 110° C. for 1 hr. (7) Raise to 120° C. for 1 hr.

(8) Raise to 130° C. for 1 hr. (9) Allow to cool gradually. An ordinary household electric oven of the table-top type forms a very convenient laboratory oven for this purpose. The temperatures of the hot-plate and oven are controlled by regulator and element switches.

[*Note.*—For information regarding suppliers of the cements and waxes discussed above, see the original article, *J. Sci. Instrum.* **13**, p. 345 (1936).]

41. Rigid Stands for Laboratory Apparatus

By L. J. WHEELER, F.R.P.S.

J. Sci. Instrum. **20**, p. 15 (1943)

Tubular section galvanized iron or electrician's conduit have proved far more useful than L- or T-section rolled material. Many of the normal laboratory clamps and fixtures may be attached easily to electrician's conduit; attempts to fix similar clamps to rolled section are either unstable or complicated.

There are three general methods of joining this material together, and so building up the type of support desired, but choice is restricted by the tools at one's disposal. If either acetylene or electric welding plant is available, this method is undoubtedly one which takes care of large inaccuracies of workmanship, while still maintaining a robust construction. If it is possible to thread the ends of the tube (½-in. gas thread for electrician's conduit, or 1-in. gas thread for galvanized iron pipes), many of the standard elbow and T-joints supplied by plumbing and electrical warehouses may be employed to join the sections together.

It may often be convenient to use "Ke-Klamps"; a large variety of elbows and joints, of many shapes and designs, which are already bored out to suit the standard outside diameter of a wide range of tubes is available. These clamps are locked to the tubes by a grub-screw provided in each section of the joint. In this manner the tubes can be very roughly cut (say $\pm \frac{1}{4}$ in. of the desired length), and the grubscrew, being placed in the centre of the clamp, will still hold the section secure. Thus it is possible to form very rigid built-up supports by three methods, the choice being governed by the equipment available.

Regarding the design of the support, quite the best construction to use, wherever possible, is the tripod type shown in the accompanying sketch of a short optical bench (Fig. 68). This method has the following advantages: (1) the support will remain firm and steady when resting on very uneven ground; (2) if it is not possible to weld small brackets to the bottom of each leg (as shown in the sketch), the leg itself may be bent at right angles—at a radius of about 4 in. for a 1-in. diameter pipe, and a ⅜-in. Whitworth bolt passed through the pipe at the foot so formed, to provide a very simple means of levelling; (3) if the top of the tripod is finished off with a flat table, any form of equipment may be attached to it. This is a better practice than making a top to suit one particular purpose, for the tripod thus becomes a complete unit which may be used on subsequent work.

If the top of the support must be large, the more usual construction

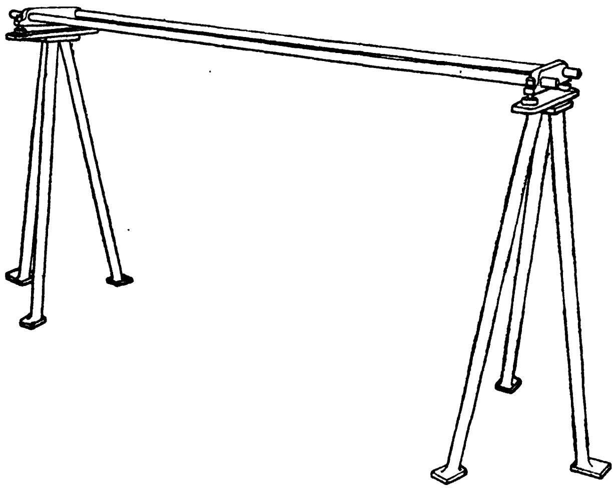


FIG. 68.—Simple optical bench made from metal tubing.

with four legs may be advisable, in which case cross-bracing, to give a triangulated framework, is desirable.

Consideration of the mechanical strength of the mount, in relation to the position and distribution of the load, will only be a serious problem when heavy equipment is to be supported. In all other cases it is fairly safe to assume that the tubing will be much stronger than required. If heavy equipment is to be mounted, formulae relating to stress and strain of beams, etc., should be consulted.

42. A Simple Anti-Vibration Galvanometer Support

By G. E. COATES, M.A., B.Sc., and Constr.-Lieut. J. F. COATES, R.N.

J. Sci. Instrum. **22**, p. 153 (1945)

Galvanometer supports have been reviewed by Strong,* who draws attention to the necessity of suppressing the horizontal rather than the

* Strong, J., *Modern Physical Laboratory Practice*, p. 590 (London: Blackie and Son Ltd., 1942).

vertical components of vibration. This may be achieved by mounting the galvanometer either on a support which damps vibrations largely by friction (e.g. sponge rubber or a pile of newspapers), or on a fairly freely vibrating support whose natural period is long relative to the periods of the interfering disturbances. The latter method is the more effective and depends on the very low response of a vibrating system to disturbances whose periods are small compared with its natural

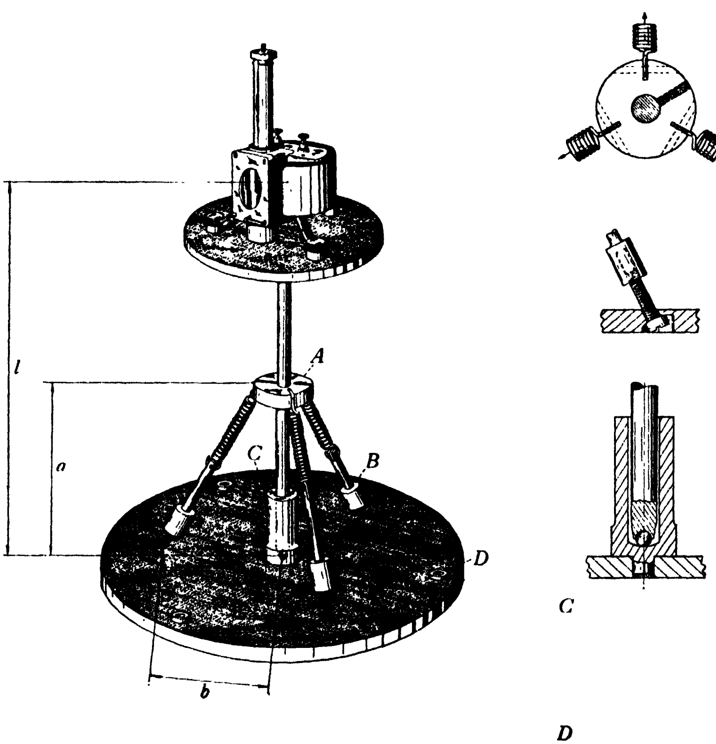


FIG. 69.—A simple anti-vibration galvanometer support.

period. By analogy with the response of an electrical tuned circuit to impressed oscillations whose frequency differs from the resonant frequency, this response diminishes with the *resistance* of the circuit, and similarly in the mechanical system the *friction* should be small. The device described below is shown in Fig. 69.

The galvanometer is mounted on a platform, provided with appropriate depressions for the levelling screws, and supported by a vertical pillar (about $\frac{1}{4}$ in. diameter and 14 in. high). The bottom end of the pillar is fitted with a hard steel ball which rests in a smooth depression at the bottom of the cup C. The pillar is kept vertical by three springs attached to the base-plate as at B and to the pillar at the collar A, which can slide up and down and is provided with a locking screw. The cup C prevents the platform from toppling over during adjustment; the pillar must not normally touch the sides of the cup. The baseplate is provided with three rubber feet D. The tension in any one spring may be adjusted by means of the screw at its lower end. The details of A, B, C and D are shown in the insets to the figure.

The platform can vibrate freely about the ball in C with a natural period determined by the following factors:

(1) The mass of the galvanometer, platform, and pillar, regarded as a mass m concentrated at a height l from the point of support.

(2) The height a of the collar from the point of support.

(3) The horizontal distance b between the point of attachment of the springs and of the pillar.

(4) The spring constant k (i.e. the force in dynes required to extend the spring one centimetre).

For small deflexions, θ, of the pillar from the vertical, the equation of motion is sufficiently nearly

$$Id^2\theta/dt^2 + \{2ka^2b^2/(a^2 + b^2) - mgl\}\theta = 0 \quad . \quad . \quad (1)$$

where I is the total moment of inertia about the point of support (in C). The motion is periodic if the coefficient of θ is positive, and if I is assumed to be equal to ml^2 (most of the mass is in fact situated on the platform) the period T is given by

$$T = 2\pi l^{\frac{1}{2}}\left[\frac{2ka^2b^2}{ml(a^2 + b^2)} - g\right]^{-\frac{1}{2}} \quad . \quad . \quad . \quad (2)$$

A model with the following approximate dimensions has proved satisfactory during a year of regular use:

$$a = 18 \text{ cm.}, \quad b = 12 \text{ cm.}, \quad l = 36 \text{ cm.}, \quad m = 2{\cdot}5 \times 10^3 \text{ g.},$$
$$k = 5 \times 10^5 \text{ dynes cm.}^{-1}.$$

In this instance $(2ka^2b^2)/\{ml(a^2 + b^2)\} = 1{,}108$ cm.sec.$^{-2}$; this satisfied the stability requirement, since $g = 981$ cm.sec.$^{-2}$, and the period $T = 3{\cdot}3$ sec. which is much longer than any normal room vibration period. The sliding collar A enables a to be adjusted to obtain the desired natural period.

An alternative arrangement suitable for support by wall bracket or retort stand has been suggested to the authors by Prof. A. C. Menzies. In this modification there is no base-plate; the cup C is lengthened to extend nearly all the way up the pillar and is clamped at the bottom by, for example, a wall bracket. The springs are attached to the underside of the *platform* at a distance b_1 from its centre, and the collar A slides on the extended cup C (at a height a_1 from the point of support). If h is the height of the platform from the point of support in C, then the period is given by

$$T = 2\pi l^{\frac{1}{2}}\left[\frac{2ka_1^2b_1^2}{ml[(h - a_1)^2 + b_1^2]} - g\right]^{-\frac{1}{2}} \quad . \quad . \quad (3)$$

in which l, as before, is the distance from the centre of gravity of the moving platform to the point of support.

43. An Anti-Vibration Support

By J. W. French

J. Sci. Instrum. **2**, p. 301 (1925)

An arrangement designed primarily to carry a large interferometer of the Michelson type is represented in Fig. 70. Although installed

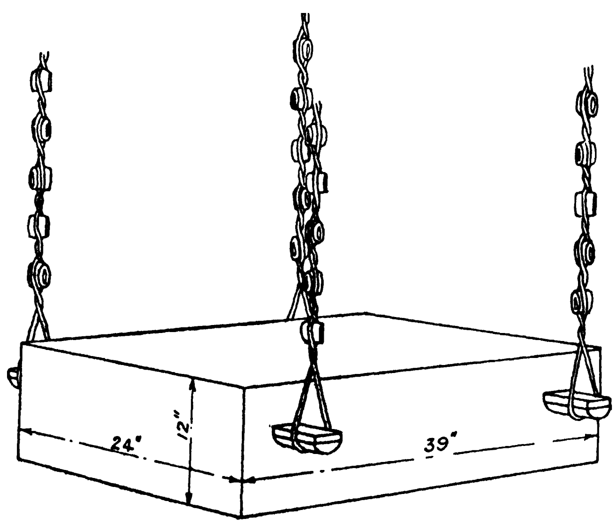


Fig. 70.—Anti-vibration support.

under conditions of the worst description in a building subjected to vibrations of all kinds, incidental to the use of electric motors, high- and low-speed shaftings, and heavy overhead runways, the images of the interferometer, when supported in the manner illustrated, are remarkably free from vibration.

The base block upon which the whole of the apparatus is carried is of concrete and has a weight of about 900 lb. It is suspended by means of four double cotton ropes twisted to form a series of loops within which are inserted short horizontally disposed lengths of thick rubber tube having an external diameter of 1·6 in. and a wall thickness of half an inch. The suspension members are about 8 ft. long and the spacing of the loops is about 4·5 in.

Elastic anchors prevent any pendular movement of the base and means are provided for carrying the load when the apparatus is not in use, thus relieving the tension of the suspension ropes and the pressure applied to the rubber.

It will be evident from the illustration and this brief description that vibrations of very different periods are damped out by the series of rubber elements, and to a lesser extent by the fibres of the cotton ropes, before they reach the base upon which the apparatus is mounted.

44. Improving the Fixation of Instrument Parts

By O. KANTOROWICZ, Dr.Phil., F.Inst.P.

J. Sci. Instrum. 14, p. 348 (1937)

A rather common type of " fixation " found in instruments is to make the parts contact on two " flat " surfaces which are held together by two screws under tension. The parts then have, as experience shows, anything between zero and six degrees of freedom with respect to each other, depending on the workmanship. If one of the parts is fairly flexible or does not extend far sideways from the line joining the two screwholes, the resistance to rotation about this line as axis will be small.

The following simple device proved successful in a rather bad case. Washers were put on the screws in between the two surfaces. One of these washers had two raised areas on opposite sides of its circumference, and it was arranged so that the line joining these humps was perpendicular to the line joining the screwholes. The other washer had one hump and was arranged with this hump pointing away from the other screw.

45. Easily Made Geometric Bosses

By R. Harries

J. Sci. Instrum. **13**, p. 419 (1936)

Very effective retort stand bosses can be made cheaply as shown in Fig. 71. Standard wrought-iron tubing is utilized in their construction; a suitable length is cut off, the ends faced up and diametral holes *A* and *B* are drilled through the tube at right angles. Slots leading into these holes from the ends of the tube are cut with the

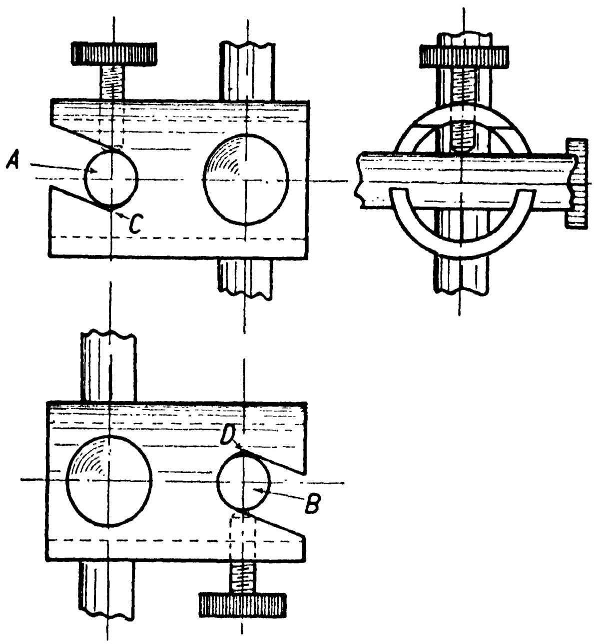


Fig. 71.—An easily made geometric boss.

aid of a hacksaw and the parts *C* and *D* filed to form V-grooves. The rod to be clamped rests in these two V's and is held in place by means of a knurled-head screw. It will be seen that these bosses provide geometric constraints, and they will take any size rod up to the maximum diameters of *A* and *B*. Since there is such a wide range of tubes to be had, bosses of almost any size can readily be made.

46. Concrete Bases for Retort Stands

By O. H. F. Pieris

J. Sci. Instrum. **13**, p. 417 (1936)

Heavy bases suitable for large retort stands, or for galvanometer lamp-stands may be made satisfactorily and very cheaply from concrete, as shown in Fig. 72. Experience in this laboratory shows that they

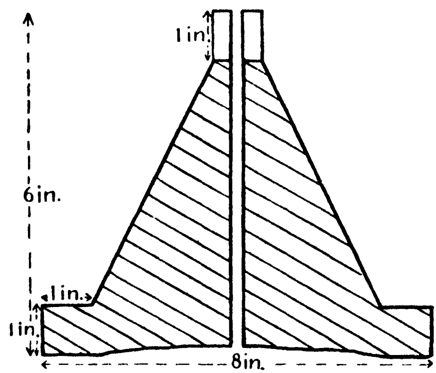


FIG. 72.—Sectional elevation of base of retort stand.

have no serious disadvantage compared with the more usual and much more expensive cast metal type, and no particular difficulty is experienced in making bases of special shape.

47. A Method of Clamping Glass Tubing

By J. A. V. Fairbrother, Ph.D., F.Inst.P.

J. Sci. Instrum. **12**, p. 169 (1935)

The following method, illustrated in Fig. 73, has proved to be very convenient for fixing glass tubing to a base-board. *A* is the base-board and *B* is a cylinder cut from a length of brass tubing. The end adjacent to the board is faced up and a V is cut into the other end by means of a hack-saw. The glass tubing *C* sits in the V and around it is passed a loop of wire or strip *E* which is fastened in any convenient way to the head of a bolt *D*. This bolt passes through a hole in the base-board and the whole is held firmly together by means of the wing nut *F*. Such a method of fixing is very useful for supporting the parts of an exhaust apparatus. The tube to be supported can be fixed at any angle in a plane at right angles to the paper and it can be easily

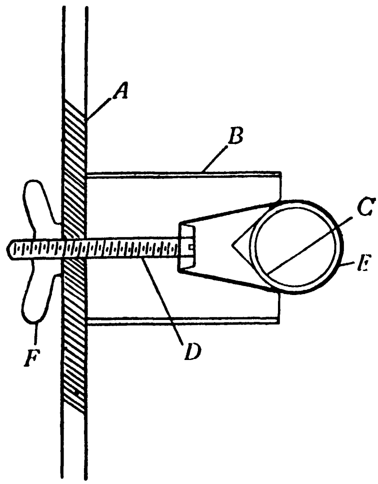


FIG. 73.—Clamping glass tubing.

torched for the purposes of degassing. The whole thing is quickly dismantled by unscrewing the wing nut.

48. A Shaking Gear for Use with Water-Baths

By S. J. FOLLEY, D.Sc.

J. Sci. Instrum. **12**, p. 257 (1935)

This apparatus, which is intended for square or rectangular tanks, is made principally of brass Fig. 74 shows a front elevation of the apparatus and Fig. 75 a side view. The axle *A* runs in the heavy bearings *B* which are fixed to the walls *C* of the tank by means of the screw clips *D*. Collars *E* with set screws are provided to fix the axle in position. In the upper end of the rocking arm *F* is cut a hexagonal hole which fits over a corresponding hexagonal portion at the end of the axle *A* ; it is held in place by the nut *G*.

The rocking motion is effected by the steel pin *H*, which slides freely along the slot *K* in the rocking arm *F* in which it is an accurate fit. The size of the excursions is determined by the position of the pin *H* in the slot of the crank *J*. The glass vessels are held by spring clips *M* attached to brass strips brazed to collars *N* provided with milled-

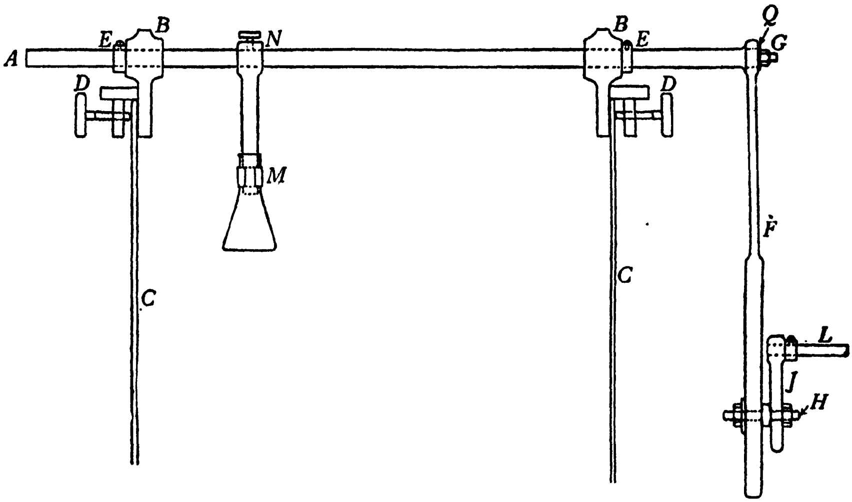


FIG. 74.—Front elevation of shaking gear.

headed set-screws. If desired, the possibility of adjusting the distance of the spring clips from the axle A can be provided for by slotting the strips and using single clips held in any required position in the slots

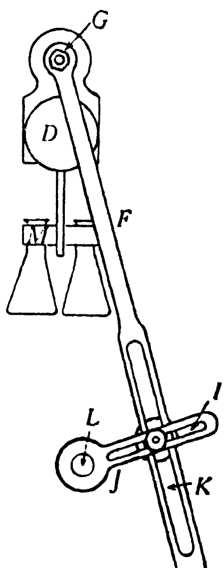


FIG. 75.—Side view of shaking gear.

by means of screws and wing nuts. The bearings *B* require only infrequent lubrication, but oil should be applied at intervals to the slot *K*.

49. An Adjustable Agitator for Laboratory Use

By N. G. HEATLEY, Ph.D.

J. Sci. Instrum. **18**, p. 204 (1941)

A need often arises in the research laboratory for some means of agitating tubes or bottles containing suspensions, etc. The device illustrated in Fig. 76 has been used for this purpose for over three years. It consists of an electric gramophone motor (not of the synchronous type), mounted on a stand in such a way that it can be tilted at any angle about the pivot *A*, and locked in the required position by the wing nut *B*. In place of the turntable any one of

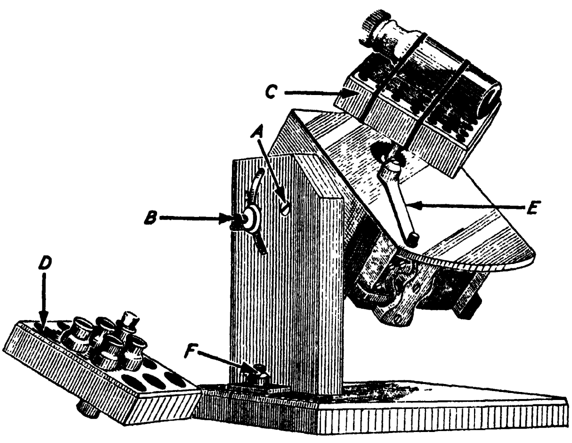


FIG. 76.—An adjustable agitator for laboratory use.

a number of interchangeable wooden blocks (*C*, *D*) is fitted. These are furnished with holes of different sizes to accommodate different types of container; or the objects to be agitated may be fastened to the block by stout rubber bands, or by wax. Alternatively they can be packed into a box which is fixed to the block.

The degree of agitation can be varied by altering (*a*) the speed (by the speed regulator *E*) and (*b*) the angle of tilt. If the latter is slight, the contents of an open vessel such as a shallow crystallizing dish can be kept stirred without danger of spilling.

The appliance has been particularly useful for getting difficultly soluble material into solution, for stirring during dialysis and for keeping tissue slices well mixed with fluid in physiological experiments. The whole apparatus can be placed in the incubator if necessary, but to prevent overheating of the motor, a 60-W. bulb or other resistance is usually placed in series with it. The motor will, of course, work equally well in a refrigerator. *F* is an on-off switch.

SECTION 3. SOLDERING, BRAZING AND WELDING

50. Soldering and Brazing

By A. S. NEWMAN and R. S. CLAY, D.Sc., F.Inst.P.

J. Sci. Instrum. **10**, p. 333 (1933)

Both soldering and brazing are simple processes if the underlying principles are thoroughly understood, and these notes are intended to be a guide to their better understanding. These processes are seldom carried out as they should be and some useful practical notes have been included.

For metals to be securely joined the joining material must come into molecular contact with the metals themselves. Nearly all metals oxidize on being heated and therefore this oxide must either be prevented from forming or be removed mechanically or chemically when the joint is made. It is for this purpose that fluxes are employed. A good flux should (1) flow through the joint and cover the whole of the surface that is to be joined, (2) have a boiling-point above that of the fusing-point of the jointing material, so that it shall not be evaporated before the joint is made, and (3) should contain no oxygen in a form that can act on the hot metal and should be capable of dissolving any slight oxide which may be on the surfaces.

Fluxes for soft-soldering. It is possible to soft-solder two metals, using oil, grease or resin as a flux, although none of these substances dissolves oxides. But in order to do this successfully the metals must be scrupulously cleaned before soldering and not exposed to the air before the flux is added; and the heat must not be great enough to carbonize the flux used.

For soft-soldering the flux most commonly used is zinc chloride or a composition containing this chloride. This chloride dissolves the oxides of the ordinary metals and thus cleans the surface if it is only very slightly oxidized. But even if zinc chloride is used, the surfaces should be thoroughly clean to start with and be coated with the flux before the heat is applied. Zinc chloride has a high boiling-point and after the water in which it is dissolved has evaporated, the chloride melts and flows over the surfaces, thus protecting them from the air and preventing them from oxidizing. Zinc chloride is unsatisfactory for aluminium as it does not dissolve the oxide of this metal; a flux containing fluorine should be used.

Many compounds are sold as fluxes for soft-soldering, claiming non-rusting qualities and the possibility of soldering oxidized work. Some of these are very suitable for special work, but zinc chloride will take the place of all of them if the work be properly cleaned after soldering. For electrical joints a flux that does not corrode the metal should be used, owing to the difficulty of thoroughly cleaning the work ; a flux with a resin base is the most suitable. For example, for small work a paste made by dissolving resin in methylated spirits is convenient. As zinc chloride rusts all iron and steel surfaces, it is advisable to keep it in an unspillable ink bottle. Slips of wood are sometimes used to apply the chloride to the work, but these injure the flux if left in for any length of time. A very suitable tool for applying the flux is the rod used to support the mantle of an incandescent burner. It is not necessary to have much of the chloride in use nor to apply a great deal to the work. As soon as the work has cooled sufficiently to allow the solder to set, it may be dipped into water and lifted out, which will leave the surface covered with hot water as the hot chloride dissolves easily. If it is dried with tissue paper, practically all the zinc chloride will have been removed, and even with steel work no subsequent rusting need be feared. But the cleaning must be thorough.

Soft-soldering. As a rule the flux does not flow over cold metal, but at a temperature of 35–40° C. it will run over the metal and will be sucked into the joint by capillary action. On increasing the temperature the water in the flux (if it is zinc chloride solution) boils, and steam is formed. If it is a small article that is being soldered, it should now be withdrawn from the heat until the bubbles cease. If bubbles again form when the article is again heated, it should again be withdrawn. This withdrawal, by the condensation of the bubbles of steam which are between the surfaces, causes the flux to be drawn back into the joint, and so ensures that the whole surface of the metal shall be covered with the flux. When a large area is to be joined it may be necessary to add more flux as the steam condenses in order to supply enough flux to cover the joint.

When the bubbling has nearly ceased the solder can be applied. By experience it is possible to estimate closely the exact amount of solder that is required to fill the joint, and if only this amount is used clean work can be done. The solder will first melt and form itself into drops, but with a slightly higher temperature it will adhere to the metals and be carried into the joint by capillary action. It should be applied at one side only, then as it flows through in the form of a wave from that side it will push the oxide in the flux before it and drive it out on the far side. Solder always tends to flow towards the hottest part, thus the flow is assisted if the parts towards which the flow is desired are further heated. The work should when possible be held together so that it cannot move during the process. Small work is, as a rule, best held by some form of clamp, of which several useful ones will be described later. Small work also is usually most conveniently soldered with the aid of a Bunsen burner or a blowpipe, as the heat can be so easily regulated with these. A Bunsen burner which behaves as a blowpipe giving an intensely hot and easily managed flame is described below. With such a Bunsen burner the soldering can be carried along a long joint by holding the flame a little in advance of the molten solder so that the metal is just a little hotter where the solder is to flow next.

When two large surfaces are to be soldered together, they should, if possible, be covered with the flux before they are clamped together. They should then be heated very slowly, allowing the work to cool slightly each time bubbles are seen, and adding more flux as the original is sucked into the joint at each cooling. In this way the whole surfaces can be covered with the flux, and then on adding the solder at one point and gradually raising the temperature, a sound joint will be made.

Sal ammoniac is an excellent flux for certain purposes. It is used when it is desirable that little or no cleaning off shall be needed, for instance it was used by the old microscope makers to solder rings or flanges to tubes. It has the disadvantage that it requires a rather high temperature to start the action, and in consequence in soldering brass there is considerable danger of softening the metal. It is not suitable for use when the resiliency of the metal has to be preserved.

In the use of a soldering-iron a common error is made in not having the copper bit sufficiently heated. It should always be hot enough to cause the solder to flow like water and to run into the joints, and when the work has any mass it is advisable to heat the work itself before applying the iron, otherwise the mass of the work will rapidly cool the iron so that the solder will not flow any distance into the joint. To all appearance a good joint may be made, but this may be only at the extreme edge and consequently have very little strength. For very large pieces of work it may be necessary to play the flame of a Bunsen burner, both on the work and on the iron itself during the operation. As large an iron as conveniently possible should be used, and it should not have a sharp point. The heat travels to a blunt point better than to a sharp one ; if, for any reason, a sharp point has to be used, the body of the bit will have to be made hotter than usual in order that the point may be kept sufficiently hot.

If several pieces are to be soldered successively to one another, it is especially necessary that the bit shall be hot but the work as a whole kept as cool as possible, in order that the last one may be raised to the necessary temperature quickly and before the heat travels to the next one to it and displaces it.

The copper bit used as a soldering "iron" must be kept in good condition. It should not be overheated or the solder on it will amalgamate with the copper and form a layer of poor conductivity over the surface of the copper. When this does happen the surface must be filed down to the clean copper and the bit "retinned". The rubbing on brick and on sal ammoniac so often recommended in books is not necessary; all that is required is to heat the iron, wet it with zinc chloride and touch it with solder which will flow over the surface if it is clean. A pad of flannelette wetted with the chloride is useful to rub the iron on after heating it; if it has not been heated too much, this is all that is required. The bit should be heated in a large Bunsen burner until a green flame appears. The Bunsen burner should be applied to the body of the bit and not to the point, so that the latter does not get overheated.

A useful method of soldering very small articles is to hold a soldering iron by the handle in a vice with the bit slanting somewhat downwards. Heat it with a Bunsen burner, apply the solder to the *lower* surface of the bit, and bring the work up to it from below. In this way exceedingly small things can be soldered without trouble.

A useful though unusual bit was made from a piece of copper in the shape of a narrow leaf about 2 in. long and 1 in. wide at the middle. It was cut from copper $\frac{1}{16}$ in. thick, and was bent along the middle to about a right angle. This was fixed to a non-conducting handle —actually an old clay pipe stem was used. The bit was filled with solder after being tinned on the inside and at the tip, and was heated and kept hot with a Bunsen burner. The work also was heated nearly to the melting-point of the solder. With this an awkward joint was successfully made.

It is worth noting that when joints are well made and soldered by heating them in a flame, as there is a certain amount of alloying of the solder with the metal where the surfaces are close together, the joint is made not with solder but with the alloy; the joint is thus much stronger than the solder used.

Brazing. The principles underlying brazing are the same as those applying to soft-soldering. As brazing and silver-soldering require a much higher temperature than soft-soldering, borax is used as a flux, its boiling-point being below the fusing-points of silver-solder and spelter. The borax should be rubbed up to a cream with water and applied to the joint. The first heating should be very slow to allow the borax to flow into the joint before the water has evaporated. On further heating, both the added water and the water of crystallization are driven off and the borax melts and flows over the surfaces which it protects from the oxidizing action of the air on the red-hot metal, it also dissolves any small amount of oxide that there may be on the surface to form a glass. The jointing material is best added at the same time as the borax. When the borax is beginning to melt it swells up greatly and sometimes this swelling causes the spelter to fall off. If so, more wet borax should be added, to which the spelter is again attached. Generally the borax as it subsides carries the spelter with it back to the place at which it had been attached. Silver-solder is mostly used for small articles, where its extra cost does not materially affect the total cost. It melts and flows more easily than most spelters. It is for instance generally used by spectacle makers and jewellers. They often make their own by adding brass (usually ordinary brass pins, as this is a suitable brass) to silver. It melts at a lower temperature than pure silver.

Gold and silver must always be hard-soldered as the lead of soft-solder diffuses into these metals.

A joint that has been soft-soldered cannot be hard-soldered afterwards unless the whole of the soft-solder is removed by filing the surface clean.

Spelters are made of copper and zinc and can be made of varying melting-points and colours. The musical instrument makers make a spelter that matches the brass so exactly that the joint is quite invisible after it has been cleaned up.

For brazing these seams in thin metal the powdered spelter should be mixed with the wet borax and applied to the seam.

For large work after the wet borax has been run in to cover the surface, dry borax is thrown on to assist the flow of the spelter.

Cylindrical and conical tubes. To make a cylindrical or conical tube of thin brass, let the edges butt together. They should be slightly chamfered, and be held together by being tied at intervals with iron wire. An intimate mixture of spelter and borax is put along the joint, and the whole tube is heated over a charcoal or coke fire to a black or dull red heat. Then, beginning at one end, the blowpipe is slowly brought along the joint without stopping, at such a rate as to fuse the spelter without melting the brass.

Where it is not possible to hold the edges together by wire, " stitches " are used. These are made with a special tool, which is not difficult to make. The jaws (Fig. 77) of a large pair of cutting pliers, say 8 or 9 in. long, are softened. Then a slot $\frac{1}{16}$ in. wide and $\frac{1}{2}$ in. deep is cut across the top of the two jaws. The plane of this slot is perpendicular to the axis of rotation of the pliers. A piece of tool steel, $\frac{1}{16}$ in. thick, about $\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. long, is temporarily riveted into one jaw *A*, and projecting into the slot in the other jaw *B*.

This piece of steel is filed flush with the outside of jaw *A* ; on the inside of jaw *A* it is filed down from the top for $\frac{1}{8}$ in. but leaving a piece projecting $\frac{1}{16}$ in. above the surface of the jaw. Below this $\frac{1}{8}$ in.

it is left projecting into the slot of jaw *B*. This projecting piece acts as a stop to determine the depth of the stitch. The small piece of steel is now taken out of jaw *A*, and hardened and tempered to a straw colour. The jaw *B* is also hardened and tempered. Then the steel is riveted firmly into jaw *A*.

In use, the edge of the brass sheet is inserted into the pliers up to the stop and the pliers closed. This makes two cuts in the edge of the brass, $\frac{1}{16}$ in. apart and $\frac{1}{8}$ in. deep, and throws up the piece between. This is the stitch. These stitches are made 2 or 3 in. apart along the

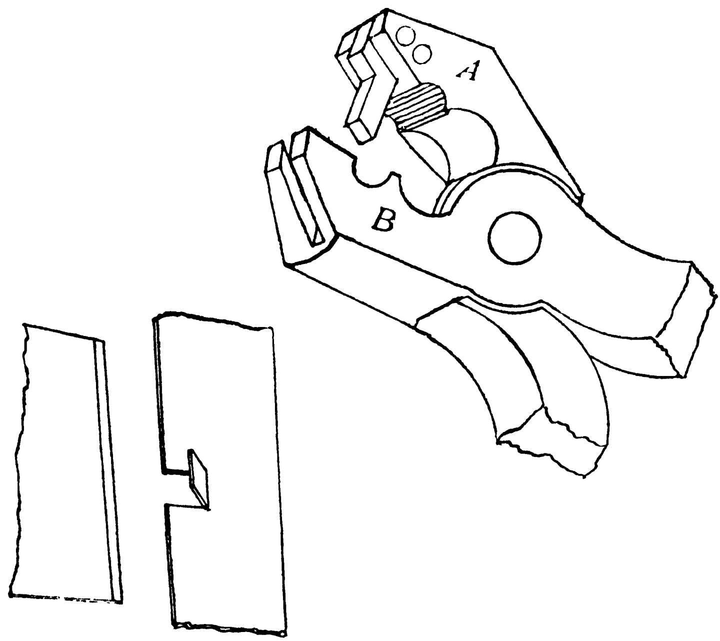


FIG. 77.—Special tool for making "stitches".

edge of one of the pieces to be joined. The edge of the other piece is chamfered so that it can be inserted under these stitches and reach well up to the base of the stitch, so that there shall be no hole there. The stitches are gently hammered down to hold the edge firmly. Then the weld is made as described above.

After welding, the seam is hammered down flat on a steel mandrel fitting the tube, being annealed at intervals during the process. The whole tube should always be heated in the annealing to avoid strains. It is filed to remove excess of spelter. Allowance has to be made for the expansion of the metal during the hammering out of the seam.

The tube is worked all over with a wooden dresser to make it fit the mandrel. It is next forced through a hole in a lead plate which is about $\frac{1}{2}$ in. thick. Finally it is turned in a lathe with a flat round-nosed tool while still on the mandrel.

Hard-soldering manganin wires. Owing to the fact that soft-solder diffuses into manganin when this metal is used for resistance coils, the ends must be hard-soldered to a copper wire and then the latter can be soft-soldered to the contact block. To make the first joint, an iron wire about $\frac{1}{8}$ in. in diameter and 4 in. long is coated at the end with borax, and a bead of silver-solder melted on to it with an ordinary Bunsen burner. Copper wire will not do, as it carries away too much of the heat. This silver-solder bead is coated with borax, and while it is heated in the Bunsen burner the ends of the wires that are to be joined are pushed into the melted bead of solder and so "tinned". To solder them together, a tiny flame issuing from a hole some $\frac{1}{2}$ mm. in diameter is used. The two wires are held side by side in this flame in which the solder melts without damaging the wire.

Alternatively, a molten bead of silver solder can be formed in a hollowed piece of stainless steel, $\frac{1}{16}$ in. thick and $\frac{1}{2}$ in. wide, which is heated electrically by passing a current of about 50 amperes through it at a potential of say 1 volt. The solder does not wet the steel and so forms itself into a globule. This is coated with borax by dropping the dry powder on to it. All that is necessary is to pass the two wires into this globule through the coating of borax and bring them together in the solder. They should be drawn out by moving them endways in the direction of the length of the wire until the joint is outside the solder, and then withdrawn, or they will sag down due to the capillary pull of the liquid solder. The solder could no doubt equally well be melted in a cup made at the top of a copper rod about $\frac{1}{2}$ in. in diameter, which is heated by such a blowpipe as described below. This method of putting the wires in the melted solder is especially useful for very small gauge wires and also for joining wires of different sizes.

Copper plating, followed by soft-solder, has also been suggested for work of the highest class, such as standard resistances.*

A Bunsen burner giving a high temperature. The Bunsen burner referred to above is very simply made, consisting of two parts only, a piece of parallel brass tubing and a brass rod fitting comfortably in the tube (Fig. 78). We have made such burners from $\frac{1}{16}$ in. to $\frac{3}{8}$ in. in diameter. To work satisfactorily certain relations must hold between A the internal diameter of the tube, B the length of the tube from the air-hole to the open end, and C the diameter of the short fine hole at the end of the rod. Taking C as unity, A should be about 7, and B about 56. The long diameter of the air-hole can be about 9, but

* *J. Sci. Instrum.* **10**, p. 256 (1933).

the exact size of this is less important. The rod should be able to pass far enough into the tube to close the air-hole. The tube is split at the back up to about the level of the air-hole and bent in order to hold the rod with a fair amount of friction. The adjustment of the flame is effected by sliding the rod more or less into the tube, as the type of flame depends on the relative positions of the end of the rod and of the air-hole. For the greatest heat the flame should roar,

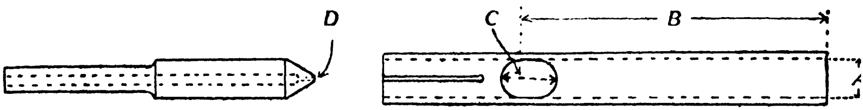


FIG. 78.—Bunsen burner giving a high temperature.

and then the hottest spot is just beyond the end of the green flame. The burner is most conveniently attached to the end of a light small-bore rubber tube, so that it may be applied easily to the work in hand. It is used with gas at ordinary pressure and will burn in almost any position. A hook may be fixed to the back of the tube, to suspend it between operations.

Clamps. Two of the most useful clamps (*a* and *b*) are shown in

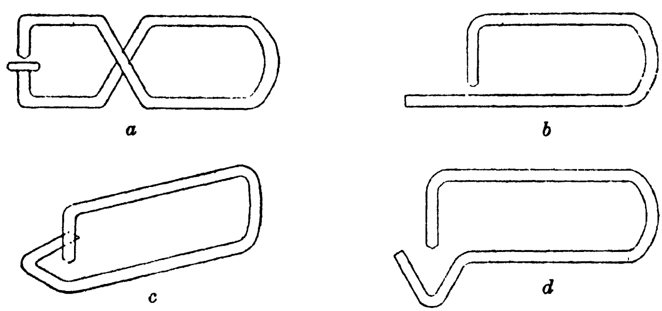


FIG. 79.—Types of clamps.

Fig. 79. The first is conveniently made from a motor-cycle spoke cut to a suitable length, and bent so that the point is opposite the "button"; the diagram shows its shape. It is used to clamp two parts when there is a flat surface on to which the button is applied. A number can be made of different sizes. The second is made from any spring wire, and is used to hold a part against the surface of a tube (into which the long end of the clamp is passed). *c* shows another useful form; in this, one end of the wire forms two sides of a triangle, on which

any flat object can lie. The other end is directed to point to the centre of the triangle.

Yet another simple clamp is made out of stout iron or steel wire which may be from $\frac{1}{8}$ in. up to as much as $\frac{1}{4}$ in. in diameter, bent to a long U, and having the ends bent again so that they face each other. These ends are filed flat. The pieces to be soldered are held between these two faces. A number of these of different lengths should be on hand.

Type *d* is a useful form for attaching a small piece to the side of a cylinder. Of all these the clamp of type *a* is the most generally useful. It can be used to hold small articles for any purpose and as it is opened by pressure on the closed end it is very easily applied with one hand. The other clamps described can obviously all be made to open on the same principle if desired.

51. Soldering Aluminium

By A. G. C. GWYER, Ph.D., F.I.M.

J. Sci. Instrum. **10**, p. 396 (1933)

A satisfactory solder for aluminium consists of an alloy of aluminium with either 5 per cent or 10–13 per cent of silicon, the latter composition being easier to work. A commercial fluoride flux, of which there are several good ones on the market, is used and is applied on the end of the solder stick. The parts to be joined are clamped together and the solder stick heated and dipped in the flux. Then, using a gas blowpipe with a small flame, the solder stick is melted and run along the joint. The solder flows readily and makes a strong and permanent joint. A rather high temperature is required as the solder begins to melt at 570° C., but apart from this and the use of a gas blowpipe the process does not differ from the ordinary soldering of brass.

52. Soldering, Brazing and Autogenous Soldering

By Sir CHARLES BOYS, F.Inst.P., F.R.S.

J. Sci. Instrum. **11**, p. 105 (1934)

Soft-soldering. Soft sawder is a term of reproach and the use of soft sawder or solder is commonly looked upon as a slovenly and untrustworthy mode of procedure. This really is a great mistake if proper design and manipulation are both employed. Indeed, in instrument making, more especially in that prior process of experimental construction, soft solder properly used is the most perfect means to an end that there is. The temperature necessary for its use does not soften or much discolour hard rolled brass, and it need not affect even the straw colour of tempered steel except where splashes of zinc chloride solution dissolve off the coloured oxide film. Not only this, but among the separable joints to be found in engineering construction which must be absolutely gas-tight under the most severe conditions is a soft-soldered joint connecting hard gun-metal and mild or not-so-very-mild steel. I refer to the solder on the taper screw of the valve screwing into the neck of a gas cylinder which may have to retain hydrogen under ever so many hundred atmospheres of pressure and not leak at all. This joint is made by forcibly screwing in the valve hot with its own thread and that in the steel neck thoroughly wetted all over with melted solder. In this case all shocks are resisted by the mechanical rigidity of the construction apart altogether from the solder present. The gas-tightness is ensured by the complete wetting of all the screw surfaces and squeezing out of all the solder except that of atomic thickness remaining where the metals are pressed tightly together or filling any crevices that may exist where the fit is not perfect. I have dwelt upon this example because it is at one end of a series which may be considered as the development of the design of a soldered joint. Perhaps the best example representing the other end of the series is the equally perfect (for its purpose) soldered joint of the lid of a sardine tin intended to be broken cold by a peeling process.

This raises the preliminary consideration of design of a soldered joint, and the considerations of good design depend largely on the stiffness of the material to be soldered. For flexible sheet metal one consideration applies, for metal thick enough to be rigid other considerations apply, as also are the most convenient soldering operations which are different in the two cases.

Thin sheet metal usually soldered by the aid of a soldering bit calls for no observation except only to endorse the advice already given (*see* Note 50), to have the bit plenty hot enough and with this to urge the importance of holding the bit so that one corner of the end of the bit lies almost tangentially in the seam, and that the bit be held there quietly until not only is the solder attached superficially but the seam is raised to its whole depth to the melting-point of the solder, so that this enters and fills the seam. The usual fault of the beginner is to have the bit nothing like hot enough and to hold it so that the point only touches the work, and then to keep rubbing the line of seam where he fondly imagines some solder may stick as if it were paint. The essence of the process is the slow firm motion of the bit so that the seam is brought up to the melting-point. Gas-heated or electrically heated bits make very long seams amenable to a single drawing over them of the bit. Please notice drawing, not pushing. It is best in each case to have dropped beads of melted solder on the joint along its length to provide the necessary supply. If then the seam has been properly wetted with zinc chloride solution and the work is so held that there is a slight downward gradient along the seam, the solder necessary for the joint alone will remain and superfluity if any will travel along with the bit and this can be allowed to drop off at the end. According to the inclination the drainage of the solder following the bit may be varied as desired, more being left as the line of seam is more nearly horizontal. For thin sheet-metal work the soldering bit is supreme. For thick work according to my practice it is hardly ever used. When it is used it is because it overcomes some cause of awkwardness, and in such cases the work in the neighbourhood should be heated by a Bunsen flame but not up to the melting-point. Then the soldering bit may be used on the hot thicker metal with much the same effect as on cold thin metal.

In the ordinary way the soldering of thin metal with a bit is the easiest of all soldering operations, but this is not always the case. Coming back to experimental construction I have within my own experience met with the most difficult of any soldering operation when soldering thin metal with a bit. When developing the radio-micrometer nearly fifty years ago, I found that I wanted to soft solder the ends of a loop of No. 36 copper wire to one end each of a small bar of thermo-electric metal, while I had to connect the other ends by a disc of copper foil about $\frac{1}{12}$ in. in diameter. The little bars of antimony, bismuth and tin suitably alloyed together were about 7 mm. long and about $0{\cdot}5 \times 0{\cdot}1$ mm. in cross-section. I placed the pieces in position and held them so by little strips and weights; I made a soldering bit of No. 18 copper wire, twisting two close turns together near one end and with a tapering point about $\frac{1}{4}$ in. long projecting. The wire was held in a wood handle. A drop of zinc chloride solution was applied to the joint, and the bit heated in a Bunsen flame was, after tinning in the usual way, made to touch the spot for a moment and the deed was done. Any hesitation meant the risk of disappearance of the bars owing to the formation of more fusible alloys. Five soldered joints had to be made for each circuit, and I found by weighing the parts and the whole that 1 mg. of solder was used in the five joints altogether. I used to wash these in boiling water which I considered to be, if not necessary, at least a wise precaution, as also wherever iron or steel entered into a soldered combination, and then such joints oiled when dry never showed a trace of rust.

Among thin metal soldering operations often considered difficult is that of soldering Britannia metal vessels and hinged lids of hot-water jugs. An ordinary bit heated in the fire and applied to a Britannia metal vessel goes straight through it, but when this is realized and care is taken soldering is not so difficult. I have resoldered a Britannia metal lid of a hot-water jug to its hinge tube using an ordinary bit heated in the dining-room fire and using ordinary tinman's solder and zinc chloride. I have, however, found the process to be far less tricky if a little bismuth is added to the solder. I have added the bismuth by guesswork only, perhaps 1 part of bismuth to 3 or 4 of solder. Simply place the metals side by side on a piece of wood and bring down on to them the hot bit and they melt together, and then seem as if they would never solidify. With this and the usual zinc chloride solution there is no difficulty at all.

Fluxes. Before passing from soldering thin or flexible metal and coming to the entirely different process of sweating thicker metal, I should like to say a few words about the zinc chloride solution or other flux, for these are used with each. Where the zinc chloride might enter, e.g. insulation, from which it cannot well be completely washed, it is best to use a less effective but non-corrosive flux, and rosin is commonly used on metal which should be as clean as possible. It should be in fine powder rather than in granular form, but the best method of application is as a thick alcoholic varnish which ensures that the crevices as well as the outer surface get a protective coating.

Personally I continue to use the killed spirit made according to the manner which I extracted from a reluctant Uppingham tinker about sixty-five years ago. I saw him make it. He had spirits of salt in a bottle to which he had added some water. How much water I asked. "Oh! a good mess of water." This I took to mean a good deal more water than spirits. Kill it with zinc, and when the bubbling is finished you have your killed spirit. Actually soldering fluid so made is absolutely perfect. Chloride of ammonium is sometimes added, but I do not know of any advantage from the addition. If killed spirit is really better than zinc chloride in sticks dissolved in water it may be from some free acid remaining. It is essential that all trace of the flux be removed after soldering. As I have said, I prefer to boil in water important work. A good washing preferably followed by a long soaking in fresh water is no doubt sufficient. A perfunctory cleaning will mean a green stain due to subsequent corrosion.

Sweating. The process of soldering thick metal is generally that of sweating. The parts that are to be joined should be clean, the cleaner the better; they should fit closely and be held together, but it is best to wet the whole of the surfaces to be sweated with the solution before they are put together. Then small pieces of solder or a number of blobs of solder, made by heating a stick and allowing it to drip on to a board, are placed on the metal against the junction and heat from a Bunsen burner is applied to the work. When the metal is hot enough to make the liquid boil off it is a good thing to take a brush dipped in the solution and apply it lightly to the work so that the solution sizzles along the line of the joint and around the blobs of solder. Then when the work is hot enough for these to melt they should at once wet and run in, filling every crevice in and about the joint. This does not always happen, but the solder can be persuaded to behave properly if it is dabbed, when hot, with the wet brush. In most cases a perfect and uniformly bright adherent surface of the melted solder can be ensured by further applications of the wet brush, and reluctant solder can be pushed about with it into corners and anywhere it is wanted. The sizzling solution on the hot metal is incredibly persuasive in awkward cases, and perfect joints can be ensured in this way. The wet brush is practically the only tool I ever use and it amuses people who have not seen it before. A word of caution is necessary as to the cooling of extensive work in thick metal. On no account should water be used on the hot metal for the solder of the joints when solid but still hot is very rotten and the differential contractions may easily make cracks or flaws in the joints which if asked to hold ether for instance will be found to fail. Let the metal cool down in the air. With large work a blowpipe may be advantageous but the most convenient of all methods of heating big work is by the use of the blue-flame burner and dissolved acetylene in cylinders. In country places where there is no gas this and the charcoal fire or even both at the same time may be used as I have done, but even where coal gas is available the hot clean blue acetylene flame is so much better than any other source of heat that I strongly recommend its use in every constructional laboratory. If intense local heat is wanted the pointed flame may be used and this will melt platinum without oxygen. According to the burner used anything from a large brushy flame to a fine blue needle-jet can be obtained.

Design. In my opening observations I referred to design in soldered work where thick metal is concerned. I must come back to this as it is of the first importance. Let it be understood that I am discussing mainly experimental construction rather than factory manufacture. I am on the preliminaries of instrument design where it is desired to extemporize a construction and for this purpose extruded rods of every kind of section are worth keeping in hand. They may be sawn up and combined and sweated together and various forms tried so as to ascertain what will in fact be best and then very often castings or pressings will take the place of the extemporized pieces. Where these are sweated together it is important that a good job should be made and not one which will fall to pieces as the result of a shock. For instance, a piece of brass rod, say 1 × ⅛ in., standing edgewise on the face of another may be sweated in position, but such a combination is too weak to be structurally sound. This is worse indeed than the sardine tin first mentioned. The surface of attachment should be greater and it should especially be extended in other directions. For instance, if the upper piece were bent to a right angle and the edge filed flat and that were sweated to a flat surface, the line of junction being angular the joint would be far stronger but still not a very strong one. If the junction could extend in another plane the strength would be enormously increased. It is well where possible to let one piece rest not on a flat surface but lie up against a shoulder. This adds greatly to strength besides being a great help in locating the parts before sweating. The more one piece can envelop the other the better so that a ring sweated on outside a cylindrical form is for practical purposes perfect. For resisting the greatest stresses if it is screwed on by a fine thread cut in each in the lathe and properly sweated all through the junction is as good as solid metal and often far more convenient. Where vessels to hold liquid are made by sweating bases and tops to a brass tube the slightest shoulder formed by turning out the ends of the tube on to which the ends may be pressed is a great advantage for locating the ends which should, however, fit the cylindrical portion fairly tightly. In sweating such joints it is convenient to make the depth down to the shoulders rather greater than the thickness of the ends so that when pressed home there is a corner all round to receive the solder and the attentions of the wet brush. The glistening silver-like melted metal all round this is excellent evidence of a perfect joint. This may be further ensured by pouring into the hot vessel very little solution and letting it run sizzling all round inside and then heating up again. An even more certain non-leaking joint is made if a fine thread be cut on both surfaces and wetted and then when the sweating process is going on the one piece be turned relatively to the other and soused and heated again and it is impossible that there can be any thread opening for leakage. It is only in this way that I have at last been able to get the amyl alcohol thermometers of my recording calorimeter to be made free from leakage, though I personally never had any difficulty. A further advantage from this construction is the fine adjustment for capacity that it gives when this must be definite. After a test for capacity has been made the amount necessary to turn the end to obtain the right capacity at once, is known when the error is known. After thorough washing with water and drying it is better to test for leakage with alcohol or ether, but carbon bisulphide is better than these for making a very small escape evident to the senses.

Brazing and silver soldering. I have never been able to find out why these simple operations are found so difficult by some people. Even the cleanliness so important when soft soldering is not so important in brazing, as much dirt burns off and the borax fluxes the oxides and other contamination into a fusible glass under which the melted copper, brass, spelter, or for work on gold or silver, gold or silver solder melt and spread. There is not much that I wish to add to the information given in Note 50. I would, however, urge the convenience of silver soldering of brass work in instrument construction instead of brazing with spelter. The cost is of but little account because so little is used. The extra fusibility, fluidity and facility make it worth while. In this it corresponds with the use of bismuth solder with Britannia metal. I have found that silver soldering may in some respects resemble soft soldering with a bit, for a wire heated in the flame with the work may be used as a soldering bit to show the solder where it is wanted to go and lead it there if it has not gone of its own accord which it should have done. Of course the blue acetylene flame is ideal for brazing.

The authors of Note 50 have referred to the nuisance caused by the swelling up of the borax which may prevent it from forming a glass over the work from the beginning. I have generally used the borax put on with water which is a help, but the real way to deal with borax though published so long ago as 1899 seems to be quite unknown. This was invented by Sir Henry Cunynghame when he was at work on enamelling for jewellery and fine ornamental work. He found especially with cloisonné enamelling on fine gold that the very small pieces of square gold wire for the cloisons and the fragments of gold solder were apt to get displaced by this swelling-up process and he invented a complete and perfect cure which is described in a paragraph of six lines only in his book*. Sir Henry Cunynghame melted borax in an earthern crucible gradually adding more as the previous supply blew off its water and settled down to a molten glass. When he had enough he poured this out on a metal slab and when cold he ground it to an impalpable powder in an edge mill made of Scotch granite. Except for the labour I do not see why the grinding should not be done in an iron mortar. It is quite likely that he wished to avoid all possible contamination with iron because of the risk of affecting the colour of the delicate enamels. Even this risk I do not understand because after pickling with acid subsequent to the soldering all trace of the borax glass is gone. Or, what is more likely, having the granite edge mill to grind his enamels where contamination by even a trace of iron would be disastrous he used the means which he had ready to hand. For silver soldering of instruments this consideration need not apply and any method of grinding should do, for granite edge mills are not easily to be had. The finely powdered borax glass, however, will not keep as a powder so he kept his immersed in a pure and heavy

* Cunynghame, H., *Art Enamelling Upon Metals*, p. 83 (London: Constable & Co. Ltd., 1899).

petroleum just as sodium is kept in a liquid free from oxygen. Then when the gold ground, the gold cloisons and the bits of gold solder were in place he painted carefully all round and over the cloisons and solder with the petroleum borax glass powder as with a cream. On heating from below the petroleum distilled and burned off, leaving the borax powder intimately in contact with all the metal to be protected. On heating up there was no swelling or disturbance and the surfaces became evenly glazed and then the gold solder on melting flashed into the lines of joint and disappeared. He used the same with silver work, and for delicate instrument work where the swelling up is a nuisance I see no reason why it should not be used also.

The preparation of the borax glass and the grinding of it to fine powder is a very tiresome operation for any individual user, while it is a simple enough factory operation. I have therefore drawn the attention of a manufacturing firm to the desirability of their having the "Cunynghame Cream" prepared and put up in bottles or tins.

Autogenous soldering and lead burning. Autogenous soldering, that is the joining of two pieces of the same metal by local fusion, is in general a factory operation and in such aspect does not come within the scope of the present article. There are times, however, when, as in my own experience, in experimental construction it may be found invaluable.

The autogenous soldering of lead by means of the hydrogen flame was invented about eighty years ago by the Count de Richmont* and this has been used for joining the lead sheets of sulphuric acid chambers and other chemical containers almost unchanged to the present day. The hydrogen cylinder replacing the hydrogen generator is the only marked change. I think I am right in saying that acetylene has been used for this, but hydrogen is almost universally used. Some years ago I wished to make up the heat interchangers of my recording calorimeter with thin sheet lead bent into a zigzag and wound round in a circle with adjacent edges autogenously soldered. Soft solder I wished to avoid because of galvanic action in contact with acid condensation products. Now I knew that lead burning was one of those highly skilled processes requiring true craftsmanship handed down from father to son and not to be undertaken lightly. In my case there was the added difficulty that the lead was only one-thirtieth of an inch thick and the joints were all radiating outwards and close together. I overcame the difficulty so completely that I could make these joints at the rate of about a foot per minute, and as the process may be useful to others and is not obvious it may be worth while to describe it. I brought down a flex from a lamp socket, then provided with direct current at 200 V., inserted a resistance of about 200 Ω, and making

* Hottzappfel, *Turning and Mechanical Manipulation*.

the lead the positive pole drew down the intended joint a thin electric light carbon made negative. This resulted in a small arc which melted the lead locally but the two pieces absolutely refused to join and appeared to repel one another. This was due to oxidation and was what I expected. The application of a jet of hydrogen might have supplied a reducing atmosphere but the heat of the flame would have melted completely the lead intended to be joined and adjacent intended joints as well. This difficulty was completely overcome by the use of a cool flame of hydrogen and carbon dioxide mixed in such proportion that the flame would barely melt lead but being a flame could have no free oxygen within it. The mixed gases were produced by two large Kipp generators and the two gases were lead to a mixed oxy-hydrogen jet of a limelight (not a blow-through jet). I described this in the year 1922*.

53. An Aid in Soldering Small Parts

By W. CLARKSON, Ph.D., A.R.I.B.A.

J. Sci. Instrum. **5**, p. 230 (1928)

An interesting and highly useful small tool for the warming of small or inaccessible parts of instruments preliminary to soldering is illustrated in Fig. 80.

A length, say 20 cm., of 3–4 mm. brass tubing is connected, preferably through a cork or some such heat-insulating material, to a gas supply (see diagram), and so bent that the stream of gas issuing from the end,

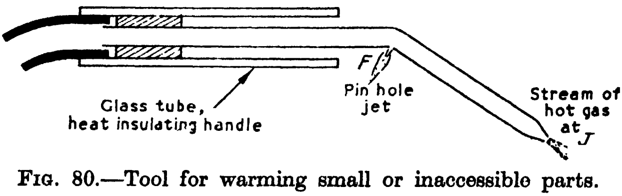


FIG. 80.—Tool for warming small or inaccessible parts.

which should be made of suitable proportions, may be played on such metal parts as are to be soldered. At a convenient place in the tube, here at the bend *F*, a pin-hole gas jet is made, where the gas is lighted, so that the tube becomes very hot. This heating is communicated to the stream of gas in the tube and thus in turn to the parts to be soldered.

Though a metal rod mounted and heated like the small soldering-

* *Gas Journal*, **158**, p. 886 (1922).

bolt previously described by the writer* is also very suitable for the same purpose the method here described has much to recommend it. For one thing the heating is not so fierce, and further, fragile parts are not subjected to strain. The diagram shows how connexions may be made in a glass tube, which, sheathing the hot metal, acts as a convenient and heat-insulating handle.

54. An Electrical Method of Soft-Soldering

By R. A. Fereday, Ph.D., F.Inst.P.

J. Sci. Instrum. **11**, p. 267 (1934)

The objects to be soldered are brought together in the correct relative positions and a sufficient quantity of soft solder, in small pieces, is placed along the line of the joint, which is also painted with a little flux. The job is connected to one terminal of a low-voltage transformer, and the circuit completed through a carbon rod which can be brought into contact with the metal at the point where the joint is to be made. Superficially, the process would thus seem to resemble one of arc welding, but actually is fundamentally entirely different, in that the voltage of the transformer is kept so low (4 V. is a convenient value) that no arc forms, the Joule heating effect at the point of contact with the carbon electrode being relied upon to heat the metal and cause the solder to flow into the joint.

The heating effect depends mainly upon the area of contact between the carbon and the metal, and a little experience is necessary to decide upon the best form of electrode to be used in a given case. Generally speaking, a fairly blunt-pointed rod will be found the most satisfactory. Provided that the object to be soldered can safely carry the necessary current, the process has useful applications in delicate work where capillary forces, for example, make soldering with a tinned iron rather difficult; the soldering of a fine wire to a larger mass of metal is a case in point.

55. Cold "Soldering"

By M. C. Marsh, Ph.D., F.Inst.P.

J. Sci. Instrum. **7**, p. 399 (1930)

It is sometimes desirable to solder wires or other small parts to an apparatus in the proximity of other parts which are easily damaged

* *J. Sci. Instrum.*, p. 395 (1927).

by heat. If the parts to be soldered are of small heat capacity, it is often possible to heat locally enough to prevent damage. For this purpose the usual type of soldering "iron" is a fairly stout copper wire, heated by a small gas-jet from a glass tube round which the wire is twisted. The length and shape of the wire are adjusted to be convenient for the particular job, and the flame adjusted for size and position to keep the end of the wire at a suitable temperature for soldering.

There are, however, occasions when heating is absolutely prohibited, but "soldering" may still be effected if the surfaces are copper or brass by the use of dental copper amalgam. The surfaces are cleaned with fine emery paper. The amalgam is worked into a plastic state according to the instructions applying to the particular make and rubbed on the surfaces to be joined in order to amalgamate them. The joint is then made with the plastic amalgam much as it would be with molten solder. It is advisable that the joint be left for several hours to harden. The results of this method are not so strong mechanically as soldered joints, as the amalgam tends to be brittle and the adhesion to the metal surface is not so good. As electrical connexions, however, these joints are very satisfactory.

56. Soft-Soldering on to Stainless or Case-Hardened Steel

By O. Kantorowicz, Dr.Phil., F.Inst.P.

J. Sci. Instrum. **15**, p. 28 (1938)

Any attempt to soft-solder a component to stainless or case-hardened steel by orthodox methods will prove a failure, for at the temperatures usual when soldering other metals the tin will not get a grip on the steel, and at higher temperatures the tin quickly deteriorates, probably by oxidation, into a pasty mass with neither sticking power nor strength, and none of the ordinary fluxes will prevent this.

A remedy was found in covering the steel spot that was to be tinned by a piece of metal that prevented access of air to the overheated solder. The following technique proved easy and successful: a brass shim, 3–5 thousandths of an inch in thickness, was cut slightly bigger than the base of the component that was to be joined, and with a narrow strip by which it might be handled extending from it. One side of the shim was well tinned and the steel part warmed to the melting point of the solder, applying the usual fluxes. The shim was then pressed with the tinned side on to the steel, and rubbed on with a warm soldering bit. More heat was now applied to the steel, the ultimate temperature of which was not measured, but which was well below red heat. The steel was then allowed to cool slowly, the shim meanwhile being moved to and fro to allow dirt to escape together with superfluous solder. The component to be soldered on was then sweated to the other side of the shim. It is necessary to keep in mind that the shim is floating on the steel during this operation.

No tests to destruction were made of the strength of these joints, but they withstood alternating tensile stresses of 50–100 g. per sq. mm. at approximately 500 c/s.

57. Soldering or Brazing of Alloy Steels

By J. P. REED, A.Inst.P.

J. Sci. Instrum. **12**, p. 364 (1935)

Occasionally constructional work involving the soft-soldering, silver-soldering or brazing of certain classes of stainless steels, nickel chromium alloys, etc., has been found to be difficult if not impossible. This is due to the formation upon the metal of an oxide film which is extremely difficult to flux. The writer has overcome this difficulty by the following technique. The areas of the metal which are to be used for jointing are first cleaned mechanically or by electrolytic pickling. In the case of stainless steels, nichrome, etc., electrolytic pickling is achieved by the use of a 5 per cent nitric acid bath and a current density of 0·1 A per sq. cm., the metal being made the anode. A light " flash " coating of copper is then electro-plated on to the cleaned areas, after which the joint can be made by the normal brazing operation. It will be found that a perfect joint is obtained by this method as readily as with a copper-copper joint, the tensile strength being dependent upon the particular jointing medium used.

58. Soldering Aluminium Brass Joints

By F. H. SIMS, M.Sc.

J. Sci. Instrum. **12**, p. 233 (1935)

In the preparation of vacuum vessels with apertures covered by aluminium foil, the mechanical strength of the waxed joint is occasionally insufficient. In such a case it was found possible to soft solder the aluminium foil on to the brass. For this purpose, an Australian solder, Kookaburra aluminium solder, was used, and the procedure was as follows. The aluminium was " tinned " with aluminium solder, by thoroughly cleaning with sandpaper the portion of the aluminium to be soldered, heating the foil until the solder just melted when applied to it, and rubbing on the solder, scratching it into contact with the surface, if necessary with a piece of wire. The brass was "tinned" with ordinary solder. The foil was then placed in position and the brass heated until the solder melted, more ordinary solder being added if necessary.

Although mechanically strong, the joint so made is generally not airtight, but painting with amyl acetate lacquer makes it quite suitable for vacuum work.

The process depends on the union of ordinary solder with aluminium solder; but it is not known whether all aluminium solders are suitable.

59. An "Iron" for Silver-Soldering

By T. F. HARLE, B.Sc., A.Inst.P.

J. Sci. Instrum. 7, p. 136 (1930)

The advantages of an "iron" in the case of soft-soldering are well known. It is not so well known, however, that the principles of the soldering iron can be applied with as much advantage to the case of silver-soldering.

The iron is made by fusing about 2 in. of platinum wire (about 24 s.w.g. or several twisted strands of finer gauge) into a piece of glass tubing. A bead of solder is fused, using a liberal supply of borax as a flux, and the iron dipped into the molten bead to "tin" it.

The iron is particularly useful when it is required to silver-solder wires of so small a diameter that the direct application of a flame would incur too great a risk of fusion. The tinned iron is heated with a small pointed gas-jet, which is found to be hot enough without the admixture of any air. When the bead of solder is thoroughly molten the iron is quickly transferred to the job, and removed before the solder sets. In general, no flux need be applied to the wires, enough being carried on the surface of the bead of solder. In electrical work this is a great advantage, as in some cases superfluous flux might impair insulation. As an example of the utility of the method may be mentioned the fact that two pieces of 44 s.w.g. copper can be soldered together with the greatest facility, an operation by no means easy to carry out by other means.

The iron also provides a convenient means of applying silver-solder to a surface to be tinned, and with its aid a large extent of surface can be tinned with a minimum amount of solder.

60. Flux for Soldering Phosphor-Bronze Hair-Springs

By C. E. HOMER, Ph.D., F.I.M., and H. A. WATKINS, L.I.M.

J. Sci. Instrum. **19**, p. 45 (1942)

A non-corrosive flux is required by certain specifications for soldering phosphor-bronze hair-springs in instruments. Several non-corrosive fluxes are available, but most of them leave residues which are either greasy or resinous. Grease and resin tend to run along the spring and thus affect the accuracy of the instrument, and a greasy residue also collects dust and dirt in the course of time.

We have found that the following solution is free from these disadvantages and is easy and convenient to use:

Lactic acid . . .	15 per cent by volume
Calsolene oil . . .	0·2 per cent by volume
Water	remainder

The Calsolene oil is a proprietary wetting agent: other wetting agents which are stable under these conditions can be used equally well. The lactic acid flux is quite active in use, and gives good joints on copper, brass, or bronze, even when they are somewhat tarnished. There is only a small amount of residue after soldering, and this is a non-corrosive white powder which can easily be brushed off with a soft brush. The flux is already in commerical use for soldering hair-springs and is proving very satisfactory.

61. Lead Jointing of Metals

By H. G. JONES, M.Sc., A.Inst.P., G. E. ROWLAND and A. WILLIAMS

J. Sci. Instrum. **12**, p. 201 (1935)

The following method may occasionally be used to avoid the difficulties experienced in soldering iron and fairly large masses of other metals. The metals to be joined are placed together, a cardboard mould is held around them, and molten lead is poured into this mould; after the lead has set, the cardboard is cut away leaving a joint which is watertight, and which will stand up to laboratory usage. No flux is required, but the surfaces should be reasonably clean and free from paint.

When joining small pieces of commercial aluminium by this method it has been found that the lead will not seize the aluminium unless a large piece of metal is held under the joint to ensure rapid cooling.

62. Welding Small Platinum Heaters and Electrodes

By A. R. Morris

J. Sci. Instrum. **23**, p. 84 (1946)

The percussion instrument now to be described for use in connexion with joining very fine platinum wires, renders the operation both simple and precise and enables inexperienced persons to make successful welds.

As will be seen from Fig. 81, the device consists of a base-plate or anvil and a hammer attached to a fixed arm arranged at a convenient height above the base. The hammer head contains a plunger shaped to a tip at its lower end and supported in the raised position by a light spring. In use, the pieces to be welded are arranged under the head and their correct position determined by depressing the hammer and observing that the point at which the weld is to be made is directly

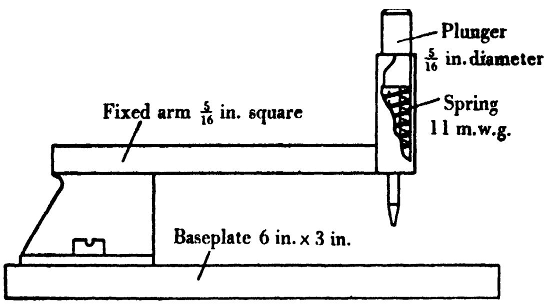


Fig. 81.—Side view of instrument.

under its tip. The joint is then raised to welding heat with a fine oxy-coal-gas blow-pipe flame and the weld is made by giving a sharp tap with the finger on the plunger.

The dimensions and construction shown are not significant, but the spring should not be too stiff; in the present instrument it is made from No. 11 Music Wire gauge wire wound at a pitch of 14 turns per inch on a $\frac{3}{16}$-in. diameter mandrel.

To attain a sufficiently high temperature for a successful weld it is desirable to keep the heated parts initially out of contact with the base-plate; this can be achieved by putting a slight set, no more than say $\frac{1}{64}$ in., into each piece as shown exaggerated in Fig. 82. This arrangement avoids unnecessary loss of heat and enables a very small flame to be used. The alignment and retention in position of the parts to be welded can be readily accomplished by the use of simple

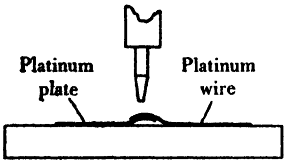


FIG. 82.—Assembly showing setting for welding.

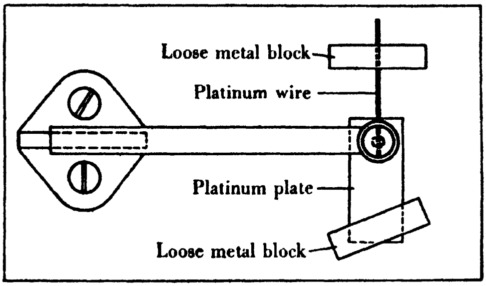


FIG. 83.—Plan view showing use of metal blocks.

weights or metal blocks. For example, Fig. 83 indicates the set-up for welding together an electrode plate and wire.

The instrument has proved very successful in the fabrication of small platinum electrodes and micro-heaters.

63. An Improved Method of Spot Welding

By L. J. BAYFORD, A.M.I.E.E.

J. Sci. Instrum. **16**, p. 124 (1939)

In the manufacture of vacuum tubes it is often required to weld an electrode, consisting of a disc or plate, on to a support wire or a tube normal to it. The following method of making a butt joint between the two has been used successfully in this laboratory.

One electrode E_1 of a spot welder is drilled axially to accommodate the required length of support wire W (Fig. 84). The latter is cut so that when inserted in the electrode approximately 1 mm. is left protruding. The plate or disc P to which the wire is to be welded is then placed on the other electrode E_2 of the spot welder. Due to the pressure which is exerted between the two electrodes during welding, the end of the wire firmly imbeds itself in the plate. Fig. 85 shows a modification for welding any required length of wire to the plate. The set screw S holds the wire in position during welding.

Similarly, eyelets may be welded to plates or other electrodes, as shown in Fig. 86. The electrode E_1 must be drilled to accommodate the eyelet suitably. The drilled-out portion of the electrode E_1 should be such that the thrust of the spot welder is taken by the flange and not by the tube of the eyelet. Metal tubes having a flange at one end can be welded in a similar way.

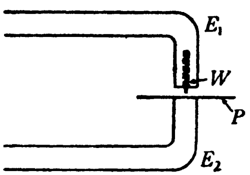


FIG. 84.—Method of spot welding.

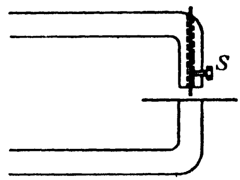


FIG. 85.—Modification for welding length of wire to plate.

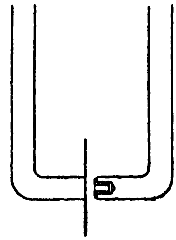


FIG. 86.—Modification for welding eyelets to plate.

It has been found that such welds are very strong and durable, and that the supporting wire remains normal to the plate.

64. Welding Fine Thermocouple Wires

By E. D. HART, M.A., M.I.R.E., A.M.Brit.I.R.E., and W. H. ELKIN

J. Sci. Instrum. **23**, p. 17 (1946)

Thermocouples are used to a considerable extent in very high frequency current measurements owing to the ease with which they may be standardized with direct current. The mutual type, in which the couple serves as the heater, is rarely employed, as the shunting effect of the indicating meter reduces the sensitivity, the direct contact or the separate heater type being preferred. A simple form to make is the four-wire type of contact couple in which a heater wire has attached to its centre a thermocouple of two other wires. This type is slightly more sensitive and has a quicker response than the separate heater type using a glass bead insulator between heater and couple. It is very easy to make by a process of welding, and the method here described has been found invaluable in the making up of experimental thermocouples with wires of size 40–50 s.w.g.

The four wires comprising the arms of the couple are cut to the same length and held side by side. If the wires are bare the welding can follow immediately; if the wires are insulated (enamel or silk, or both) they can be cleaned by Bell's method (see Note 121), i.e. by wrapping the wires round a piece of 26–30 s.w.g. copper wire, heating to redness in a flame and quenching immediately in alcohol.

The wires are then twisted together lightly and evenly, and one end is gripped in the positive bull-dog clip of the simple circuit shown in Fig. 87. To prevent possible damage to the wires it is better if the serrated jaws of the clip have been filed flat. The ends of the twisted wires are now trimmed with a sharp knife to ensure that they are all the same length, and any splayed ends resulting from this are tucked in again. A thin carbon rod—lead from a soft drawing pencil answers well—gripped in the other clip is momentarily brought up to the free ends of the twisted wires and quickly withdrawn. The wires will melt at the end and fuse to a small blob as the arc extinguishes itself (Fig. 88 (*a*)). The wires can then be unclipped and the loose ends

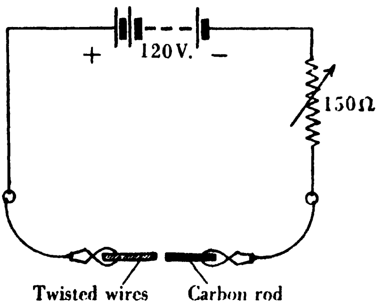


FIG. 87.—Circuit for welding fine thermocouple wires.

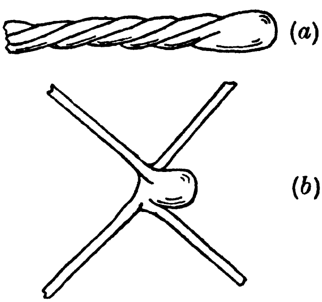


FIG. 88.—Welded thermocouple wires: (*a*) after welding, (*b*) cross-wire after untwisting.

untwisted and spread out to form the cross-wire thermocouple of Fig. 88 (*b*).

The voltage source is preferably an ordinary 120 V. high-tension battery in good condition; standard mains-driven power units may be used, but they are usually unreliable owing to their higher internal impedance which drops the voltage as soon as the arc is struck. An alternating current source may not be used, as carbon is then deposited in the weld, giving an unreliable joint. By using direct current and observing the polarity mentioned above, this effect is obviated. The variable resistor in the circuit may be used to control the weld to some extent. With the full value in circuit, the wires may not weld; with a low value the arc tends to be explosive and may disintegrate the weld, but a little adjustment soon finds the optimum setting.

SECTION 4. TECHNIQUE OF GLASS MANIPULATION AND SILVERING

65. Drilling Holes in Glass

By B. BROWN, B.Sc. (Eng.)

J. Sci. Instrum. **4**, p. 205 (1927)

It is known generally that holes in glass are drilled by use of a copper tube and an abrasive such as emery powder. There is nothing at all wrong with this method, but a special tool is necessary and it is not always convenient to have such things prepared—the hole is required immediately. The writer has found the following method very useful indeed, as it may be applied with material always at hand.

For the drill take one of the ordinary type and sharpened in the usual manner. Generally speaking, the actual size of the hole is of small importance. If, however, it is necessary to keep the diameter to within fine limits, it is better to choose a drill about 0·005 in. smaller than the hole required.

A cutting compound must be made up and this should consist of a saturated solution of camphor in spirits of turpentine. The drill should be run slowly and a copious supply of the compound applied. A good cutting pressure should be given to the drill, but this must not be so great as to cause flexure. It is very necessary to have a good support beneath the glass part which is being cut. After a short time a smooth hole will result, but one must not expect the cutting to be done at the same rate as for, say, mild steel.

In the laboratory the file is a most useful tool for the cutting of glass tube and rod. By use of the solution mentioned above much better results will be made possible; indeed, any shape may be cut out with the expenditure of a little care.

66. Manipulating Glass

By Sir CHARLES BOYS, F.Inst.P., F.R.S.

J. Sci. Instrum. **4**, p. 299 (1927)

I am tempted by Mr. B. Brown's Note (65) to offer some supplementary notes on that and cognate subjects.

Mr. Brown raises three matters—drills for glass, camphor in turpentine, and filing glass—on each of which I believe I can give useful additional information.

Drills for glass. Holtzapffel* says glass may be drilled with the double-cutting pointed drill of the drill bow, or with one in which the four facets meeting in a point are replaced by a pair of curved facets forming a curved diametrical double cutting edge, and he says lubricate with turpentine. He does not mention camphor. Threlfall in his *Laboratory Arts* treats of the drilling of glass in a manner which makes one almost believe he is writing of metal. He uses the ordinary Morse twist drill with lots of kerosene and he discusses the relative merits of this lubricant and the camphor-turpentine mixture of ancient tradition. He cannot find any superiority of one over the other. He also mentions the use by Faraday of a three-square file ground smooth and with the tip broken off, but in my copy of Faraday's *Chemical Manipulation* I can find no mention of this either in the paragraph cited or elsewhere.

Coming now to my own ideas and practice, I look upon that obtuse but short cross edge at the end of a single cutting flat drill or of a twist drill as most objectionable when drilling glass. It serves a useful purpose if a twist drill is used for drilling brass (which is wrong), for it meets with so much opposition as to prevent the acute edges from digging in, as they are so prone to do when the said obtuse edge breaks through.

It is this blunt cross edge which requires so great a thrust when drilling iron or steel and which is advantageously relieved by the use of a small leading hole. In the case of glass it gives rise to so much stress as to limit very greatly the speed of drilling, and the sudden change when it breaks through may very easily lead to a fatal crack. The four facets of the double cutting drill recommended by Holtzapffel meet in a point, and so this defect is avoided, but the double cutting drill is a futile sort of design, as the facets must make an acute angle with the work and much too great an angle of relief to give due support to the edge. No tinkering with the angles can put it right, for whether more or less one or other fault is magnified. It is now more than fifty years since I wanted to drill a hole through the knob of a bell jar for a beehive to afford ventilation, and with the considerations mentioned above in mind I made a drill of tool steel which I still look upon as the ideal steel tool if diamond is not available. This I made as follows: I heated the end of a piece of Stubbs steel wire red hot and with one blow on an anvil slightly spread the end. Then I filed it to the shape of a flat single cutting drill, with this difference, that I filed the flat faces at the very end slightly convex so as to meet at a point with the

* *Turning and Mechanical Manipulation*, vol. II, p. 553, *footnote*.

two cutting facets. This form gives a low angle of relief, a right angle between the cutting face and the work, and there is no obtuse cross edge to burst through the glass. Such a drill must be used dead hard with appropriate lubricant. To prevent damage in hardening it is well to melt cyanide of potassium in the drill, or soap, and keep the blow-pipe flame off the edges, or better not use a blowpipe at all, and quench vertically in really clean water. I have never used mercury, but this is recommended by Threlfall. I cannot now remember if I ground that drill before or during the drilling, but I do remember well that it cut through the glass very quickly and I had no trouble whatever. The hole was about $\frac{3}{16}$ in. in diameter and about an inch through.

Another form of drill for glass can be made in a very few minutes by grinding a very acute three-sided pyramid at the end of a file, using only the lightest pressure on the stone to avoid heating even to a straw colour. This is suitable for drilling conical pits in glass or for scratching a hole through window glass or through glass tube.

Lubricant. Whatever may be the true theory of the different lubricants used in cutting metal, my own belief is that for cutting glass all that is wanted is a mobile liquid of low surface tension so that it may instantly insinuate itself and wet everything up to the cutting edge and wash away the dust. Turpentine used to be the most generally accessible liquid having these properties, but Threlfall's kerosene or paraffin is now even more easily available. I have not tried tetrachloride of carbon or acetone or other liquids having the two properties mentioned, but I should expect them to do as well.

Files. The ordinary three-square file of the toolshop is not really three square at all but six squares, for after the file-maker had cut the three flat faces with teeth he cut teeth along the corners. Such a file may cut notches in metal better than one in which the final corner teeth have not been cut, but it is useless for notching glass tubes before breaking them. The essence of such a cut is a notch deep and sharp at the bottom, and this can only be cut by a file in which only the three faces have been cut with teeth. The corners then cut deep into the glass. The slender and somewhat irregular hard points along the edges which give the glass notching file its value are tender and are apt to be rubbed off by the unskilled user of the file. He rubs the file quickly backwards and forwards on the glass with equal pressure on the two strokes and the file is soon spoilt. The tender hard points will stand up to a heavy slow forward cut, as they are supported from behind, but unless the back-stroke is without pressure, being unsupported from behind, they break away. So important is it that the notch should be deep and sharp that it used to be general practice to use an old razor blade for this purpose. Using tools on glass is generally very bad for the tool, and Threlfall says that Morse drills are ruined in the process. Similarly a razor blade after notching glass would serve its original purpose very badly.

Leading cracks. A small size of glass tube, after being properly notched, will generally break square at the notch if pulled or bent in the direction to open the notch. As the tubes are larger the process becomes more hazardous. Of course the lapidary's steel slitting disc armed with diamond dust will always make a clean cut right through, but this valuable tool, which ought to be in every general workshop, is rarely found except in a geological laboratory. It becomes desirable therefore to do something to induce a crack to take the desired direction from the primitive notch. Notching all round is a mistake; a single notch made with one firm stroke is best, and no lubricant is required. Then a fairly thick copper wire, say 14 gauge, in a handle, with the end bent to the curve of the tube, heated dull red and laid on just beyond the notch in the desired direction and held still, will often start the crack. At the first starting of the crack the minimum of heat should be used, as otherwise it may get out of hand. If a crack does not appear, touching the notch with the wet finger will help. When once started it will follow the hot wire obediently as desired and the tube may be severed square across or at an angle if it is to be used for a liquid prism.

It must be remembered that glass tubes are like all hollow glass ware. The interior is in a state of tensile stress and the exterior notches are not so very potent. On the other hand, if a glass tube can be cut on the inside and warmed on the outside it will be far more easily severed. A glazier's diamond set at the side of the end of a rod, with an adjustable stock like a depth gauge, is the perfect tool for severing tubes from the inside, or a dead hard steel point or edge of corresponding form may be used, but it does not last long. I have made very clean square cuts in glass tubes by turning an iron disc about $\frac{1}{8}$ in. thick, with a V-edge of such a size as just to go in, and screwing it on to the end of an axial rod with stock. Then, notching the tube on the outside and inserting the disc made dull red hot to the identical depth, the state of stress is reversed and the exterior becomes tense. Then the break follows almost immediately and perfectly square. Quite narrow rings may be severed in this way, suitable for making cells.

The state of stress in a glass tube could be reversed by heating the part where the cut is required to a barely visible red heat and then blowing through the tube with bellows to cool it from the inside. An external notch then should be very effective.

Shanks and nibbling glass. Chemists used to be familiar with the use of a key with a suitable ward for crushing the edge piecemeal of a clock glass, so as to make a notch for a glass rod in a beaker covered by the glass. The action of the key is not to get hold as by a pair of pliers and break a bit out. That would instantly start a crack right across the glass. The key merely crushes the edge locally and the process is surprisingly rapid. The softness of the metal is an essential factor. The optician, in bringing rough lenses and other things to the desired shape, uses what is equivalent to a key with a ward of variable width, that is, a pair of soft iron square rods very loosely hinged at one end and with scissor loops at the other. With this tool glass vanishes in grit, and provided there is no attempt to get hold of a piece of the glass and break it out, the process is certain and rapid beyond all expectation. This however is no good for tubes. Shanks is the name of the tool.

Diamond tools. The most generally known diamond tool is the glazier's diamond, which does not need description. The essence of this is the curved natural edge in the extra hard exterior surface of the stone. The diamond is mounted and should be so held that the curved edge is in line with and tangential to the cut. With a light pressure (to be determined by trial) and a rapid stroke the diamond glides over the glass almost silently or with a gentle singing noise. If held more steeply, so that the actual point bears on the glass, both the sound and the appearance of the mark are entirely different. A conspicuous scratch takes the place of a fine line. It is instructive to make a diamond cut in the back of an old photographic negative and examine it immediately in full sunlight, by the aid of a lens. The action of the edge is to tread down a surface line of the glass into the interior, where it is swallowed, and it produces a bursting lateral pressure. This may at once develop a crack part way through the glass, or there may at first be no visible crack. It is then that the full sunlight shining across the line shows up what is happening. A fine line on the surface is visible and its shadow in the photographic film. Gradually the shadow of the line broadens as an actual parting of the glass develops, and the light which did fall where the shadow is now is reflected on to the film on the other side. After a quarter of a minute or so the crack is fully developed. When therefore a bending force is applied to the glass at one end of the crack, in a direction to open it, the still unsevered glass is progressively divided by the extension right through of the initial crack, and the glass has been cut.

Where such thin glass as microscope cover glass is required to be cut a glazier's diamond is no good. For this a sharp splinter of diamond, called when mounted a writing diamond, is perfect. It is not difficult to prepare tools of the writing diamond type, but much finer. Take a piece of bort—a kind of spherical mass of diamond with a radial crystalline structure—and if a diamond crushing mortar is not available place it within a ring on a hardened anvil. Hold a flat-ended hardened steel punch on the piece of bort and strike it with a hammer. The minimum stroke that will break the diamond should be employed, and this can be led up to by degrees. It is surprising what a blow a diamond will stand. As Sir William Crookes so beautifully showed, a diamond crystal may be placed between two jaws of mild steel and these pressed together until they have swallowed the diamond, which may then be taken out unharmed, leaving two perfect half impressions of its form in the steel. When the bort has been broken a multitude of fine diamond splinters will be found, and suitable points can be picked out and slipped into holes drilled in brass wires which should then be pinched to retain the points. The easiest way to secure them is to wet the hole with a drop of chloride of zinc solution, apply a speck of soft solder and heat gradually until the solder flashes into the hole and envelopes the diamond, leaving only a point outside. Such tools properly mounted and moved, and resting on the glass with an almost infinitesimal pressure, may be used for ruling the finest lines. If such a line is examined immediately with a microscope the glass shavings may sometimes be found in the form of perfect helices, like shavings made with a plane held askew.

The soft steel discs of the lapidary for slitting, and metal tubes for cutting out larger holes in sheet glass than can be drilled, are armed with diamond dust by pressing it in to the edge or end with the clean black surface of a flint. While emery or carborundum may be used in this way the materials are so inferior to diamond dust that this is greatly to be preferred.

Holtzapffel, in describing the drilling and slicing of hard materials by the use of tools armed with diamond dust, always refers to the lubricant as the " oil of brick ", which was valuable because it was so extremely limpid.

Oil of brick, so far as I have been able to find out, was olive oil into which a red-hot brick had been immersed. Soap and water is also used and lubricant of some kind is essential.

Diamond tools are used for trueing emery wheels. If the wheel is turned slowly and the diamond is fed very slowly the emery crushes before it, and it is marvellous, after a diamond has travelled in this way some miles over the emery under considerable pressure, to find the stone entirely unmarked by the process. It is equally astonishing to see the diamond end stone of a chronometer balance, on which the fine hardened steel point carrying the weight of the balance wheel has been twisting backwards and upwards a million times every three days for years and years. By the aid of a lens the polish marks on the diamond may be made out, but not a mark to indicate where the pivot has rested.

Ebonite is very destructive to steel tools, so that diamond tools are preferable in making fountain pens, for they then last in adjustment, whereas steel tools have to be ground so often that the cost of constant adjustment is greater than the initial great expense of large diamond tools. Why is ebonite so destructive to steel edge tools that it is best not to use steel taps upon it, and yet taps made from ordinary brass and roughly filed up work perfectly ?

67. On Drilling Small Holes in Glass

By N. G. Heatley, Ph.D.

J. Sci. Instrum. **15**, p. 340 (1938)

One method of drilling holes in glass is to use an ordinary twist, or better still, diamond-headed, steel drill, tempered head hard and lubricated with either turpentine, camphor dissolved in turpentine, or dilute sulphuric acid ; alternatively the article may be drilled under water. (The drill can be hardened best by heating to a cherry red heat and quenching in mercury.) Some authors recommend a high speed, whilst others insist on a very low speed, of the order of 12 r.p.m. In any case a considerable amount of pressure must be applied, which prevents this method from being used with delicate apparatus (such as a thin flask), and extensive splintering can usually only be avoided if the hole is drilled from both sides. Holes can also be made with the fractured end of a hardened file dipped in lubricant and worked backwards and forwards by hand.

Another well-known method is to grind out the hole with a rod or tube (preferably of copper) which is dipped at frequent intervals into a thin paste of carborundum powder in water or glycerol ; when a tube is used it is an advantage to have the end slotted, since the grinding paste will then not need replenishing so often. This method is excellent for large holes but tedious for smaller ones, though if diamond dust can be substituted for carborundum powder the operation may be considerably speeded up, and a semi-permanent grinding surface is said to be formed on the tool.

For holes up to $\frac{1}{8}$ in. in diameter a much quicker and yet inexpensive way is to use a small diamond suitably mounted, for such a diamond " spark " can be bought for a few shillings. This may be mounted in a brass or steel rod by cutting a slot in the end of the latter, placing the diamond in the slot, and brazing it in position ; diamonds can be bought already mounted in this way. An alternative method of mounting is that used by many china riveters ; the temper is drawn from a U-sectioned umbrella rib which is then bent round in the form of a tube, except for about $\frac{1}{8}$ in. at one end. The diamond is laid in this open channel, which is then squeezed together with pliers so as to grip it firmly. A constriction is generally made just below the diamond to prevent it slipping down the tube, and solder may or may not be applied. It is sometimes helpful to file away some of the mount if the diamond is deeply buried, but after two or three holes have been drilled the mount will have become worn away where necessary. The number of holes which can be drilled before the diamond works loose will depend entirely on the shape of the diamond and the way in which it is mounted; a flattish "spark" is most satisfactory, for when properly mounted it can sweep out a hole slightly larger than the mount, thus completely avoiding wear of the latter. Fig. 89 illustrates two profiles of an ideally mounted "spark" (shown stippled) with which many dozens of holes may be drilled. For holding these bits, a bow-drill—requiring one hand only—is generally used by riveters, but a drill which revolves in one direction only is almost as satisfactory. The drilling tip must be kept well lubricated with thin oil or a mixture of oil, turpentine and camphor.

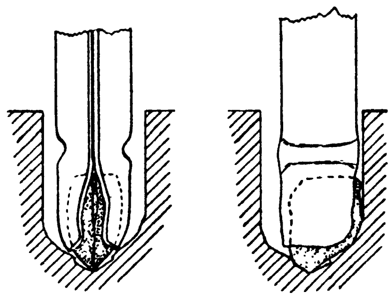


FIG. 89.—Method of mounting diamond for drilling holes in glass.

Where very small holes are required, this type of mounting in a metal tube is not really satisfactory, though the use of hypodermic needles as mounts has been moderately successful. Better results have been obtained by mounting the diamond in an ordinary sewing needle, in the following way. A needle with an elongated eye is chosen and the upper half of the eye is broken off. A flattish fragment of diamond, slightly broader than the diameter of the needle, is pressed between the prongs formed by the remainder of the eye, and the whole is dipped first in flux, and then in molten solder; it must be dipped several times in the latter as it cools, so that the diamond is completely encased. The excess solder is then carefully removed with a file, the final trimming taking place automatically as the first two or three holes are drilled. Since only a slight pressure must be applied to these bits, a bow-drill is not suitable for holding them. Holes less than 1 mm. in diameter and over 15 mm. deep have been drilled in plate glass with this type of bit.

Carborundum dental burrs can be obtained in a great variety of shapes and sizes at very moderate prices, and though these are not so effective as the diamond bits for actually *drilling* holes, they are very useful for shaping or enlarging holes or cavities which have already been made. They should be kept well wetted with water, and driven at a high speed.

68. A Simple Glass-Blowing Machine

By Major C. E. S. PHILLIPS, O.B.E., F.Inst.P., F.R.S.E.

J. Sci. Instrum. **21**, p. 17 (1944)

The object of this contrivance, illustrated in Fig. 90, is to provide a means of doing certain glass-blowing jobs which often arise in a laboratory and normally require skill and experience. Unless the art of working glass is frequently practised, technique rapidly deteriorates, and it is then that this machine is especially useful. It has been made largely from scrap and such odds and ends as could be got together. The general idea is that there must be a means of supporting the horizontal glass tubing at each end and revolving it slowly and evenly while heat from a gas flame is applied locally at one or more points, with provision made for blowing into the tube if required. It must also be possible to shorten or draw out the glass tube when softened by heat and to handle tubing of various diameters and lengths (within practical limits). These conditions are realized in the way described below.

Two 3-in. self-centring chucks are screwed facing each other to the ends of two co-axial horizontal tubular spindles (gas pipe carefully turned to 1 in. external diameter) which are supported in pairs of bearings as shown in the figure. An inch plank, 9 in. wide and 3 ft. long, carefully planed so as to have parallel sides, is screwed to a wooden base. At the left-hand end it carries two fixed substantial wooden columns 6 in. high, on which the bearings are mounted. At the right-hand side are two other wooden columns which stand upon a saddle that can slide upon the plank and be moved by a string fore and aft attached to winders. The distance between the chucks can be varied in this way; the maximum separation is 14 in.

The chucks are driven by cycle chain over 48-toothed bicycle sprocket wheels from a light countershaft which carries two small bicycle sprocket wheels each having 16 teeth. One of these smaller wheels is fixed to the shaft and the other is capable of sliding along it. Since the sliding sprocket wheel must continue to revolve equally with the fixed one while it is being moved forward or backward, it has a longitudinal slot cut in its centre which engages with a $\frac{1}{8}$-in. metal rod sweated along the shaft. Thus for any position (within limits) of the movable wheel upon the shaft the two always rotate together. A metal arm projecting from one side of the saddle engages with a groove in the circumference of the boxwood centre of the movable sprocket wheel, so that if the position of the saddle is changed the sprocket wheel moves correspondingly and the chucks continue to rotate at exactly the same speed.

The countershaft is carried in bearings made from bored brass plates brazed to the top of a pair of shelf brackets. It is belt-driven by a $\frac{1}{4}$-h.p. electric motor, the speed of which is controlled by a variable resistance consisting of two carbon rods from torch batteries lowered into a weak solution of common salt. 40 r.p.m. seems to be the best working speed.

Many simple operations can be done by the machine with great neatness, such as joining two glass tubes, drawing down a large tube and sealing a smaller one to it, etc. If, however, a bulb is required or a small tube has to be sealed into position within a larger one, as for instance in the case of a mercury trap or a filter pump, it is necessary to be able to blow into the glass tube when it is softened locally and steadily revolving.

For this purpose the device described below is fitted to the left-hand spindle. Into the end remote from the chuck a solid wooden cylindrical bush 3 in. long is tightly fitted and bored so as to take a 4 in. length of $\frac{1}{2}$-in. brass tubing. This can therefore be pushed partially into the hollow spindle through the wooden bush and fixed into position by a set-screw. At its inner end a sweated-in nipple enables a narrow rubber tube to be attached, and pass into the spindle so as to project for a couple of inches beyond the open jaws of the chuck. A glass tube pushed into the free end of the rubber tube can be drawn into the chuck by releasing the set screw and pulling the brass tube to the left, thus drawing the rubber tube through the chuck into the spindle and enabling the chuck jaws to be closed down lightly but firmly upon the glass tube itself. Since all rotate together when the machine is started up, it is necessary to find some way of blowing into the brass tube while it revolves. This was done by sweating a small brass plug into the left-hand end of it (which is beyond the spindle) and boring it with a widely tapered hole into which the conical end of a short length of metal tubing was pressed by a horizontal spring held stationary. One can by this means blow down the fixed tube (through a length of rubber tubing for convenience) into the glass tube held in the chuck; the fixed tube is not shown in the figure. The right-hand end of the glass tube being sealed up with a cork or by heating it and the distance between the chucks reduced, it can be gripped in the right-hand chuck, and all is ready for the work to proceed.

If the machine is then switched on and a blow-pipe flame used to soften the central portion of the glass tube, the saddle may be moved forward and the glass allowed to thicken in the well-known way and, when sufficient " metal " has accumulated, a light breath into the tube causes it to enlarge evenly. The saddle may be finally and slowly drawn back as the glass expands and a graceful pear-shaped bulb is obtained.

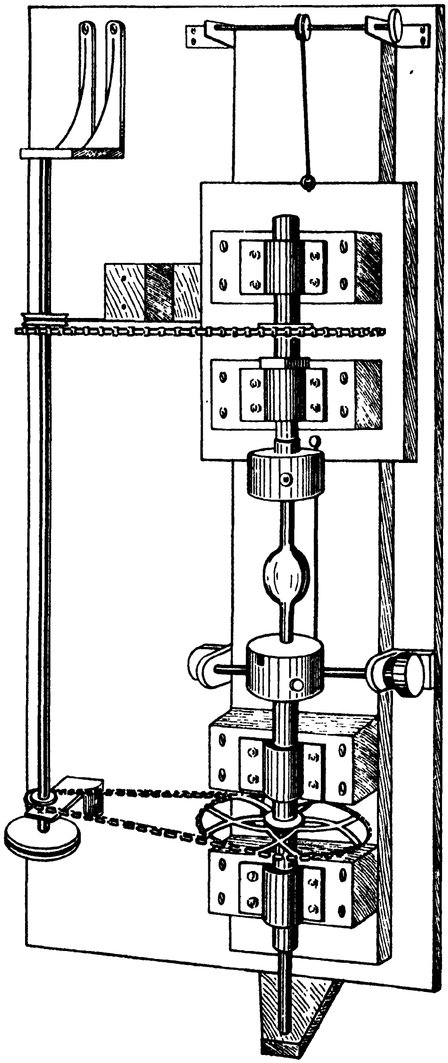


FIG. 90.—A simple glass-blowing machine (view from above).

Numerous modifications of this method will of course suggest themselves, depending upon the requirements, but thistle funnels and much other glass apparatus can thus be made with great neatness and symmetry owing to the uniform heating of the glass and the fact that in spite of the softening at its centre both end portions are firmly supported and remain co-axial.

69. A Chuck for Glass Tubing

By J. M. SOMERVILLE, B.Sc., F.Inst.P.

J. Sci. Instrum. **22**, p. 114 (1945)

It is often necessary to hold glass tubing firmly so that it may be rotated in a glass-blowing lathe or similar device. The conventional three- or four-jaw chuck has the disadvantage of concentrating the stresses in the glass in a restricted region, and the glass is easily broken if a little too much pressure is applied in an effort to get a good grip. Wooden collets are sometimes used, but the tubing is readily broken unless it is accurately circular in cross-section and quite straight in the region gripped by the collet; commercial glass tubing often possesses neither of these properties.

The chuck described below avoids concentrated stress since the grip on the glass is obtained by wrapping steel wires tightly round it, and there is no tendency to break tubing which is bent or not quite circular in section. It can grip tubing whose diameter varies along its length and permits quick centring of slightly bent tubes. It may be made in a small workshop, since only simple turning and drilling processes and the cutting of a ratchet are required.

A ball-race supports a tube *A* (Fig. 91) co-axially with the main barrel *B* of the chuck, and to each end-face of *A* three steel wires are attached by equally spaced collars *C* which can turn on bearings parallel to the axis of *A*. The other ends of the wires at the front of the chuck are attached to adjusting screws *D* radially mounted in the ring *E* which may be rotated relative to *B* but which is prevented from moving laterally by the flange *F*. The wires at the rear of *A* are attached to similar adjusting screws mounted on *B*. The radial positions of the screws are controlled by nuts *G* and lock-nuts *H* and each screw is prevented from rotating by a slot in its side which engages with a pin set in a boss on the inside of the ring *E*. (For the sake of clarity this detail is omitted from Fig. 91.)

The glass tubing is inserted in the chuck as shown in Fig. 91 and the ring *E* is rotated so as to wrap the six steel wires round the glass. Since the ball-race allows the cylinder *A* to rotate freely, both front and back wires will be tightened at the same time. The ring *E* is prevented from turning backwards by the ratchet and spring-loaded pawl *J*, and the tension in the wires can thus be maintained. The glass is gripped very tightly, but with the chucks made and used in Sydney we have never broken a piece of tubing, although in trying to do so a wire has been wrenched from its hard soldered junction with the adjusting screw. If necessary the grip on the glass may be relaxed instantly by pulling out the pawl *J* when the ring *E* springs back and releases the tension in the wires.

The chuck is not accurately self-centring but centring can be obtained quickly by a few adjustments of the screws *D*. Similar adjustments will centre the end of a piece of tubing which is slightly bent. We have found that in practice the setting of the rear adjusting screws

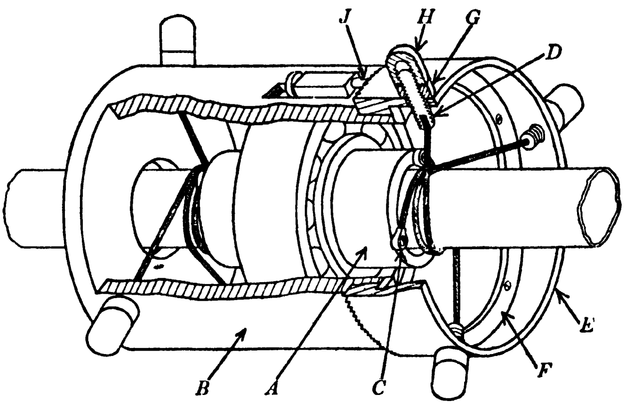


FIG. 91.—Sectional view of chuck for glass tubing.

may be fixed once and for all and all necessary adjustments made with the front screws.

The chuck has handled satisfactorily a range of tubing diameters of between two and three to one. The chuck described takes tubing of diameter from $\frac{3}{8}$ in. to $1\frac{1}{4}$ in. Since the tubing is gripped effectively at only two places it is clear that lack of straightness does not produce any stresses in the glass, nor need the diameters at the two places gripped be the same.

The wires should be as flexible and strong as possible, and probably watch-springs would be as good or better than the stranded steel wires we have used; the greater the flexibility the greater will be the accuracy of centring.

70. Hints on Silvering Glass

By F. E. J. OCKENDEN, M.I.E.E., F.Inst.P.

J. Sci. Instrum. **15**, p. 206 (1938)

The work of silvering small pieces of glass or optical components becomes considerably simplified if it is realized that it has two distinct and separate aspects, first, making up the solutions (which are quite inexpensive, and will keep for many months or even years when once compounded), and, secondly, the actual application of the solutions to the article to be silvered. The apparently complex instructions therefore become less formidable if the two sections are tackled independently, the solutions being made up on one day, put aside for a day or two to settle, and subsequently used as required for silvering purposes.

The formula used by the writer is a well-known one due to Edel, and calls for the following components:

(A) The silvering component: silver nitrate, 1 oz.; distilled water, 8 oz. Dissolve the silver nitrate in the water and add ammonia drop by drop until the brown precipitate first formed is redissolved. Filter (or leave for a day to settle and pour off carefully) and add distilled water to make a total of 16 oz. *Note:* the operation of adding ammonia is usually overdone, and it is useful to hold back a crystal or two of the silver nitrate and effect a final "balance" with these.

(B) The reducing component: potassium sodium tartrate (Rochelle salts), $\frac{1}{40}$ oz.; distilled water, 10 oz.; silver nitrate, $\frac{1}{180}$ oz. Dissolve the Rochelle salts in the distilled water, boil and add the silver nitrate, continue boiling until a heavy grey precipitate is formed. Allow to cool and filter, or leave to settle and decant. Make up the remaining clear solution to a total of 16 oz. The principal difficulty in the above formula is the measurement of $\frac{1}{180}$ oz. of silver nitrate. This may readily be overcome, however, by setting aside $\frac{1}{4}$ oz. of the original silver nitrate solution A (before treatment with ammonia) and making this up to a total of $5\frac{1}{2}$ oz.; 1 oz. of the diluted solution then contains $\frac{1}{176}$ oz. of silver nitrate, which is amply accurate enough.

The two solutions when once made up should be kept in clean glass-stoppered bottles. Solution A is best stored in a bottle which is protected from the light, either by a covering over the glass, or by being placed in a cupboard which is normally dark. The orange bottles in which a well-known firm of chemists supply many of their medicines have been found by the writer to be all that is required even when stored on an open shelf in the daylight. Solution B keeps perfectly in an ordinary bottle; the sides become covered with a light deposit of silver after a while, but this does not appear to affect the efficiency of the solution.

The actual silvering of an article is carried out by immersing it in a mixture of equal quantities of solutions A and B, each diluted with an equal volume of distilled water; it will thus be seen that the ultimate quantity of solution made from 1 oz. of nitrate is 64 oz. The average quantity required for silvering a small article such as a small lens or a few coverglasses is about 2 oz., so that the cost of the process and the trouble involved in making the solutions is relatively small.

The first essential for successful working is perfect cleanliness, both in regard to the article to be silvered, the vessel used to contain the solution, and the measures used for mixing it. A small glass or porcelain dish having parallel sides is the best vehicle for carrying out the silvering operation. This need not be much larger than is required to contain the article, and should not have too large a proportion of surface to volume, since the whole of the surfaces immersed in the solution, whether horizontal or vertical, will receive the silver in equal amount, the deposition occurring at any liquid/solid surface junction irrespective of the action of gravity. The vessel should be well cleaned in the ordinary way, then rinsed out with several washings of tap water followed by a final rinse in distilled water. It should then be put aside containing a quantity of distilled water sufficient to cover the article ultimately to be placed in it.

The latter must in its turn be thoroughly cleansed in a similar manner, that is to say, by the ordinary mechanical and "soap and water" methods. A further treatment, however, is now required to destroy entirely all grease upon the surface, and the only sound way of ensuring this is by treatment with undiluted nitric acid. Where a supply of this is plentiful the article should be immersed in it for a few minutes, but when only one face has to be silvered it is sufficient if this surface be held horizontally and a small quantity of the acid caused to flow over it. It will be found that the surface becomes "wetted" as the acid advances over it, and that this wetness is not lost after the acid has been rinsed off. In either case the surface must be well washed with tap-water and then with distilled water, finally being placed in the vessel already filled with distilled water. On no account whatever must the surface be touched or allowed to become dry after the preparatory process is completed.

A warning may be noted at this point. It is inadvisable to use caustic soda or any other strong alkali in an effort to clean away the grease, such materials having a slight etching action on glass surfaces, and their use may result in a degree of fogging too slight to be noticeable on the glass itself, but painfully apparent as soon as the silver has been deposited.

A serious obstacle to successful silvering is oxidation of the deposit by the oxygen which is all too readily dissolved in water solutions. To avoid this the following procedure should be adopted. By means of a small glass measure (a miniature test-tube serves excellently) a suitable quantity, say ½ oz. of solution A, is taken, mixed with a similar quantity of distilled water and transferred, preferably filtered, into a larger test-tube. Solution B should be measured off, diluted and transferred in a similar way to another tube. The contents of each tube should now be gently boiled for a few minutes and then cooled, without shaking, in a vessel of cold water. On no account should the same tubes be used for A and B or any mixing occur until the moment when the immersion of the article in the combined solutions takes place. The two cooled tubes, one of each solution, being at hand, the distilled water covering the article is poured off; where the quantity is small and there is danger of the object being tipped out this process can be carried out conveniently by means of a small glass syringe, fountain-pen filler or the like. The moment the removal of the bulk of the distilled water is completed the contents of the two tubes should be mixed, shaken gently, avoiding as far as possible the absorption of air, and poured over the object until it is well covered. The whole should then be put aside, covered by a clean lid or sheet of filter paper, for about 3–4 hours (little is gained by exceeding this time, although it may be left for as long as a week-end without in any way affecting the perfection of the silver covering formed), after which the fluid may be poured off the silvered surface, rinsed off in tap water and allowed to dry. The deposited film gains somewhat in mechanical toughness by being left for 24 hours after drying, and where any work has to be carried out which may damage the film this point is worth bearing in mind.

71. The Silvering of Small Mirrors

By E. A. Baker, D.Sc.

J. Sci. Instrum. 8, p. 392 (1931)

The apparatus shown in Fig. 92 has been found of use in the silvering by the chemical method of mirrors only a few millimetres in diameter. A glass tube *A*, slightly larger inside than the mirror, is drawn out as shown with a constriction at *B*. The mirror is inserted into this tube and retained by a second tube *C* sliding easily into *A* and kept in place by a rubber tube *D*. The lower end of the tube *C* may be partly closed in the flame if the mirror is very small.

Cleaning and silvering solutions are drawn into the apparatus as into a pipette, and if the Brashear process is used, sediment is easily kept down by repeatedly flushing out the tubes with the silvering solution. After rinsing out with water and alcohol the apparatus is dried out by a stream of air before removing the mirror.

In the normal way the mirror is used by reflection through the glass, hence the silver has to be removed from one face. If the film is tenacious it may safely be removed by electrolysis. The mirror is lightly held at its edges by a pair of tweezers connected to the positive pole of an accumulator, and the silver removed by applying to it a small roll of filter paper soaked in silver nitrate solution and held in a wire connected to the negative pole.

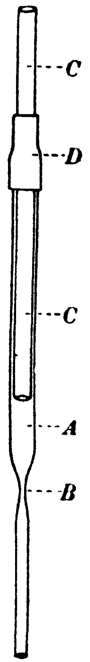


FIG. 92.—Apparatus for silvering small mirrors.

72. A Glass Cell for Colour Filters

By B. H. CRAWFORD, B.Sc., A.Inst.P.

J. Sci. Instrum. 7, p. 328 (1930)

This cell was designed for work in which a high degree of accuracy was not essential, but in which a number of cells were required of various sizes ; hence it was desirable that it should be cheap and easily made. An example is shown in Fig. 93 with two compartments, one wider than the other. The faces of the cell, *A*, may, for most purposes, be made of thin plate glass. The spacing pieces, *B*, are made from glass strips cut a trifle wider than the final required cell thickness, bent to shape in a blowpipe flame, and then ground down to the required thickness. The cell is cemented together with shellac. The edges of the parts *B* are smeared with shellac varnish and fragments of solid shellac stuck on all round. The cell is then assembled, lying on its side, on the shelf of an oven, blocks of wood being placed round the cell to prevent the parts sliding out of position. When the shellac is thoroughly melted all over, the cell is removed from the oven, the parts are pressed together and their positions finally adjusted, and the cell is allowed to cool.

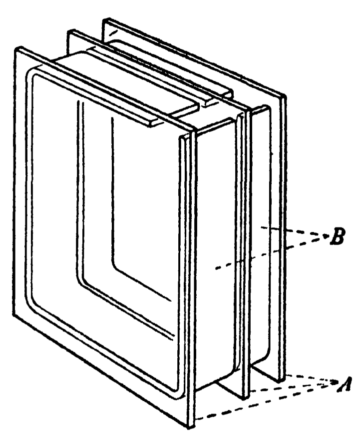


FIG. 93.—Glass cell.

No special precautions in cooling are necessary, and the cell can be warmed up again to readjust its parts or to replace broken ones.

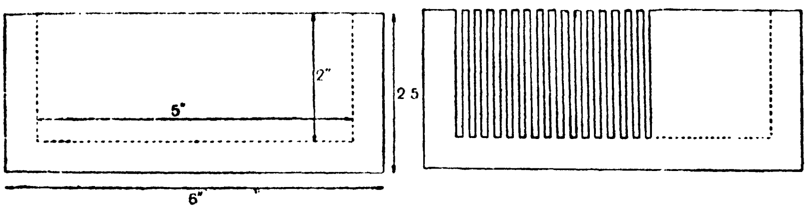
It may be added that this cell will stand temperatures up to 80°–90° C., the cell holding together even when the shellac has become slightly soft.

73. Plate Glass Cells

By W. Pinfold

J. Sci. Instrum. **9**, p. 331 (1932)

A strong and useful type of glass cell for liquid colour filters or for examining specimens can be made quite easily and cheaply in the manner described below, provided that no great degree of accuracy is demanded. The body of the cell is made of best plate glass, which can be bought in suitable thicknesses and of excellent quality as regards both flatness and parallelism. To cut the glass a power-driven saw is simplest, but failing this the job can be tackled quite easily, though not as quickly, with a woodworker's bow-saw upon which is stretched a length of wire, or even an old hack-saw blade (using the smooth edge), and some 120 grade carborundum powder as an abrasive. The cells may be of any size. The detailed account which follows describes



(a) (b)

Fig. 94.—Preparation of plate glass cell.

the procedure followed in making a cell internally 5 in. long, 2 in. deep, and 1½ in. wide, with sides ⅛ in. in thickness.

A piece of plate glass 1¾ in. thick was obtained and ground rectangular with external dimensions 6 in. by 2½ in. The internal dimensions required were marked off on the polished faces as shown by the broken lines of Fig. 94 (*a*). Next a vertical cut was made down one of the side broken lines as far as the horizontal line representing the bottom of the cell, and was followed by similar parallel cuts, leaving about $\frac{1}{16}$ in. thickness of glass between successive cuts, until the opposite side line was reached. When these cuts are made the block of glass presents the appearance shown in Fig. 94 (*b*).

The next step is to break out the tooth-like pieces left by the sawing with a light mallet or by finger pressure, leaving a solid piece of glass to serve as the ends and base of the cell. To make a neat job finish off by locally grinding the serrated base with a piece of flat metal or an old flat file and some carborundum and water.

All that remains now is to cut two pieces of $\frac{1}{8}$ in. plate glass 6 in. long by $2\frac{1}{2}$ in. wide to form the sides, and finally stick the whole together, using an adhesive that will not dissolve in the proposed liquid contents of the cell.

74. A Capillary Mercurial Barometer

By Sir Charles Boys, F.Inst.P., F.R.S.

J. Sci. Instrum. **19**, p. 168 (1942)

In the early eighties of the last century I made for myself a capillary mercurial barometer which on account of its simplicity, the ease with which it may be constructed and the small amount of material consumed might seem to be a very second-rate affair, but which is in fact a far better instrument than many a barometer of conventional make, and it is unique in that I believe it might, if suitably packed, be sent by parcel post and be found to read correctly again when hung on a wall, and this without any manipulation of the instrument.

The materials required are: about a foot of rather thick-walled

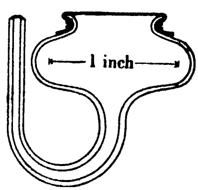


Fig. 95.—Section of bulb of barometer.

quill-glass tubing, about $\frac{1}{4}$ lb. of really pure mercury, vacuum distilled by preference, a strip of wood to carry the barometer tube, and about 3 in. of scale divided in inches or millimetres. The time required is about half an hour from start to finish if the materials are ready.

The glass tube should be washed really clean and dried. Then a bulb should be blown near one end a little more than an inch in diameter and very oblate, as shown in Fig. 95. Then close to the bulb about 1 in. of the tube should be heated until quite soft and this should be drawn out into a tube 40 or 50 in. long and 1 mm. in bore or even less. Then break off the portion of tube beyond the capillary part leaving the tube open at the end. Now make a sharp cut in the glass tube on the other side of the bulb and very near to it and apply a hot spot of melted glass at the end of the cut to cause the tube to break off here. Heat the lip of the bulb with a small blowpipe flame until soft, and partly with the tang of a file and partly by spinning the bulb by turning the capillary tube between the finger and thumb to produce centrifugal force cause the opening to assume the form of a thistle funnel with a small but pronounced neck. Next, and this should be done without any delay, the tapering tube close below the bulb should be heated in a bat's-wing gas flame and be bent into the form shown in the figure, and as soon as the hot glass has cooled to a temperature not less than that of the mercury already heated to make sure that it is dry, support the bulb and tube in an upright position, preferably upon the strip of wood already prepared to receive it, and pour in the hot mercury. Tie two or three thicknesses of fine linen over the thistle funnel so as to prevent mercury from running out or dirt from entering while leaving the mercury open to atmospheric pressure. Now slowly tilt the mounting until it is nearly horizontal, watching the mercury gradually filling the tube but not enclosing any bubbles. When the mercury has reached the end of the tube a small blowpipe flame is directed on to the capillary a few inches from the end when the mercury will part and the glass seal itself at the place and the loose end can be drawn off. Now gradually raise the upper end until the tube is vertical when the mercury will fall to very nearly its proper level. Above the mercury there is a very good vacuum. Any air that had begun to be adsorbed on the glass capillary will expand into the vacuum so that if the tube is once more brought horizontal this will be swept up to the end of the capillary where a second sealing through the mercury will leave it trapped. By using glass immediately after it has been drawn the mercury comes into far more intimate contact than it ever would do with glass which had had time to collect on its surface gases and vapours. This is made evident by the brilliance of the reflexion of light from its surface and the freedom of movement of the mercury. The barometer is finally placed upright and the capillary neatly sealed again about 33 in. above the bulb and the superfluous tube removed. So far as I can remember I found the contact between the mercury and the glass so intimate that the whole column of mercury would remain suspended with the upper few inches in a state of tension. The scale of inches or millimetres is then to be slipped behind the capillary and so placed that the mercury reading upon it agrees with that of a standard barometer in really good order. Thus the capillary depression is counteracted and the instrument is complete. If the cross-section of the capillary is not more than about 1/1000 of that of the bulb, the scale will not need adjustment.

75. Flasks made from Burnt-Out Electric Lamp Bulbs

By G. T. P. Tarrant, Ph.D., F.Inst.P.

J. Sci. Instrum. **12**, p. 92 (1935)

An experiment recently carried out involved the destruction of a small glass flask, and the sight of a burnt-out 100-W. electric lamp bulb suggested that such bulbs could be employed usefully. The following method of opening the bulbs proved very serviceable.

Take a few feet of bare copper or soft iron wire (No. 18 gauge is very suitable); twist roughly from this a wire ring of from 2 to 2¼ in. diameter, and attach symmetrically to this three pieces of the same wire. The bulb is placed in this ring and the three pieces of wire are brought round the bulb and are twisted together on the axis of the lamp on the side removed from the bayonet cap This acts as a holder for the bulb of the lamp and permits its being turned round in the blowpipe flame without burning the hands. An extra wire is then twisted firmly round the bayonet cap and its end is bent into the prolongation of the axis, so that the lamp can be easily rotated.

It is necessary first to blow a hole in the lamp. To do this a bushy flame is applied for a few seconds to the glass near the bayonet cap, the lamp being rotated continuously, and the flame is then narrowed considerably on to the junction of the glass and cap. Directly the sodium colour appears in the flame, the rotation is stopped and the flame concentrated at one point. The bulb then blows open, the pressure inside being sometimes more and sometimes less than that of the atmosphere, depending on the temperature and the type of the lamp involved.

The bayonet cap is next separated by rotating the bulb with a medium flame on the glass near the cap, removing from the flame and pulling rapidly. A tap with a file breaks off any isolated corners and a few more seconds' rotation in the flame softens the glass edge so that it can be shaped with any convenient metal tool. Though somewhat rough, the flask thus produced is quite strong and will stand heat well.

SECTION 5. VACUUM AND PRESSURE TECHNIQUE AND DEVICES

76. Notes on the Design of Vacuum Joints in Metal Apparatus

By R. M. ARCHER, B.Sc.

J. Sci. Instrum. **13**, p. 161 (1936)

Soldered joints in evacuated apparatus should be strong, easy to make and open, and cheap. Those described here were designed by the author in an investigation on metallic Dewar vessels, but they are of general application also. All are such that the soldering of one part is not apt to cause unsoldering of another—a common defect—and all have proved satisfactory under hard working conditions. The sketches illustrate the principles only and are not to scale.

Solders and fluxes. As a rule, equal weights of tin and lead make a satisfactory solder, but in most cases tin may be added up to 64 per cent. Zinc chloride is a good flux for brass and copper, but for nickel silver or iron, ammonium chloride, or a mixture of this with zinc chloride, is recommended. Crow* showed that these fluxes can remove films of both the red and the black oxide from copper, while tallow or vaseline cannot. Resin has some action on the red oxide but not on the black, but it and other organic fluxes make the parts foul if overheated, are not easy to remove, and are not usually wanted in evacuated apparatus.

In Dewar vessels the minutest leak is disastrous; and with these and in other cases also, to ensure success, a preliminary tinning of the parts is essential. There must be perfect wetting by the solder, but prolonged overheating may cause it to penetrate the solid metal parts too far and weaken them considerably.†

The finished solder must be clean and bright, and defects such as pits, re-entrant angles, or rough places should never be removed by cutting or scraping. The only safe way is to reheat locally by a small flame applied very briefly.

If the instructions are followed and the finished joint is washed in hot water, subsequent corrosion will be negligible; but failure to adopt

* Crow, *Trans. Faraday Soc.* **20**, p. 199 (1924).

† Dickonson, *J. Inst. Metals* **24**, p. 315 (1920); Duncan, *Metal Industry* **24**, p. 53 (1924); Miller, *J. Inst. Metals* **37**, p. 183 (1927); and Hartley, *J. Inst. Metals* **37**, p. 193 (1927).

the technique recommended may sacrifice some of the advantages of the designs.

Joints for tubes. The "push-in" joints so commonly used let flux and molten solder run through them if the fit is loose, and corrosion or stoppages may follow. If it is close, patches may remain unsoldered, or a strong force may be needed when opening the joint. These defects are absent in the annular joint (Fig. 96) where the brass cup *C* fits the lower tube tightly or is silver-soldered to it. Sometimes the rim of the cup is omitted, the solder adhering to the wide flat plate. As

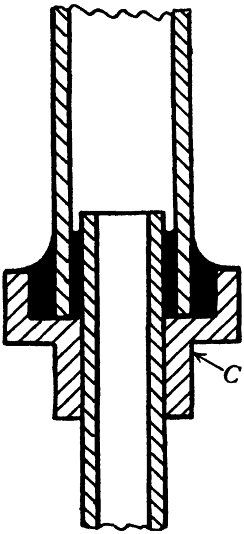


FIG. 96.—An annular joint, between metal tubes, which does not allow solder or flux to pass through it, and can be made and opened easily.

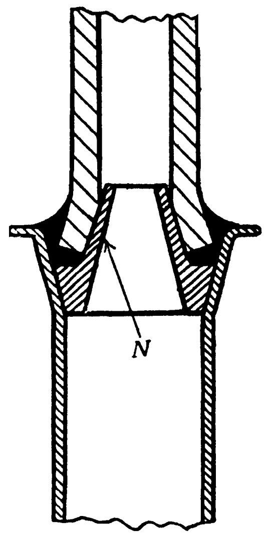


FIG. 97.—An easily made and opened annular joint between a thick lead tube and a brass or copper one. The lead tube is not likely to become choked by solder, and the brass nipple may be removed easily when necessary.

hard-soldered joints may have cracks or pinholes even when made skilfully, flushing them with soft solder may be necessary. According to Crow* the strength of a joint increases, up to a certain point, as the thickness of the solder is diminished. Hence strong joints may be made by coating flat or coned surfaces with solder and pressing them together before it sets. Bare patches are avoided and excess flux squeezed out. Cones give good alignment, but if the taper is too slight they may jam and opening will be difficult.

Fig. 97 shows a thick-walled lead "sealing-off" tube joined to a

* Crow, *J. Soc. Chem. Ind.* **43**, p. 65T (1924).

wide copper tube. The lead tube is widened by a conical mandrel turned to and fro, to avoid twisting the soft metal, and the lead cone, which must be scraped clean and bright, is wetted by flux and "tinned" by brief immersion in molten solder or tin. Then it is washed and pressed on to a brass nipple *N* soldered previously into the coned copper tube. Solder is melted into the cup by a small blowpipe flame applied outside it, and a film is spread upwards round the cone by a wire moistened with flux. A bright capillary film should be formed, but the lead must not be overheated.

In the strong glass-to-metal joint (Fig. 98), a thin inner copper tube is driven into a truncated brass cone which is then soldered into a coned outer copper tube and gives two annular channels, a long one at one end and a shallow one at the other, the shallow one being used for attaching the main metal tube. The clean glass tube should have rounded edges, be well annealed, and be dry and warm when it is dipped into the deep channel which has been filled with an easily fusible alloy. When the alloy has set its outer surface is cut clean and some "vacuum" wax melted on to it. Little vapour from it can leak inwards between the alloy and the glass. If the alloy is put between the glass and the inner tube only it will crack the glass after a short time. A suitable alloy consists of 8 parts by weight of bismuth, 4 of lead, 2 of tin, 2 of cadmium, and 3 of mercury. It is doubtful whether the mercury is necessary, and probably other alloys could be used. Unlike ground cones this joint produces no side pull on the tubes if they are not quite in line.

A flat ground flange *T* on a glass tube (Fig. 99) can be joined to a ground metal plate by a little Prout's glue *G* put into an annular groove in the metal plate *M*. A sleeve *S* may be inserted to maintain centring, if the metal side tube has to be turned in azimuth. Little vapour can leak inwards from the glue, but if wished a "vacuum" wax may be substituted. For safety the device should be held in a clamp which gives an axial pressure. This joint is strong and may be closed or opened easily and quickly.

When the tops of two thin concentric tubes have to be united an easily opened joint may be made by soldering the tapered bottom of a cylindrical brass plug into a female cone formed at the top of the outer tube. A hole wider than the inner tube goes through the plug and is enlarged near the bottom where a few coarse threads are cut. A thin brass sleeve with a thread cut on a wider part at the bottom is soldered or brazed to the inner tube, the top of which projects an inch or more through the sleeve. When the sleeve is screwed into the plug its top edge, which is bevelled, presses on a narrow seating in the plug and so closes the bottom of an annular channel between the inner tube and the hole in the plug. If, before the parts are screwed together, the tops of the inner tube and of the hole are moistened with flux, neither solder melted into the channel nor flux added afterwards can reach the threads and make them bind. The solder should be stirred to disperse any " pockets " of flux. If the outer wall of the channel has been made thin by reducing the diameter of the plug near the top, the solder may be melted by a flame and poured out without much heat reaching the massive tapered part. The inner tube and

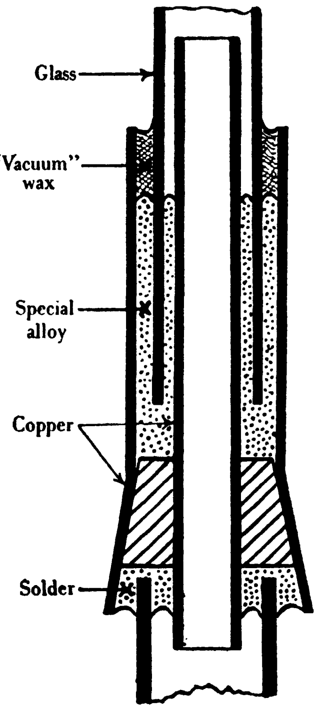


FIG. 98.—A strong joint between glass and metal tubing which puts no lateral strain on the glass and is easily dismantled for cleaning.

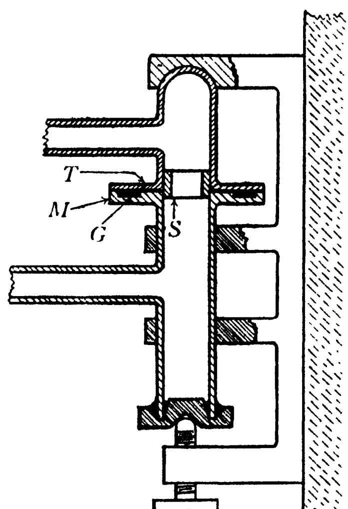


FIG. 99.—A glass-to-metal joint which may be opened and cleaned easily and is often convenient in evacuation plants.

sleeve may then be unscrewed without unsoldering or loosening the plug in its coned seat.

Joints for hemispherical or similar spinnings. An annular channel to contain the solder can be made by spinning the rim of the lower hemisphere a little outwards to form a lip. But the joint so made often leaks at points just inside the rim where it is not easy to rub it with the soldering bit. Even if it is well tinned the solder may part from it after some use, probably due to contractile stresses—a reason for avoiding wide channels. An improvement can be effected by carrying the solder over the rim of the lower hemisphere on to its external surface, where conditions are good for cleaning, tinning and rubbing.

A second method of obtaining a channel for the solder is to spin the rim outwards as before, and then insert a slightly tapered metal ring tightly into the nearly cylindrical part below the rim. Or a ring with an outwardly spun lip may be fitted on to the outer surface.

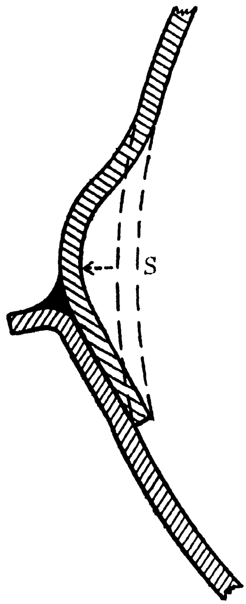


FIG. 100.—A strong equatorial joint between copper hemispheres which is solder-tight and is easy to open. It has proved very satisfactory in Dewar vessels.

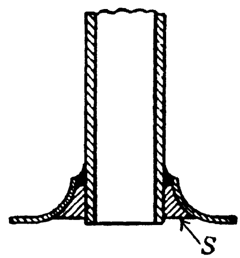


FIG. 101.—A joint between a thin tube and a spinning with a shallow nipple. It is well adapted for Dewar vessels.

Such channels are effective if well made, but it is not easy to make the channel solder-tight.

All difficulties were overcome by the development of the joint shown in Fig. 100, which has been found to stand up to the strains of the metal Dewar vessels during evacuation and cooling. As it is easier to spin metal outwards than inwards, both cones are designed to be formed by outwards spinning, the male cone outwards at a point S near the rim, and the female at the rim. The female cone has a horizontal lip which gives good conditions for soldering and if tapped by a soft mallet, facilitates opening. The unsoldered joint should be sufficiently airtight for the cones to separate suddenly when the internal air pressure is raised gradually, but a little work with a hammer or burnisher may be necessary to make so good a fit. If a mere film of flux is rubbed on the freshly tinned cones with a pad before they are put together, a little solder melted inside the lip will seal the joint as the blowpipe flame is passed round the outside. Additional flux used when more solder is added will then not leak through the joint.

A brass socket *S* (Fig. 101) soldered very tightly to a narrow tube may be used for joining it to a hemisphere and will greatly strengthen the part round the nipple.

General notes. (*a*) When the halves of a spherical vacuum vessel are to be united or separated without becoming tarnished, a wide flat flange of thin nickel-silver or other badly conducting alloy may be soldered to the rim of each hemisphere before it is polished. When the polished halves are put together the flanges are in contact and a little solder of low melting-point may be applied at the edges without the inward passage of much heat. Similarly, if a thin straight tube of nickel-silver is attached to a vacuum vessel, a plate soldered to the outer end of the tube may be removed without appreciable transfer of heat. A screw inside the vessel may then be turned by a screw-driver passed through the tube, or an object may be inserted or removed.

(*b*) Metals not wetted by soft solder may be used as barriers or mechanical supports and removed when the solder has set. Thus, an aluminium rod inside a tube will prevent entry of solder and may be removed after solidification. Similarly, parts to be united may be clamped together by a duralumin bolt which, although reached by the solder, will not be held by it and may be removed afterwards.

(*c*) In an evacuation plant* with metal tubes and glass taps, the use of many annular joints and of spare vertical pipes closed by cups of solder made it easy to clean, repair, or extend the plant. " Flexibility " was ensured.

[*Note.*—For a general survey, including theory, and an excellent bibliography, *see* Scott, W. J., *J. Sci. Instrum.* **23**, p. 193 (1946).]

77. A High-Vacuum Connexion

By M. J. Moore

J. Sci. Instrum. **21**, p. 124 (1944)

The usual method of fixing removable glass tubes of small diameter (up to ½ in.) to a vacuum system is to place the part to be fitted a

* *Report of Oxygen Research Committee* (London: H.M. Stationery Office, 1923).

short distance inside a tube projecting from the main pump system, and to make the joint with a low vapour pressure wax. Unless the parts so connected are a good fit, leaks are often caused by vibration cracking the wax, or in the case of glow discharge tubes the wax has often been known to melt because of the heating effect of the discharge current. The method here described has been used for attaching discharge tubes, glass stop-cocks, Pirani and ionization gauges to vacuum systems. Joints so made have remained tight for more than four years.

The sectional drawing (Fig. 102) shows the arrangement used for small-diameter glass or metal tubes. It consists of a standard type of brass cone-seated tank connexion, *A*, which has one end silver-soldered to a tube connected to the vacuum system. The demounted joint is made by means of a small ring of good-quality soft rubber

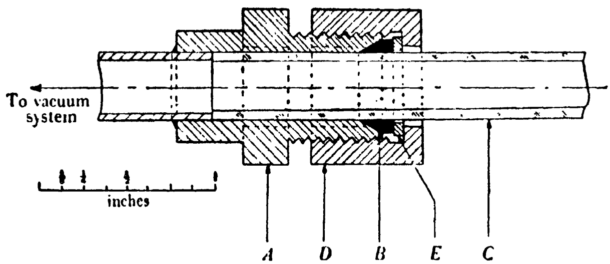


FIG. 102.—A high-vacuum connexion.

tubing *B* (a short piece of soft rubber gas tubing is satisfactory), smeared with Apiezon M grease, which is a fairly tight fit on the glass or metal tube *C*. The ring *B* is compressed by the union nut *D* on to the cone seating of *A* and against the wall of tube *C*. The tube *C* need not be a good fit in *A*. The washer *E* prevents the rubber ring being dragged when the union nut is tightened and in addition prevents the rubber from creeping along the wall of the tube.

In addition to the above applications it has been used successfully to connect together metal, and glass to metal tubes up to 1½ in. diameter. By using a double-ended tank connexion, glass to glass joints may also be made. In special cases where it is undesirable to use the rubber ring *B* when joining metal tubes together, a lead ring may be substituted with satisfactory results. The connexion has also been used as a vacuum-tight gland for transmitting longitudinal and rotational motion.

78. A Receiver Changer for Small-Scale Vacuum Distillations

By W. V. Thorpe, Ph.D., and R. T. Williams, D.Sc.

J. Sci. Instrum. **14**, p. 178 (1937)

We have frequently felt the need for a reliable means of changing receivers during a small-scale fractional distillation *in vacuo* in which fractions of about 1 ml. were collected. For this purpose the "triangle" devices such as Fischer's or Geissler's and their modifications are unsatisfactory owing to the relatively large surface of glass which is wetted by the distillate before it gets to the final receiver. More satisfactory are devices such as that of Bruhl* in which new receivers are placed under the end of the condenser by turning a stopper or tube. Unfortunately, these are liable to fail at a critical moment owing to the stopper or bung binding and preventing a change of receiver. This is especially probable at low pressures. We have, therefore, modified Bruhl's apparatus to eliminate this defect.

The receivers, mounted in a revolving carrier, are rotated as required by a magnetically actuated claw, engaging with a ratchet wheel attached to the hollow spindle of the carrier, the whole being placed in a Bruhl jar of 5 in. internal diameter. The details are shown diagrammatically in Figs. 103 and 104.

The carrier holds twelve glass tubes *A*, *A* each 2 in. long and $\frac{5}{8}$ in. diameter and consists of two aluminium discs $3\frac{1}{2}$ in. in diameter, separated by four brass posts $1\frac{1}{4}$ in. long. The top disc *B* has twelve holes a shade larger than $\frac{5}{8}$ in. diameter round the edge and a large central hole; the bottom disc *C* has twelve corresponding holes $\frac{3}{8}$ in. diameter and a central hole $\frac{3}{8}$ in. in diameter. This bottom disc is held by screws to a flange *D* fixed to the hollow spindle *E* and can be easily removed and replaced by another carrier with a different number of smaller or larger tubes.

This hollow spindle rotates on a cone bearing on the solid post *F* rising from the base plate, and is lubricated by a drop of Hyvac pump oil. It carries in addition to the flange *D* a ratchet wheel *G* with 48 teeth, and is rotated by the movement of the claw *H* when the pole-piece *K* is attracted to the electromagnets *M* when current is passed. On cutting off the current the pole-piece springs back to its original position, the claw slipping over the teeth of the ratchet wheel, a backward motion of the wheel being prevented by the claw and spring *R* held in a post mounted on the opposite side of the base

* Bruhl, *Ber. dtsch. chem. Ges.* **21**, p. 3339 (1888).

plate. The claw H is connected with the pole-piece of the magnets by a light spring *N*. The movement of the claw is controlled by the adjusting screw *P*; overrunning of the carrier is prevented by the tension of the spring attached to claw *R*. The magnets were adapted

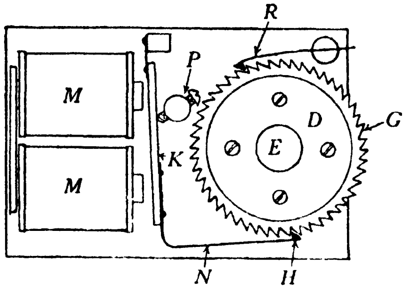


FIG. 103.—Plan of receiver changer mechanism.

from an ordinary electric bell and are connected with a 3-V. battery and a bell-push outside the Bruhl jar.

For use with twelve receivers the pole-piece is adjusted by the screw *P* so that it moves two teeth of the ratchet wheel at a time;

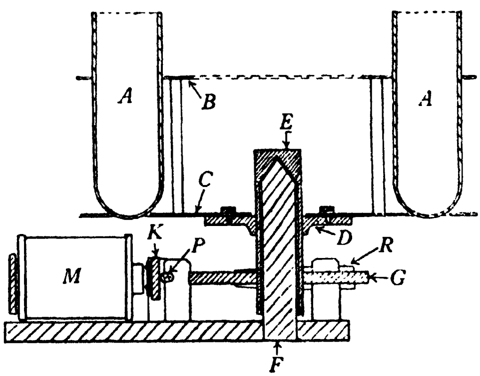


FIG. 104.—Receiver changer mechanism showing carrier.

a new receiver, therefore, comes into place by pressing the bell-push twice. The pole-piece can also be adjusted to move three teeth at a time so that a carrier with eight or sixteen tubes can be used. The response to the bell-push is rapid and there is no risk of a drop of distillate falling between the tubes at ordinary rates of distillation.

The apparatus has been used successfully at a pressure of 0·1 mm.

79. A Double Liquid Air Trap

By R. W. Conway

J. Sci. Instrum. **12**, p. 234 (1935)

As part of the exhaust technique for lamps and valves it is frequently necessary after a high vacuum has been obtained to admit a quantity of gas, such as argon or neon from a reservoir attached to the main exhaust tube. This is usually done by closing the main tap above the mercury vapour pump and opening the reservoir cocks for a time, sufficient to admit the required gas pressure. In many cases it is necessary to prevent mercury vapour from the pump or grease from the stopcocks from being carried over into the lamp, and this is usually effected by placing a liquid air trap between it and the rest of the apparatus. Now if the gas from the reservoir is admitted to the apparatus on the side of the liquid air trap remote from the lamp, there is a danger unless it is admitted very slowly that it will carry vapour with it, and that this vapour will not all be frozen out. This being so, it is advisable to admit the gas on the lamp side of the liquid air trap and to interpose a second trap to prevent the tap grease vapour from the reservoir cocks being carried over into the lamp. The double trap shown in Fig. 105 avoids the use of two separate traps and economizes in space and liquid air.

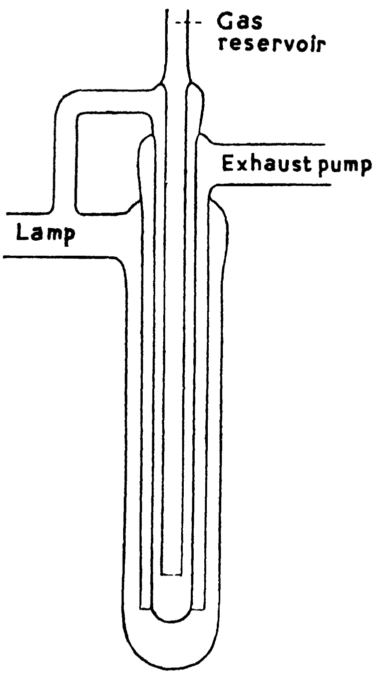


Fig. 105.—Double liquid air trap.

80. A Modified Mercury Trap

By J. E. CRACKSTON, M.Sc.

J. Sci. Instrum. **13**, p. 371 (1936)

The probability is not entirely negligible that a condensable atom will rebound from a cold surface on which it impinges. It is worth while, therefore, where a trap is necessary, to design it so that an atom in passing through it is forced on to the cold surface several times. The probability that a condensable atom like mercury will survive in a free state will then become negligibly small.

The writer has had in use for some years a mercury trap designed with this end in view. Fig. 106 shows that it is a modification of the usual straight tube type of trap. This modification consists of attaching "umbrellas" at intervals to the inner tube whilst the outer one is drawn down between the umbrellas into waists whose diameter is less than that of the peripheries of the umbrellas. There is a waist above and below each umbrella. When exhausted, an atom entering down the inner tube may ricochet from side to side up the annular space but cannot pass in a straight line from the bottom to the outlet at the top of the outer tube. Furthermore, if an atom happens to get inside an umbrella, its velocity on emergence must have a downward component.

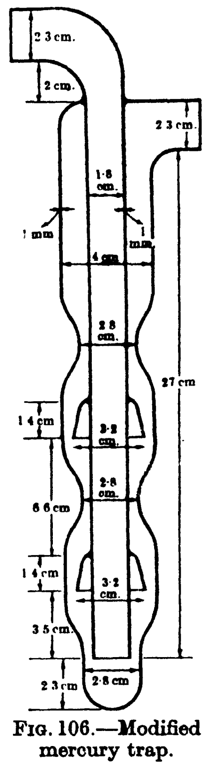


FIG. 106.—Modified mercury trap.

The length of the trap is of necessity rather greater than that usually employed, but this is offset by the fact that tubes can be used as wide as is convenient for the glass-blower to handle and for immersion in a liquid air or solid carbon dioxide container. Also, whilst there are two umbrellas in the diagram, it is clear that even one would give an enormously increased measure of protection. The dimensions in the diagram are approximately those of the writer's trap.

81. A Combined Vapour Trap and Cut-Out

By E. L. MAYS

J. Sci. Instrum. **9**, p. 168 (1932)

Fig. 107 illustrates a form of combined vapour trap and mercury cut-out.

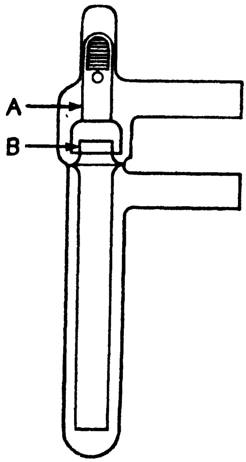


FIG. 107.—Combined vapour trap and cut-out.

The apparatus was designed as a simple and strong unit for use with high vacua, where constriction of the system was not permissible, and economy of volume desirable.

Very rapid operation of the bell-shaped cut-out standing in a few millimetres of mercury was obtained by an electromagnet lifting the soft iron core of the sliding member *A*. Alternative means of raising the bell may of course be used. The lower part of the apparatus acting as the cooling tube was immersed as usual in a Dewar flask with liquid air or other cooling medium.

Pressures of several centimetres of mercury may be controlled by lengthening the inner tube *B*. The apparatus is of glass and may conveniently be fused to a vacuum system, particularly in view of its compact and simple nature.

82. A Seal for Electrodes

By S. MUNDAY

J. Sci. Instrum. **6**, p. 360 (1929)

A very efficient type of seal for electrodes, especially when in the form of thin wires, may be made in the following manner.

A small egg-shaped bead is turned and a hole of suitable size for the wire is drilled along the major axis. The bead is then soldered on the wire. A thin rubber tube is slipped over both bead and wire as shown in Fig. 108 (*a*); bicycle-valve tubing is very suitable.

The hole in the wall of the vessel into which the electrode has to fit should be tapered and of such size that the bead, when the rubber tubing is stretched over it, will stop about midway along the hole (Fig. 108 (*b*)).

To assemble the seal the rubber should be stretched fairly tightly over the bead and wire, the whole pulled into the tapered hole and then, when the bead is wedged, the rubber tube at the big end of the hole should be allowed to spring back.

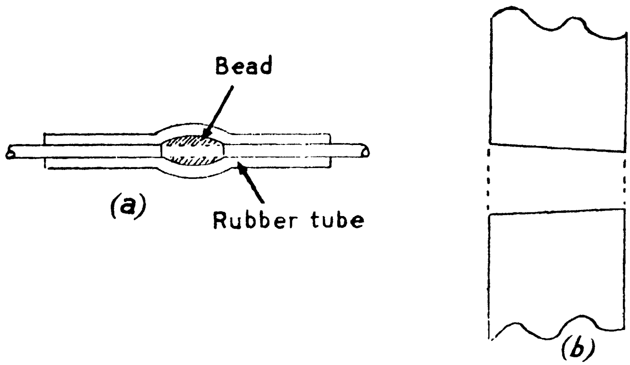


FIG. 108.—Seal for electrodes.

The big end of the hole should, of course, be on the "pressure" side of the apparatus.

The writer has made many of these seals, some of them holding up to pressures of 1100 lb./sq. in. with satisfactory results.

83. A Flexible Seal for Electrodes

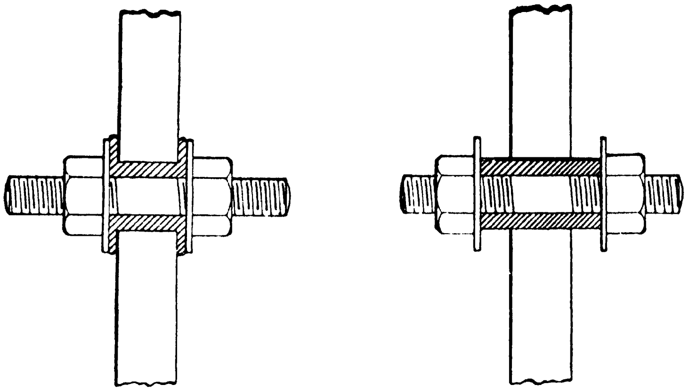
By M. C. MARSH, Ph.D., F.Inst.P.

J. Sci. Instrum. 6, p. 234 (1929)

It is often desirable to make electrical connexions through the walls of a thick glass or metal vessel. The seal produced by the method described below has proved satisfactory for pressure and ordinary vacuum work, and has the advantage of being non-rigid, thus reducing the risk of breakages. Further if the wall is a conductor, the lead is insulated from it.

The lead is a rod threaded at both ends. A piece of ordinary rubber tubing, whose internal diameter is such that it is a good fit on the rod, is pushed over the plain portion. Its length should be about twice the thickness of the wall and it should have square-cut ends. To obtain these, the tube is cut with a wet razor-blade while stretched over a rod revolving in a lathe. The diameter of the hole in the vessel should be approximately the same as the outside diameter of the rubber. Washers and nuts are put on each end of the rubber

(Fig. 109 (*a*)). When the nuts are screwed up the rubber is compressed and flanges are formed as shown in Fig. 109 (*b*). For greater flexibility a greater length of thick-walled tubing is used. The only essentials of the method appear to be that the rod, hole and rubber tube should



(*a*) (*b*)

FIG. 109.—Flexible seal for electrodes.

have smooth surfaces. If there is a convenient shoulder on the rod this may take the place of one of the nuts, but care should be taken in this case to see that there is a definite flange on the rubber each side of the wall. Also tube may be used instead of rod if desired.

84. Sealing Electrode Leads into Experimental Apparatus

By A. J. MADDOCK, D.Sc., M.I.E.E., F.Inst.P.

J. Sci. Instrum. **11**, p. 405 (1934)

In many instances, leads have to be sealed through experimental apparatus to connect with internal electrodes and suitable wires are not always available. Dumet leads can readily be obtained from burnt-out electric lamps or thermionic valves. Seals are easily made from these in either lead, soda or lime glass apparatus.

The stem of the lamp or valve (from which the cap can be removed by heating it gently and pulling off when the solder on the contacts melts) is shattered in a vice to remove all glass from the leads and a short length of fine glass tubing then fused down on to the Dumet section of the wire; for rigidity in the final construction, the glass should be long enough to grip the nickel and copper wires also. In a satisfactory seal the Dumet wire, when cold, should appear a bright red colour. Wires with these glass beads on them may then be fused into the apparatus.

If a complete stem is required with several leads, it is possible to break off the bulb carefully near the base, cut off the stem squarely and reflare in the blowpipe flame; the whole stem, after having had suitable electrodes mounted thereon, can then be sealed into tubes or bulbs as desired; the exhaust tube can also be extended if desired.

85. Two Methods of Sealing Off Large Exhausting Tubes

By B. George

J. Sci. Instrum. **21**, p. 125 (1944)

The pumping speed of a high-vacuum system is restricted by the line resistance which for pressures less than 0·01 mm. of mercury is known to be approximately proportional to tube length/(inner diameter)^3. Thus the pumping resistance of a constriction of 1 mm. diameter and 5 mm. length equals that of a 10-mm. tube of 5 m. length and, therefore, is often the main speed-limiting element in the system.

When sealing off large exhausting tubes, constrictions can be avoided by applying one of the following methods: a glass rod, shown in Fig. 110 (*a*), bent at a right angle, is sealed into the wall of the tube; its free end is conically shaped and lies in the axis of the tube. When the zone 1–2 is heated with a micro-flame the collapsing wall of the tube is caught by the end of the rod; while this happens the attached exhausted vessel is pulled away. The glass rod which does not reduce appreciably the cross-sectional area of the tube, supports the thin central parts of the collapsing glass tube. By applying this method, tubes with inner diameters up to 9 mm. have been sealed off with success.

Another sealing-off point of low pumping resistance is shown in Fig. 110 (*b*). It consists of a tube which is thickened up in such a way that the original inner diameter is maintained. Owing to the increased thickness of the wall, the speed of the collapse is easily controllable as in the case of a normal constriction. The process is done in two steps: first, the zone 1–2 is heated with a small soft flame, and the sealing-off point drawn out to the size of a normal constriction (dotted lines); the second step is to seal off this constriction in the

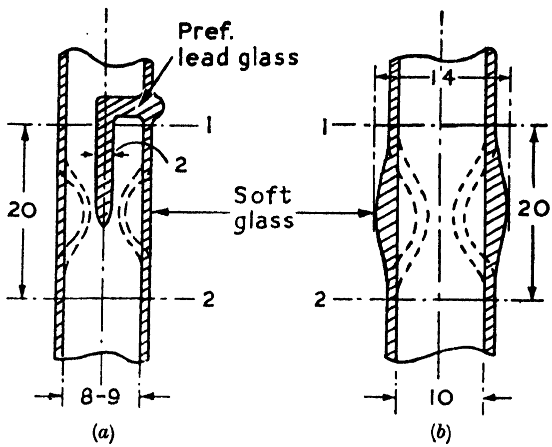


FIG. 110.—Two methods of sealing off large exhausting tubes. (Dimensions are in millimetres.)

usual way. Although the largest exhausting tubes used as shown above had an inner diameter of 10 mm., the same principle may be applicable for larger tubes. Moreover, it seems that if the two methods are combined, tubes of much larger diameter may be handled.

86. Sealing Electrodes into a Steam Chamber

By S. MUNDAY

J. Sci. Instrum. **21**, p. 67 (1944)

The following method was used to insert a thermocouple into a cylindrical brass casting containing superheated steam at about 100 lb./sq. in. gauge pressure. Owing to the high temperature, the method of insulating the wires with rubber tubing, described by Munday in Note 82, was impracticable.

A $\frac{3}{4}$-in. B.S.P. threaded hole was made in the wall of the casting (Fig. 111). A brass piece *A* threaded externally to suit, was bored out at its lower end to $\frac{3}{8}$ in. diameter and at its upper end bored and threaded to $\frac{5}{8}$ in. diameter, 26 threads per inch. Another brass piece *B* was bored out to $\frac{3}{8}$ in. diameter and threaded externally to fit piece *A*. This formed a kind of gland joint. The insulators *C*, which were of Bakelite bonded asbestos, were turned and drilled in one piece to ensure that the holes for the wires were in line. After this operation the piece was cut into two and the rough ends faced up. The asbestos had been found very satisfactory material in a former steam apparatus and withstands the erosive action of steam quite well. It is easily machined.

Two brass spheres about $\frac{3}{32}$ in. diameter were turned and drilled to suit the wires upon which they were soft soldered about 2 in. from the ends.

The holes at the larger ends of the insulators were countersunk to such a depth that, when the insulators were threaded over the wires, with the brass spheres fitting into the countersinks, and pressed hard

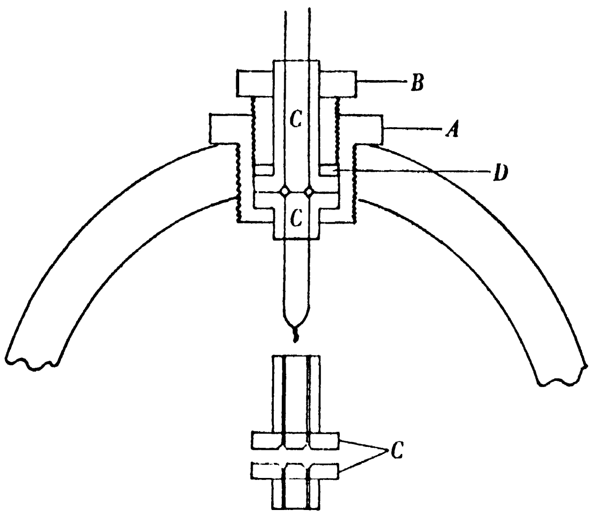


FIG. 111.—Method of sealing electrodes into a steam chamber.

together in the hand, there was just a little daylight showing between the two larger faces.

To minimize the danger of twisting the upper insulator relative to the lower one a brass washer *D* was inserted between the face of *B* and the shoulder of the upper insulator. When *B* is screwed up tightly it presses the two faces of the insulators together, and the shoulder of the lower one on to the bottom of the hole in *A*. At the same time the spheres are pressed hard into their seatings and a tight joint results. By unscrewing *B* the couple can be removed for examination and re-calibration if needed.

87. A Vacuum "Lead-In"

By H. Herne, M.A.

J. Sci. Instrum. 23, p. 244 (1946)

It was desired to build a silica evaporation chamber to prepare electron microscope specimens; and to provide adequate heating of the silica fragments a current of up to 50 A. had to be passed through a metal base-plate into a high-vacuum chamber. A quick and simple method of doing this was to use a conventional metal-rubber anti-vibration bush as an insulator; the outer metal cylinder of the bush was soft soldered to the base-plate, and the inner one to a solid conductor which would carry the required current.

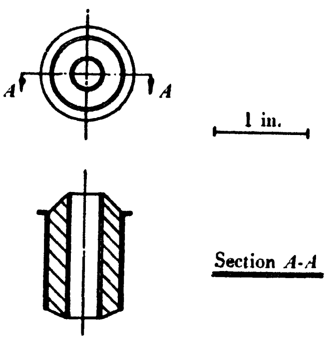


Fig. 112.—Bush as supplied.

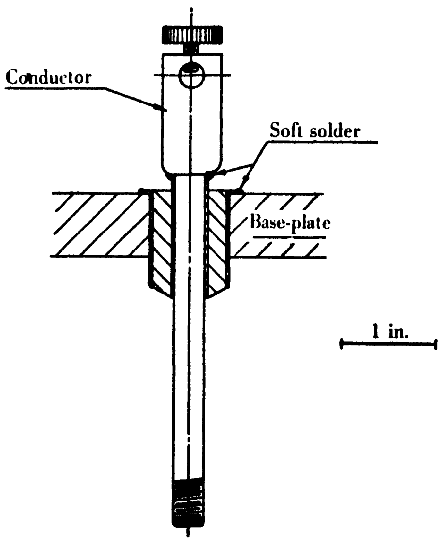


Fig. 113.—Vacuum "lead-in" made from bush.

The particular bush used was a Metalastik one, shown in Fig. 112, although presumably any similar metal-rubber bonded bush would have been equally suitable. In this particular type the metal cylinders were brass-plated iron to which the rubber was bonded by moulding. A small amount of this rubber was trimmed away with a sharp knife as can be seen by comparing Fig. 112 with Fig. 113. A brass rod was soft-soldered to the inner cylinder and this unit was then soft-soldered to the base-plate, as shown in Fig. 113. The cross-sectional area of the central conductor was approximately 0·1 sq. in.; had this conductor been copper its nominal rating would have been at least 200 A.

The only precaution taken in fitting this lead-in was that the rubber-metal bond was nowhere heated during the soldering operation. This could be achieved by using a soldering iron and an active flux such as zinc chloride or Baker's Fluid, whilst the bush itself was immersed in cold water with only the edge to be soldered above the surface. It is planned to fix a similar bush to a stainless-steel base-plate by first fusing on to the base-plate a layer of silver solder and then soft-soldering to the silver solder by the above method.

The resultant lead-in was completely vacuum-tight, the pressure under the bell jar being less than 10^{-5} mm. of mercury as measured by a McLeod gauge. The lead-in carried a large current without heating, had mechanical strength and high shock resistance and was very easy to fit or replace without any special manual skill. The insulation resistance after fitting was better than 20 MΩ, the limit of the megger used, and the spacing of the central electrode from the base-plate enabled a high voltage to be fed into the vacuum chamber if necessary.

A similar bush with an appreciably shorter axial length of rubber would provide a method of passing movement into the vacuum system; this could often replace a flexible metal bellows. The rubber bonders who make the standard products are usually willing to make bushes to special patterns; then almost any blend of rubber may be used in the bonding provided that the underlying brass plating is in the α-phase. The rubber may be chosen, therefore, for either its mechanical properties, or its vacuum properties, or its resistance to fluids such as vacuum oils.

88. Insulating Joints in Vacuum Tubes

By W. Ehrenberg, Ph.D., F.Inst.P.

J. Sci. Instrum. **16**, p. 162 (1939)

A rigid and heat-proof joint between insulated electrodes in a vacuum tube is always a matter of some consideration. When recently faced with the problem of making rigid joints between insulated nickel flanges for a vacuum tube, which were to run at bright red heat, we found that we could accomplish it by using a ceramic setting compound as sold for the coating and setting of heater wires for electric furnaces.

The method can be understood from Fig. 114. The wire *d* is butt-welded to the one plate *a*, and a suitably formed ceramic insulator *c* is pushed over the wire. The insulator is then locked, for instance by welding a piece of nickel strip on the end of the wire. The second plate *b*, which has a hole of the diameter of the shoulder of the insulator *c*, is then put in position and fastened by a bead of the setting compound which finds a hold on the piece of nickel strip. After drying, the parts are fired in a flame or in a vacuum or hydrogen furnace. Three symmetrically arranged joints of this type give a perfectly rigid assembly of the two flanges.

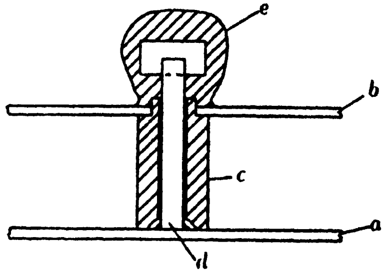


FIG. 114.—Insulating joint for vacuum tubes.

If specially made insulators are not available, insulators known as fish-spine beads can be used, and a number of variations suggest themselves according to the problem. The essential feature of the scheme is to fix metal plates spaced by ceramic insulators in position by beads of a setting compound that are afterwards sintered.

89. A Method of Controlling the Pressure inside an Apparatus which is being Evacuated

By S. RAMA SWAMY, Ph.D.

J. Sci. Instrum. **11**, p. 28 (1934)

It is often found necessary to keep a constant pressure inside an apparatus which is being evacuated, such as a sputtering tube. Slight leaks inherent in the system and the liberation of adsorbed gas from the electrodes in the tube by the discharge through it, prevent the shutting off of the pump. If the pump is kept continuously working, the resulting vacuum is often too high for the purposes of the experiment. The appearance of the discharge cannot be used as an indication of the pressure inside the sputtering tube, since the walls of the tube are rendered opaque in a few minutes by deposition of the material of the cathode.

A small discharge tube with plane aluminium electrodes about 1 cm. in diameter and a special tap are inserted between the apparatus and the pump (Fig. 115). A paper scale (not shown in the figure) is pasted on the discharge tube so that the length of the cathode dark space can be read, when a discharge is passed. The length of the dark space depends on the pressure in the tube as well as on the current density of the discharge*. The tap is an ordinary glass one, the barrel

* Aston and Watson, *Proc. Roy. Soc. A*, **86**, p. 169 (1912).

of which bears two tapering cuts *C* as indicated in the figure, leading from the ends of the hole running through it. These cuts can easily be made with an ordinary glass cutter or a very fine three-cornered file. Since the admission of gas into the system by the two factors mentioned is usually constant for any particular pressure, that pressure can be kept constant by adjusting the tap so that the length of the dark space remains constant at a predetermined value depending on the particular requirements of the experiment. If the same coil is always used for the discharge, the length of the dark space and the

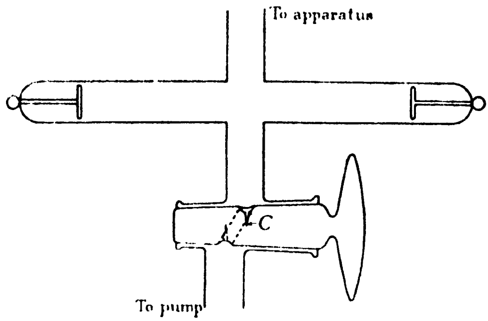


FIG. 115.—Pressure controller.

current density will both depend on the pressure only and thus for any particular dark space there will be a corresponding pressure and current density. The dark space can therefore be used as an indicator for maintaining the pressure constant. The discharge tube can be calibrated under experimental conditions, using a McLeod or other type of gauge. A circular scale and a pointer attached to the tap assist considerably in its adjustment. The method has been found useful for pressures of about 0·1–2 mm. of mercury, and particularly so when the introduction of mercury vapour into the apparatus from a McLeod gauge is not desirable.

90. An Improved Form of High Vacuum Leak

By W. BOGG

J. Sci. Instrum. **14**, p. 412 (1937)

The type of leak or needle valve frequently used in high vacuum apparatus,* such as continuously evacuated cathode-ray oscillographs,

* Cf. Kaye, G. W. C., *High Vacua*, p. 51 (London: Longmans, Green and Co., 1927).

electron microscopes, etc., for controlling the flow of gas consists of a simple needle which is forced in and out of an orifice by means of a screw to which it is attached. While a leak of this type can be made to operate in a manner which is perfectly satisfactory, the control may become very erratic as the leak is closed if the needle is not accurately in line with the centre of the screw. A further disadvantage is that there is a tendency for the operator to continue to turn the screw after the needle has seated, as there is no definite stop to limit its travel. This frequently results in the enlargement of the orifice, together with grooving of the needle itself. In order to avoid these difficulties a new leak has been evolved on the following lines.

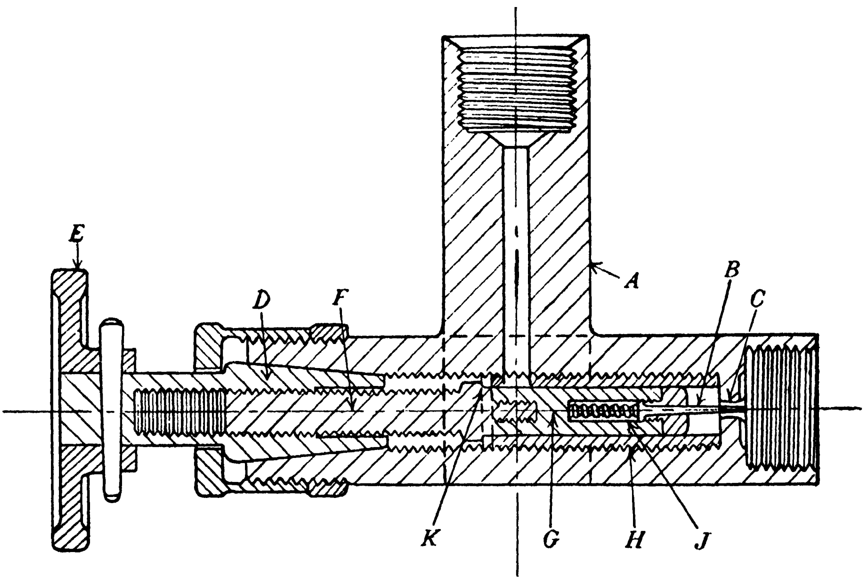


FIG. 116.—High vacuum leak.

It consists primarily, like the normal leak, of a needle which is arranged to open or close an orifice, but it is arranged so that it cannot rotate in the latter and yet is free to align itself with the orifice. Once the needle has completely closed the orifice, subsequent operation of the valve merely compresses a spring without forcing the needle further into the orifice. A stop is fitted to limit the amount by which the spring is compressed, so that it is virtually impossible to damage the needle or its seating in any way. Further, owing to the absence of rotation of the needle, it enters its seating in a perfectly uniform manner so that the flow of gas through the orifice can be controlled down to a much smaller value than is usually possible with a normal leak.

Fig. 116 shows the improved leak in detail. *A* is the main body of the valve and *B* and *C* are the needle and the orifice respectively. The cone *D*, which is accurately ground to fit *A* and is made vacuum tight by a slight smear of Apiezon grease, has an internal thread cut in it so that on rotating the knob *E* the shank *F* is moved along the axis of the valve. The shank *F* is attached to a square piece of brass *G* which slides in the housing *H* ; this is a short length of brass rod which is screwed into *A* and has a hole through it filed out to a square cross-section so that *G* is prevented from rotating, while it is free to slide in the same manner as is *F*. The needle *B* is carried inside *G*, while the spring *J* serves to align the needle in its seating and prevents damage to them both. The travel of the moving part is limited by the shoulder *K* on the shank *F* which seats on to the housing *H* almost immediately after the needle has seated, so that the latter cannot be forced into the orifice. The spring *J* is slightly compressed under these conditions. The flow of gas occurs between G and its housing, where the fit is purposely made slightly loose.

91. Leaking and Controlling Small Quantities of Gas

By A. S. Husbands, B.Sc.(Eng.), A.M.I.E.E.

J. Sci. Instrum. **23**, p. 190 (1946)

The need for a sensitive and simple control of the gas pressure in the discharge tube of continuously evacuated, cold-cathode, cathode-ray oscillographs, has led to the trial of several devices for leaking small quantities of air. The electron-beam current of this type of discharge tube is critically dependent on the gas pressure, the variation of which is employed to control the beam current. The discharge tube communicates directly with the main body of the oscillograph only through the very small anode aperture. This permits the use of a relatively hard vacuum in the main body of the oscillograph which is practically independent of the discharge-tube pressure. The discharge tube is fitted with a pipe for the inlet of gas and another for evacuation, and may be treated as an isolated container in which the gas pressure is controlled by the systems to be described. In the case of the cathode-ray oscillographs concerned, air is the gas normally employed, thus saving the complication of a special gas supply, but the methods hereafter described are applicable to other gases and to other types of apparatus involving gas-pressure control.

Various types of needle valve have been used to leak air directly from atmospheric pressure to the discharge-tube pressure, which is of the order of 0·01 mm. of mercury at a rate roughly of the order of 10 c.c. per sec. or more, depending on the size, voltage and exhaust pumping system of the tube. In general needle valves proved unsatisfactory with this large expansion ratio and gave erratic and insensitive control of the electron beam current. Needle valves leaking from a reservoir at a pressure of about 1 mm. of mercury have given excellent results, but the method necessitates the use of a separate rough vacuum pumping system. In each case the discharge tube was continuously exhausted by an oil diffusion pump.

A more satisfactory valve for working directly from atmospheric pressure consists of a rubber disc, approximately $\frac{3}{8}$ in. diameter $\times$ $\frac{1}{8}$ in. thick, pressed over a small hole at the conical end of a larger hole in a brass block (Fig. 117). Pressure is applied to the disc by means of a

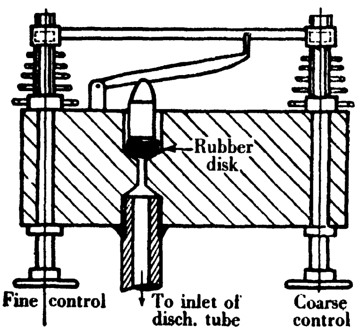


FIG. 117.—Rubber-type variable leak valve.

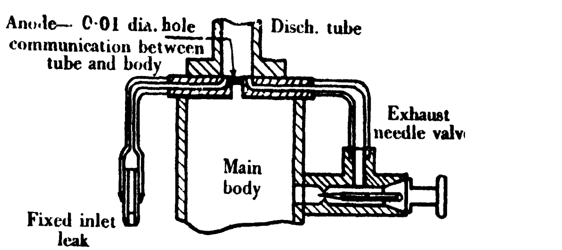


FIG. 118.—Control of discharge tube pressure by an exhaust valve.

metal plunger, through a system of links and screws designed to give a large mechanical reduction of motion. Air leakage takes place across the face of the rubber disc and is variable from zero up to a value considerably greater than that required for the discharge tubes. The physical properties of the rubber are critical for satisfactory operation. Thus, a too soft rubber tends to stick over the hole and seal it entirely after pressing fully closed, while too hard a rubber results in a very critical control.

The most satisfactory system, so far tried, employs a fixed inlet air leak and a variable valve in the pipe used to exhaust the discharge tube. Fig. 118 shows the method applied to the discharge tube of a 20-kV. cathode-ray oscillograph, where it has given a very satisfactory performance throughout two years of use. In this particular case exhausting of the discharge tube was effected through the main body of the cathode-ray tube with a controlling needle valve, of the type described by W. Bogg (see previous Note), inserted between the discharge tube and the main body. Within wide limits, any rate of gas flow may be employed and the pressure is then governed by the exhaust valve, whose aperture is large for high rates of flow (and vice versa) for any given pressure. Thus, in the cathode-ray tube shown, the sensitivity of control was largely governed by the rate of flow of the fixed inlet leak, since a large needle-valve aperture corresponded to an insensitive control with the particular shape of needle employed. In practice it was required that the beam current should be variable in the ratio 1/100 at cathode voltages between 10 and 20 kV. Accordingly, a fixed inlet leak was selected to admit the minimum quantity of air necessary to attain the highest required tube pressure, when the needle valve was almost closed. In these conditions the vacuum of the main body was not unduly impaired by an excessive flow of air, and the needle valve, having a $\frac{1}{16}$-in. diameter hole, covered a wider range of beam control than was actually required. In addition, the control sensitivity was ample, and varied with the value of beam current in a manner very roughly inversely proportional to it. The latter property was especially valuable in view of the wide range of beam currents required.

Several methods of manufacturing fixed inlet leaks were tried, and, initially, drawn-out glass capillary tubes were employed. These were tedious to make for the correct leakage, but their main disadvantage was the reduction, and eventual termination of leakage, which occurred within a few minutes of use. This phenomena was attributed to dust blockage, but the addition of a coarse porous filter was ineffective in preventing it, owing probably to the inclusion of dust between the filter and the glass tube end. A number of readily available porous materials, mainly of carborundum-carbon composition, were tried, but these gave too high a rate of leakage for the cathode-ray tube application. Satisfactory leaks were made from Steatite in the form of porous pellets about $\frac{3}{16}$ in. diameter $\times$ $\frac{1}{8}$ in.–$\frac{1}{4}$ in. long, one of which has been in use on the 20-kV. oscillograph for about two years with no apparent change in its leakage rate. The pellets were sealed into the inlet pipe of the discharge tube by means of low vapour-pressure wax. Both fired and unfired Steatite pellets were tried and there was no apparent change in the diffusion rate on firing. However, unfired or partially fired pellets were adjustable to give an increased rate of air flow by filing the outer exposed face.

92. A Simple Variable and Greaseless Leak

By G. C. Eltenton, B.A., A.Inst.P.

J. Sci. Instrum. **16**, p. 27 (1939)

The difficulty of obtaining a high resistance with an open scale in the required low pressure range, without elaborate machining, led the author to design the capillary leak illustrated in Fig. 119. The moving part consists of a tungsten wire *W* twice the length of the capillary *C*. The latter is chosen so that the tungsten wire after straightening will just pass smoothly through. One half of the wire is then thinned by dissolving uniformly in a 50 : 50 molten solution of sodium nitrite and nitrate. Nickel hooks are spot-welded to the ends of the wire after it has been threaded into the capillary and these engage with glass

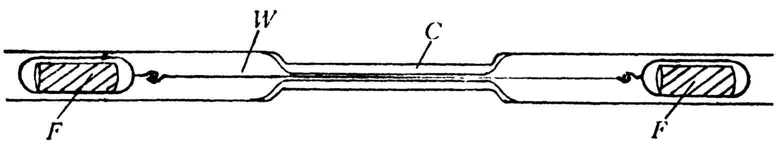


Fig. 119.—Capillary leak.

hooks on the envelopes surrounding the iron cores *F*, *F*. If tap grease presents no difficulties, magnetic operation can be dispensed with by mounting the leak vertically. One of the cores is then replaced by a thread and winding tap in the usual way. With a tungsten wire of diameter 0·1 mm. and about 8 cm. of capillary a pressure drop of 40 cm. of mercury was maintained. The pressure in the ionization chamber of mass-spectrograph was then 2×10^{-3} mm. when the leak was closed and 8×10^{-2} mm. when open. Other ranges could of course be obtained by changing the dimensions or the pressure in the gas reservoir. Other metallic wires can be used when corrosive gases are involved.

93. An Electrolytic Hydrogen Leak

By P. C. Thoneman, M.Sc., A.Inst.P.

J. Sci. Instrum. **23**, p. 217 (1946)

An electrolytic cell containing sodium hydroxide as an electrolyte, with a thin palladium tube as a cathode, has been found convenient for introducing pure hydrogen into a vacuum system. The speed of the leak depends mainly on the surface condition of the palladium and the temperature of the electrolyte. No attempt was made to bring the palladium surface into an active condition as, according to Barrer,* it is then very susceptible to poisoning.

With a current of 2 A. and a tube of 1·5 sq. cm. surface area a leak of about 4 c.c. (N.T.P.) per hour could be maintained steadily. The electrolyte temperature was about 70° C. There is a considerable delay amounting to 5 min. or more before the leak reaches its final speed. This interval is less after the electrolyte has been warmed by the current.

Both platinum and nickel were found to be satisfactory as anode materials. It was necessary, however, to limit the current density to approximately 100 mA./sq. cm., since otherwise the anode disintegrated and the anode material deposited on the cathode in the form of a spongy mass.

All materials used were chemically pure and the cathode tube was brought to a dull red heat before introducing the electrolyte. It is anticipated that a similar arrangement will prove convenient for the introduction of deuterium into evacuated systems.

94. An Improved Cut-Off for High Vacuum Work

By R. W. Ditchburn, Ph.D.

J. Sci. Instrum. **8**, p. 267 (1931)

The ordinary mercury cut-off has two important disadvantages: (1) that it will support only a few centimetres difference of pressure so that it is impossible to let down the low-vacuum side without also letting down the high-vacuum side; (2) that in the event of an accidental break on the low-vacuum side, mercury is flung into the high-vacuum side with destructive violence.

The cut-off shown in Fig. 120 (*a*) was primarily designed to eliminate the second disadvantage, but with slight modification it will also overcome the first and enable gas at atmospheric pressure to be suddenly admitted to the low-vacuum side without disturbing the high vacuum. The following points of design are important:

(1) The taper at *H* where the two ground surfaces come into contact must be fairly sharp, to avoid sticking.

(2) If the float should stick slightly and then fall suddenly it would smash itself on the bottom of the tube *T*. To avoid this the connecting

* Barrer, R. M., *Trans. Faraday Soc.* **36**, p. 1235 (1940).

tube *B* is led out in such a way as always to leave some mercury in the bottom of *T*.

(3) The bulge (in the float) at *C* is required to ensure that it always rises and falls vertically.

The cut-off shown in Fig. 120 (*a*) does not protect the low vacuum against a break on the high-vacuum side. The more complicated form shown in Fig. 120 (*b*) safeguards both sides.

If it is desired to be able to admit air at atmospheric pressure to the low-vacuum side without affecting the high vacuum, the design

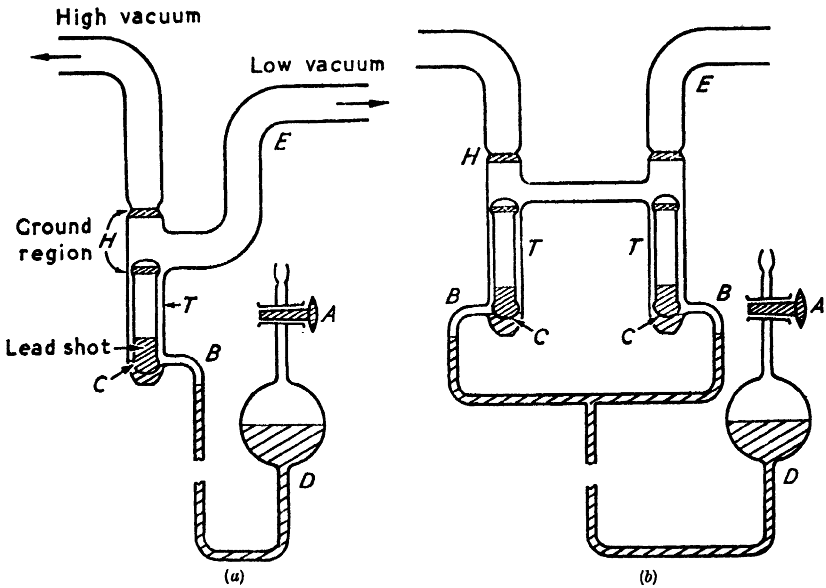


FIG. 120.—Cut-off for high vacuum work.

shown in Fig. 120 (*a*) should be modified by transferring the tap from *A* to *D*, i.e. it should be placed so that it is always in the mercury. With the design shown in Fig. 120 (*b*) it is not necessary to place a tap in the mercury. The same object may then be achieved by increasing the pressure in the bulb *C* above atmospheric so that the pressure at *E* is atmospheric.

When the valve is merely to be used as a safeguard against a sudden breakdown rough grinding will do. If, however, it is to be used for withstanding a large difference of pressure for more than a few minutes, good grinding is necessary.

95. A High-Vacuum Valve

By M. J. Moore

J. Sci. Instrum. **21**, p. 162 (1944)

Several sizes (½ in. to 2 in. diameter) of standard globe valves made from good-quality bronze were obtained, and slight alterations were carried out on them before being installed in various vacuum systems.

The globe valve, of the type illustrated in Fig. 121, is dismantled and thoroughly cleaned. A brass retaining ring is machined to fit round the valve body at the joint where the bonnet is screwed into the body, to prevent the rubber sealing-ring being squeezed out by the pressure. (The rubber rings used in this joint were obtained from meat-paste containers or tobacco tins.) In place of the ordinary gland packing the main seal on the spindle is made by the Neoprene ring which has a hole cut in it approximately 15 per cent less in diameter than that of the spindle; this ensures that a good contact pressure is obtained on the spindle. It is necessary to chromium-plate the spindle, otherwise after a short period of standing the Neoprene tends to adhere to the bronze spindle, with the result that when the spindle is rotated the surface of the rubber may be damaged and so impair the efficiency of the vacuum seal. Above the Neoprene there is put a layer of a mixture of Apiezon M grease and graphite, which both acts as a secondary seal and also serves as a lubricant to ease the movement of the spindle. This is followed by a ring of asbestos packing which prevents the escape of the grease mixture and ensures that it shall be kept in contact with the spindle and the Neoprene sealing ring when the asbestos is itself forced down by the pressure of the brass ring and gland nut. A piece of good-quality rubber sheet takes the place of the usual composition disc and serves as the vacuum seal within the valve.

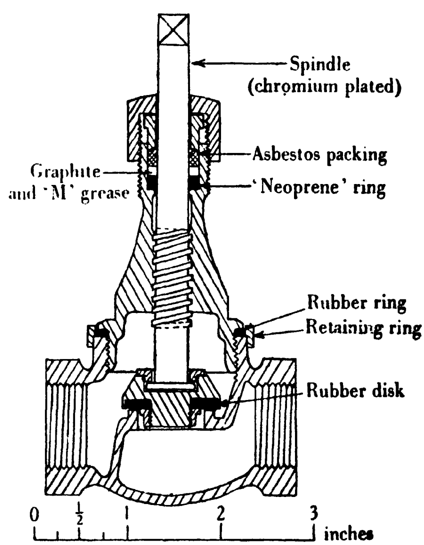


FIG. 121.—High-vacuum valve.

The valves were installed so that in the event of a " shut-down " vacuum test on a piece of apparatus the gland system was remote from the test-piece. This, however, is not necessary. Actual tests have shown that the gland system remains perfectly vacuum-tight over long periods of " shut-down ".

Several of these valves have been in use for about four years and have proved most reliable in operation during this period.

96. A Multiple High-Vacuum Valve

By R. I. Garrod, Ph.D., A.Inst.P.

J. Sci. Instrum. **23**, p. 191 (1946)

This note describes a high-vacuum valve which will allow the simultaneous or independent exhaustion of several different sections of a high-vacuum system. It is illustrated in Fig. 122.

A mild steel cylindrical pot *A* is machined from solid rod and has four holes drilled in its base. Into these holes are soldered four brass pipes, of which *B* and *C* are two. The four pipes are connected to the various sections of the vacuum system. The top end of each pipe is chamfered to an annular width of about $\frac{1}{16}$ in. and may be sealed off from the main body by a Neoprene washer *D*, mounted in a brass holder *E*. The holder is attached to a steel shaft *F* through a universal joint consisting of a ball turned on the end of the shaft and resting in a conical seating. (A split disc *G* prevents the ball from coming out of the holder when the shaft is moved upwards.) The washer *D* is thus free to align itself on the top of the pipe when the valve is closed. Each shaft is lapped and slides in a bearing in the steel cover *H* of the pot, being lubricated with a trace of vacuum grease; a simple vertical movement of the shaft opens or seals the pipe from the main body of the valve. A stop *I* limits the movement of the shaft if desired. The cover has a small groove machined around its inner edge and into which is fitted a gasket *J* consisting of a piece of 20-A. fuse wire, the ends of which are butt-welded in a small gas flame, to form a loop.* The cover is fastened down on the pot by six Allen screws, the fuse-wire ring being squashed in the process and thus forming a vacuum-tight seal.

In the cover itself, around each shaft, is fitted a brass holder *K*, which sits in a small recess in the cover and is screwed down to it. A seal is made between the holder and the cover by a ring *L* of 5-A. fuse wire, in a similar manner to the gasket *J*. The outer and inner

* Strong, J., *Modern Physical Laboratory Practice*, p. 128 (London: Blackie and Son Ltd.).

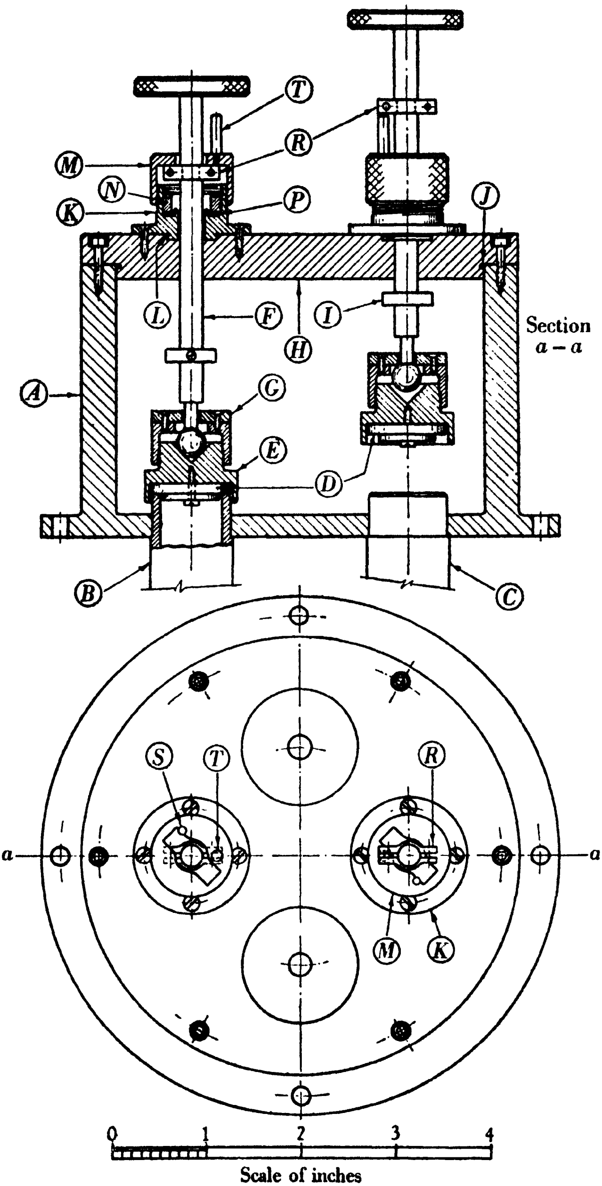


FIG. 122.—Multiple high-vacuum valve.

sides of the holder are threaded for screwing down the cap *M* and the clamp ring *N*. A Wilson type seal,* consisting of the Neoprene washer *P*, seated in the well of the holder and clamped down by the ring *N*, prevents leakage of air down the side of the shaft into the pot.

To seal effectively each pipe from the pot, the washer *D* must be held firmly in contact with the top of the pipe. A simple and quick method, used in the present design, for locking the washer on to the top of the pipe under pressure is as follows. Around a recess in the shaft is fitted a split collar *R*, consisting of two wings which can be screwed together to form a cross-member with the shaft. The top of the cap *M* contains a slot through which the collar and shaft may be withdrawn. During initial assembly of the valve, each cap is so positioned on its holder that when the washer *D* is in contact with the pipe, the collar *R* is just clear of the under-side of the cap top. The procedure for closing each tap is therefore to push the shaft down with one hand so that the collar is fed through the slot, and then a clockwise rotation of the cap *M*, performed with the other hand, of 60–90°, locks the washer *D* on the top of the pipe, under pressure. To open the tap, the cap is rotated in the opposite direction, until a small pin *S*, on the under-side of the cap, comes in contact with the wing of the collar *R*, when the shaft may be withdrawn through the slot. A small rotation of the shaft then enables the wing of the collar to rest on top of a small pillar *T*, attached to the cap, and so keeps the tap open. In the diagram the left-hand tap is shown closed and the right-hand one open.

97. A Simple High-Vacuum Release Valve

By R. JACKSON, Ph.D., F.I.M., F.Inst.P., and A. G. QUARRELL, D.Sc., F.I.M., F.Inst.P.

J. Sci. Instrum. **15**, p. 208 (1938)

All-metal vacuum apparatus is frequently constructed without special provision for the admission of air, and resort is therefore made to the simple expedient of forcibly separating two ground surfaces, with consequent danger of distortion. We have found that an ordinary Schrader tyre-valve serves admirably as an inexpensive, trouble-free release valve which will maintain a high vacuum. The valve is soldered to the apparatus wherever convenient and in such a manner that the atmospheric pressure is tending to open the valve and admit air. The spring incorporated in the valve, however, exerts such a pressure on the valve seating that a truly " vacuum-tight " seal is obtained. Air

* Wilson, R. R., *Rev. Sci. Instrum.* **12**, p. 91 (1941).

can be admitted to the apparatus by depressing the central pin in the same way that air is released from a car tyre. We have had one of these valves in continuous use for the past year without experiencing the slightest trouble.

98. A High-Pressure Valve

By M. J. Moore

J. Sci. Instrum. **18**, p. 23 (1941)

Fig. 123 gives the constructional details of a quick release high-pressure valve which has been used in conjunction with a Wilson expansion chamber working at a pressure of 50 atm.

The valve body *A* has a taper seating and into this is forced a hard rubber tapered plug *B*, making a gas-tight joint. The spindle *C*, to which the rubber plug is attached, is split and has a flexible rubber

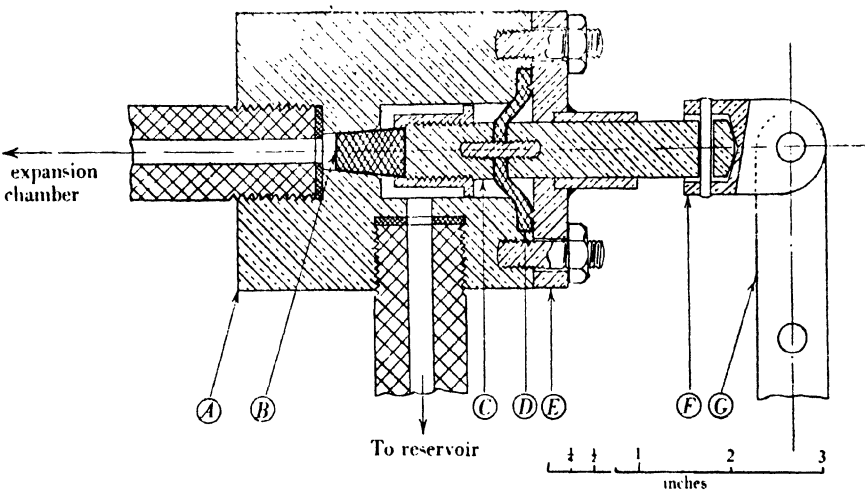


Fig. 123.—High-pressure valve.

diaphragm *D* fixed to it. The diaphragm is also clamped to the valve body by means of the spindle guide plate *E*; this plate has a **V**-shaped tongue which bites into the rubber and prevents it from slipping. The spindle is connected by a coupling *F* to a closing lever *G*.

This valve has been most satisfactory in operation over a long period and there has been no trouble from leaks. By a slight modification of the spindle guide, the valve could be converted to the screw-down type.

99. A Self-Seating Valve

By J. H. Marvell

J. Sci. Instrum. **17**, p. 115 (1940)

The valve shown in Fig. 124 may be of interest to those engaged in work on gases either under vacuum or at relatively high pressures. It consists essentially of a screwed spindle S having a very fine thread and carrying at its lower end a hardened rustless steel ball spun into the suitably bored ball-seat. The ball is left free to rotate in order to prevent localized wear on the surface. The housing A has a sharp-edged seat at B so that the ball on its first impression moulds the seat to suit. The spindle gland may be of any approved type suitable for the desired purpose.

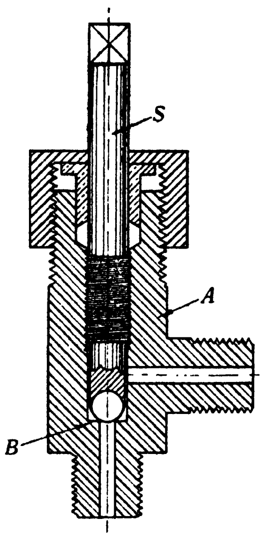


Fig. 124.—A self-seating valve.

Experience with this type of valve over a number of years has shown it to have many advantages over most types of gas valves in general use. It has been found to be perfectly tight under the highest vacuum and has easily withstood pressures up to 120 atm. It may be used with fairly fine adjustment for small rates of flow and is capable of rapid opening to its full capacity. Its chief advantage, however, lies in the fact that it needs very little attention, since the ball makes its own seat each time it is screwed down. Apart from periodical cleaning it has never been found necessary to renew the ball or seating except on rare occasions when corrosive gases have been in constant use.

100. A Glass and Brass Valve

From The Taylor-Hobson Research Laboratory

J. Sci. Instrum. **4**, p. 454 (1927)

Fig. 125 illustrates a very simple yet efficient type of valve which was designed by Mr. William Taylor some years ago. Essentially the valve comprises a disc, cut from ordinary plate glass, which lies on a "knife edge" seating, a piece of ground glass being used to "grind" the seating to a true plane.

This valve is suitable for use with liquids or gases, and has the advantages of being easily constructed, of having no perishable parts,

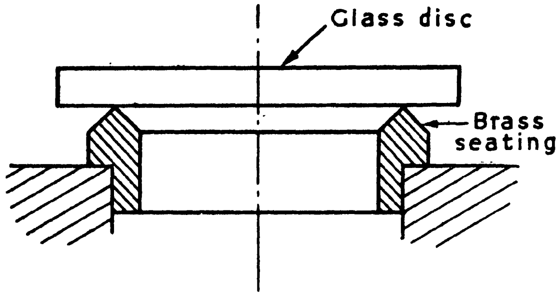


FIG. 125.—A glass and brass valve.

and of not being easily fouled by dirt. Originally the valve was designed for use as a control valve in connection with a thermostatic appliance, but it has since been applied to a diversity of purposes with considerable success.

101. A Simple Micrometer Gas Inlet Tap

By L. SAGGERS

J. Sci. Instrum. **12**, p. 93 (1935)

It is often necessary to be able to control the input of gas into apparatus to micro-limits. The tap described below (Fig. 126) allows of reproducible settings.

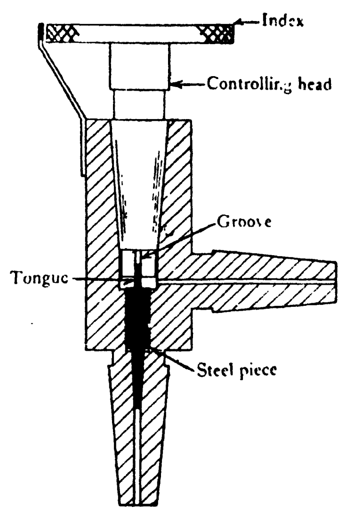


FIG. 126.—A simple micrometer gas inlet tap.

The main body of the tap is machined from brass and the side-piece is screwed and soldered into it. Within this body are two separate parts—a controlling head or stopper, with a circular knurled head divided on its upper surface, which is ground to fit in a taper hole in the body, and a steel screw with a tapered needle extension. These two parts are connected by a tongue on the upper end of the steel screw which fits in a diametral slot in the lower end of the stopper, so that the two turn round together. The screw has a diameter of 6 mm. and a pitch of 0·5 mm. A groove is cut along one side of the screw to a depth greater than that of the thread, to enable the gas to pass. Turning the head therefore alters the amount the taper needle projects into the lower fine hole, without disturbing the fit of the head in its seating. Clearances have necessarily to be left between the screw and the stopper, and in the slot above the tongue, to allow of the motion of the screw.

102. A Three-Dimensional Adjustment of an Electrode *in Vacuo*

By J. L. Miller, D.Eng., Ph.D., M.I.E.E., F.Inst.P., and J. E. L. Robinson, M.Sc.

J. Sci. Instrum. 9, p. 264 (1932)

The form of apparatus employed in making an electrode, capable of three-dimensional adjustment from outside a vacuum, is shown in Fig. 127. All movement of the electrode carrier *E* is effected by sliding or rotation at the three joints *XX*, *YY* and *ZZ*. Vertical movement of the electrode is obtained by rotation of the top piece *A* with respect to the remainder of the assembly, which serves to draw up the electrode carrier *E* by motion of its threaded end in *A*. *E* is prevented from turning in *B* by the small pin and keyway *G*, and the lower limit to the movement of *E* is set by the washer *F*. Tilting of the electrode is obtained by rotation of *B* with respect to *C*, the two surfaces *YY* being milled equal small angles θ (of the order of 1° or 2°) from the horizontal. Thus 180° rotation serves to swing *E* from the vertical position to an inclination 2θ to the vertical, and, if desired, the periphery of the ring may readily be calibrated in terms of the deflexion from the vertical. Horizontal displacement is obtained

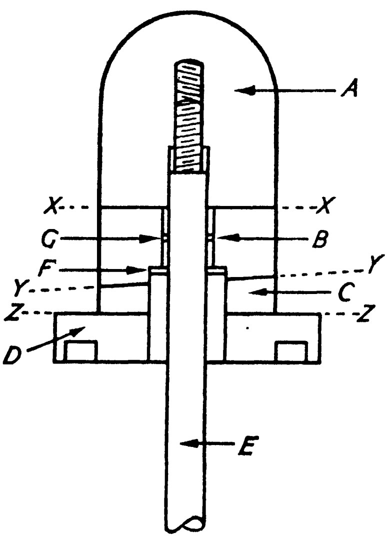


Fig. 127.—Electrode capable of three-dimensional adjustment.

by sliding C with respect to D. Rotation of C with respect to D about ZZ gives the further movement of the whole for complete orientation.

E is arranged to carry the desired electrode, and the bottom of D may be shaped as required for fitting to the apparatus, though for convenience in preparation it is undesirable that D should form an integral part of the apparatus.

The method of preparation of the six plane surfaces will depend upon the facilities available. The joints XX and YY may often be more easily prepared than ZZ for the reason that radial symmetry of surface only is required in the former cases, whereas complete two-dimensional freedom of movement is required in the latter. The pairs of elements composing XX and YY may be ground in, in pairs, direct from a fine lathe or milled finish. ZZ may be prepared by hand lapping on plate glass or cast iron, but care is required to prevent rounding at the edges. Preferably, all the faces are prepared either by hand scraping or by a surface grinding machine, when very little hand-lapping with a very fine abrasive suffices to give an excellent surface.

By these methods joints have been prepared up to 7 in. in diameter. Much larger sizes may be similarly made, of course, if required. Good quality rolled brass is a reliable material to employ ; mild steel has the advantage of being suitable for surfacing on a magnetic surface grinder. The surfaces can be lubricated by either a hard or soft grease, but for joints of relatively great diameter, it appears that a soft grease is preferable in order to maintain ease of turning after prolonged use.

In the device described, movement is in a horizontal plane. The arrangement has been successfully used, however, for small joints where the surfaces were in a vertical or intermediate plane, no means for supporting them being necessary, as friction under atmospheric pressure was sufficient to hold them in position.

103. A Quick Method of Checking Pumping Speeds

By G. C. Eltenton, B.A., A.Inst.P.

J. Sci. Instrum. **15**, p. 415 (1938)

It is often desirable to make a quick check of the power of a pump after reassembly or in order to find the best rate of heating for a given pressure. This method, illustrated in Fig. 128, consists essentially of an *un*calibrated capillary C with a fine adjustment tap T_1, a coarse capillary K of known cross-section and a pressure equalling device M. With T_2 open, via a filter, to the atmosphere or any other gas reservoir, T_1 is adjusted until the pressure in the vacuum line attains the desired value as measured on a McLeod gauge, situated in the section through which the pumping speed is required. After a steady state has been established T_2 is closed and the time for the mercury in K to rise between two marks A and B is noted. If quantitative results are required, T_1 must be closed and the mercury columns levelled. (It is only necessary to do this once if A and B are kept the same in subsequent experiments.) The volume of air V at N.T.P. is then found from the area of the capillary

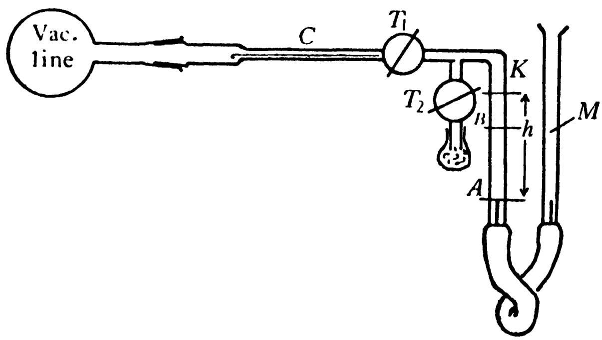


FIG. 128.—A quick method of checking pumping speeds.

and the height h between the levels before and after the experiment. The pumping speed is then Vp_a/pt, where p_a and p are the atmospheric and pumping pressures respectively, and t the measured time.

If it is more convenient to attach the device itself at the point in the line where the speed is required, this can be done provided of course the McLeod gauge is situated in the dead space and not " down-stream " from the device. To minimize space and to avoid blocking of fine capillaries the resistance of C can be conveniently increased by the insertion of a suitable wire. In this way the overall length of the apparatus need not exceed 15 cm.

104. An Apparatus for Stirring under Vacuum

By B. R. ATKINS, B.Sc.

J. Sci. Instrum. **23**, p. 84 (1946)

A device (Fig. 129) is described by means of which a rotating shaft can be introduced into a vessel maintained under vacuum or at a pressure not exceeding approximately 2 atm. An axial displacement of the shaft is also permitted.

The apparatus is a modification of the rotary mercury seal, in which a head of mercury is built up sufficient to withstand the pressure difference between the atmosphere and the interior of the vessel.

A bright steel shaft 4 ft. long and $\frac{1}{4}$ in. diameter is placed concentrically inside a seamless drawn-steel tube measuring 40 in. $\times$ $\frac{5}{8}$ in.

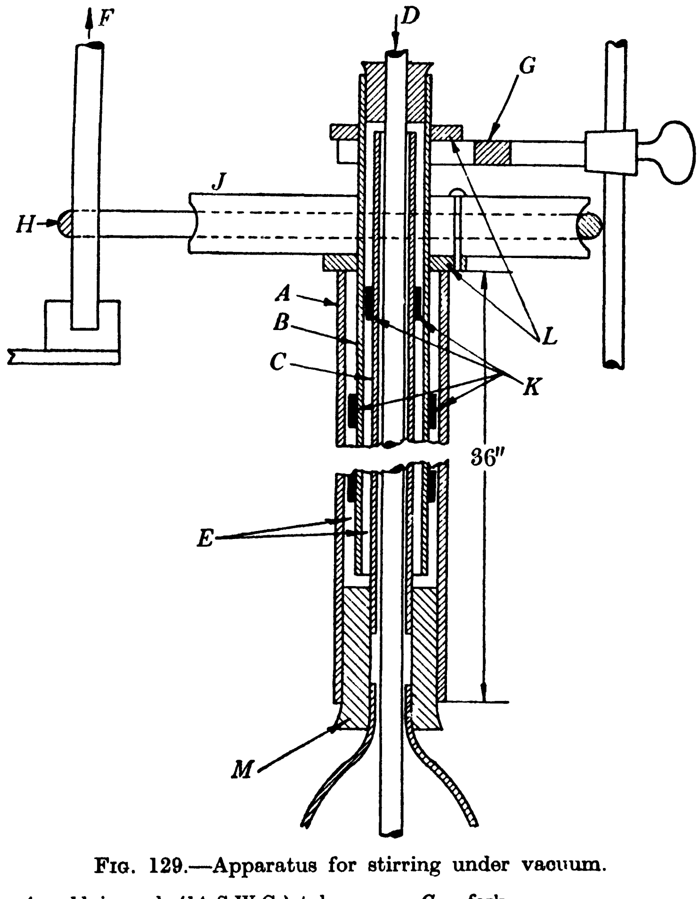


FIG. 129.—Apparatus for stirring under vacuum.

A = 1$\frac{1}{8}$ in. o.d. (14 S.W.G.) tube.	*G* = fork.
B = $\frac{3}{4}$ in. o.d. (16 S.W.G.) tube.	*H* = rubber belt.
C = $\frac{7}{16}$ in. o.d. (18 S.W.G.) tube.	*J* = pulley.
D = $\frac{1}{4}$ in. diameter rod.	*K* = steel ring bearing.
E = mercury.	*L* = brass bearing.
F = electric motor.	*M* = vacuum rubber tubing.

i.d. $\times$ $\frac{3}{4}$ in. o.d. It is convenient to fix the rod to the top of the tube with a rubber bung, but for high-vacuum work brazing is preferable. The shaft and tube act as the rotating unit corresponding to the bell and stirring rod of the ordinary mercury seal. The container for the mercury (corresponding to the annular well of the mercury seal) is constructed of two concentric drawn-steel tubes 40 in. × $\frac{5}{16}$ in. i.d. × $\frac{7}{16}$ in. o.d. and 36 in. × $\frac{15}{16}$ in. i.d. × $1\frac{1}{8}$ in. o.d. joined at the bottom by a piece of vacuum rubber tubing. Steel rings are shrunk on to the inner and the rotating tubes to act as bearing ; slots are cut in these to prevent obstruction to the mercury. A wooden pulley 6 in. in diameter and 1 in. wide is attached to the rotating tube with a brass bearing underneath to support the rotating unit where it rests on the outer tube. For techniques in which it is required to lower the stirrer while it is rotating, a bearing ring is fixed to the rotating tube above the pulley. The stirrer is elevated to its higher position and supported by placing a forked bearing under this ring. When the fork is removed the stirrer drops into its lower position. The pulley is driven by a flexible rubber belt operating from a shaft of $\frac{1}{4}$ in. diameter turned by a $\frac{1}{50}$-h.p. motor running up to 2,000 r.p.m. When working, the apparatus is half-filled with mercury : the length of the container is sufficient to contain a head of 30 in. of mercury and in addition to allow the stirrer to be moved up and down. The vacuum system is connected to the apparatus by a narrow neck fitting into the vacuum rubber tubing at the base.

105. A Convenient Apparatus for Distilling Metals

By R. V. Jones, D.Phil., F.Inst.P.

J. Sci. Instrum. **11**, p. 167 (1934)

This simple apparatus (Fig. 130), which can be opened with very little trouble, is intended for coating small articles whose dimensions do not exceed 4 or 5 cm.

The metal is evaporated from either a crucible or a tungsten wire of 200 microns diameter formed into a helix of 1·5 mm. diameter at *A*. An uncoated tungsten helix is the simpler to make, and should always be used for distilling high melting-point metals, as alundum attacks tungsten at high temperatures ; also impurities in the alundum themselves distil at about 1200° C. The crucible is the more convenient form for metals with low melting-points and it eliminates trouble caused by poor-quality tungsten which sags when heated. It is constructed by forming a conical helix of 200 microns diameter tungsten wire, coating it with alundum and then baking out *in vacuo*. In both cases the ends of the wire are spot-welded to 1-mm. tungsten leads which are sealed into the lower ground joint of Pyrex. A nickel shield *B* is placed round the heater, and is electrically connected to it. An aluminium discharge electrode *D* is sealed in the upper ground joint, and may be raised to a potential about 200 V. above that of *A*, when an electrostatic field is set up in the chamber which tends to concentrate the evaporated metal in the neighbourhood of the electrode *D*. This feature is undesirable if sharp " shadows " are required, as the evaporated metal does not travel in straight lines when the field is applied, but it is useful when

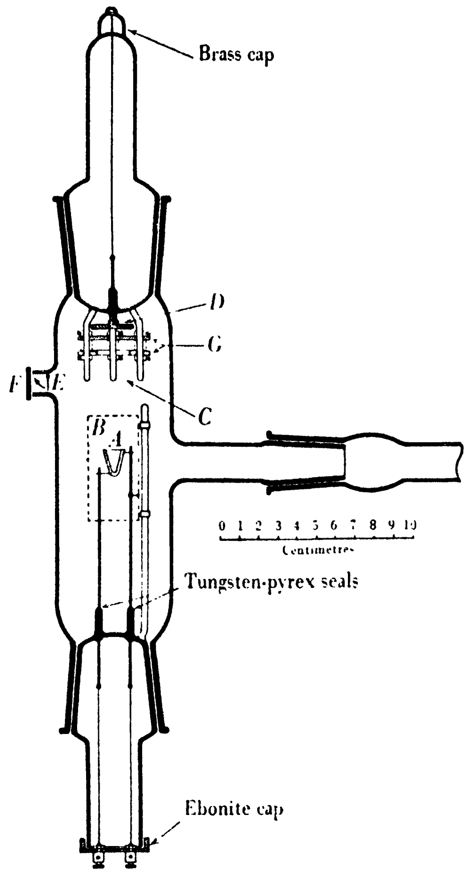


FIG. 130.—Apparatus for distilling metals.

making mirrors. Three Pyrex legs *C* project from the upper ground joint, and a series of brass discs *G* with apertures to cast shadows in desired places are made to fit on them ; the discs are held in position by collars with set-screws. The article to be coated can usually be fitted on to this system ; if not, a special support can be made in thin Pyrex-rod and fused on to one of the legs. A window *F* is provided for examining the article during distillation ; this is screened from the condensing metal by an iron disc E which is hinged on a support and which can be pulled aside when desired by an external magnet. The chamber is exhausted to 10^{-4} mm. of mercury via a third ground joint, which enables it to be removed from the pump system for cleaning. Only the upper ground joint need be opened between distillations, to introduce the article to be coated; when required, extra fragments of metal can be dropped into the crucible at the same time.

106. The Formation of Metallic Blacks on Thin Foils by Evaporation

By R. V. JONES, D.Phil., F.Inst.P., and B. V. ROLLIN

J. Sci. Instrum. **13**, p. 130 (1936)

In 1930 Pfund* described an elegant method of blackening surfaces by the evaporation on to them of metals in an atmosphere of air at about 0·5 mm. pressure. This technique, with its easy control of the thickness and the state of division of the black deposit, would appear very suitable for coating the receivers of radiation-measuring instruments. Recent attempts, however, to apply the method, showed that while other parts of the distillation apparatus were blackened, the thin receivers remained bright.

It occurred to us that the lack of deposit might be due to the receivers becoming too hot from the radiation of the evaporating filament: it is well known that ordinary metallic deposits will not form if the temperature of the surface is too great. Most of the cooling of the receivers was due to the gas surrounding them, and no increase in its thermal conductivity could be obtained by raising the pressure. The conductivities of hydrogen and helium are much greater than that of air, and so it was hoped that if one of these gases were substituted for air it would cool the receivers sufficiently for deposition to occur. Distillations were therefore performed in each of these gases, and the desired blackening was effected without further difficulty. The gas pressure was not critical, varying from 0·1 mm. for finely divided blacks to about 3 mm. for coarse fluffy deposits. Enough hydrogen could be let in conveniently from a Bunsen burner through a palladium tube.

The use of these gases has the added advantage that they are inert with respect to most of the metals evaporated, so there is no risk of a grey deposit due to oxidation, which sometimes occurs if too great a pressure of air is used. All the metals tried were found to give excellent blacks of any thickness above 4×10^{-5} mm. on films as thin as 5×10^{-5} mm.

* Pfund, A. H., *Rev. Sci. Inst.* **1**, p. 397 (1930); and *J. Opt. Soc. Amer.* **23**, p. 375 (1933).

The mechanism of deposition of these metallic blacks is not well understood, but it seems probable that the temperature of the surface is an important factor, as carbon dioxide, which is an even worse conductor than air, also proved equally unsuitable as the evaporating medium.

107. A Vacuum Tank for Use with a Single Crystal X-Ray Goniometer

By M. F. PERUTZ, Ph.D., and G. L. ROGERS

J. Sci. Instrum. **23**, p. 217 (1946)

On X-ray diffraction photographs of protein crystals, fibres or organic crystals of very small size, air scattering tends to obscure the central portion of the picture at angles $2\theta \leqslant 10°$. The elimination of this effect is often desirable and assumes particular importance in the case of substances of large molecular weight where clear observation of small-angle reflexions is essential. Since the majority of specimens do not require any apparatus more elaborate than the ordinary single crystal goniometer, it was decided to build a vacuum tank which is sufficiently large to take the instrument in use. Photographs taken in this tank show a striking absence of background compared with pictures taken in air under otherwise identical conditions. In cases where the diameter of the pinhole collimator is not limited by the small angle of the diffraction pattern which has to be recorded, the vacuum tank allows the use of pinhole systems of a width which would otherwise give rise to a prohibitive intensity of air scattering; wider pinholes, in turn, permit a substantial reduction in exposure time, which is particularly valuable in the case of small and weakly reflecting crystals.

A diagram of the instrument is shown in Fig. 131. It consists essentially of a steel tube 14·5 in. in diameter and 12 in. high, welded to a steel base plate $\frac{1}{2}$ in. thick. The lid consists of a similar plate recessed with a circular groove, machined flat and fitting on to the machined top of the steel tube. The two machined surfaces were further ground in by hand, until a greased joint between them was sufficiently effective to maintain a vacuum of about 1 mm. of mercury. The X-ray beam is admitted through a $\frac{1}{4}$-in. hole, covered with a thin nickel foil which serves at the same time as a filter for copper radiation. Electrical connexions for the goniometer motor are made through two Bakelite plugs sealed into the base-plate with Picein. The entire tank is mounted on three adjustable legs which slide on rails. Rails are also mounted on the base-plate inside the tank to carry the goniometer which can

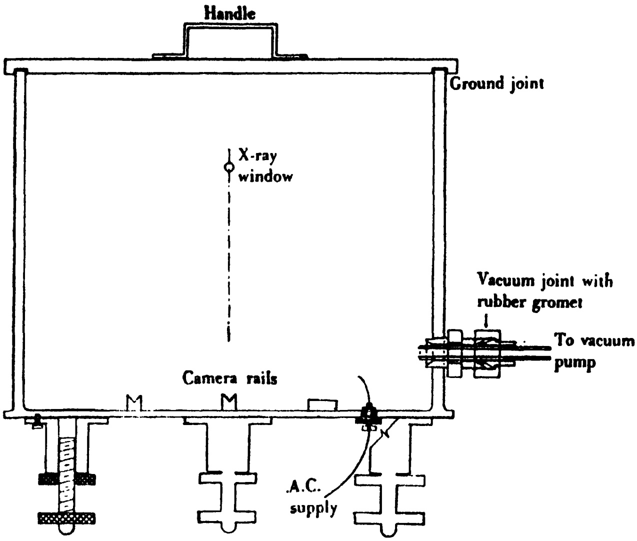


Fig. 131.—Vertical section through vacuum tank.
Scale 1 : 8, except for the tank-joint which is enlarged to 1 : 4.

thus be adjusted to the beam in the usual way. The tank is evacuated with a Hyvac pump which can maintain a pressure of below 1 mm. of mercury, if run continuously; actually, any pressure below 100 mm. of mercury is sufficient to reduce air scattering to negligible proportions.

108. A Vacuum Furnace

By W. Ehrenberg, Ph.D., F.Inst.P., and F. Ansbacher

J. Sci. Instrum. **20**, p. 164 (1943)

The authors describe a simple furnace with an internal heater, suitable for heat treatment of materials or parts under vacuum conditions which is both easy and economical to construct and to operate.

An ideal device from the physicist's point of view would be the combination of an immersion heater and a vacuum flask. While this combination is not easily adapted to ordinary high-temperature furnaces, it forms a ready model for a vacuum furnace. In a vacuum the exchange of heat takes place by radiation only. Heat losses are therefore reduced by a reflecting screen, e.g. of clean copper which has a high reflecting power in the infra-red. Glass, incidentally, is practically a "black body". The equilibrium temperature of the charge depends on the solid angle subtended at it by the heater. The heater therefore should have as large a surface as possible or preferably surround the charge completely, so that in equilibrium its temperature need not exceed the temperature of the charge by a large amount. Finally, in order to prevent an unnecessary loading up of the vacuum system by gas given

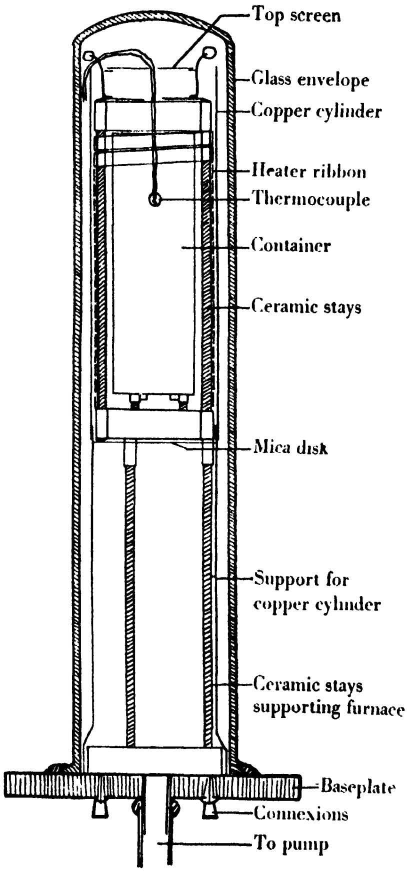


FIG. 132.—Cross-section of vacuum furnace.

off by the furnace itself, the whole construction should be as light, even flimsy, as is compatible with mechanical stability.

Fig. 132 shows a cross-section of the complete set-up, and Fig. 133 the details of the heater. The whole furnace is built up on a base-plate which carries the pumping tube and also the electrical leads, and is enclosed by a Pyrex glass envelope sealed to the base-plate with sealing compound. The heater element and the container of the charge are supported by three ceramic stays. The heater is a helix of nickel strip $\frac{1}{4}$ in. wide and 0·004 in. thick, wound closely on a set of six ceramic rods and forming an almost closed cylinder. It is spaced by thin ceramic washers which also guarantee a minimum spacing between the heater and the radiation screen outside as well as the container inside. The ceramic rods themselves are kept in position at the top and bottom by a rigid framework of nickel strip. The radiation screen is a cylinder of copper sheet supported independently, with copper shields at both ends.

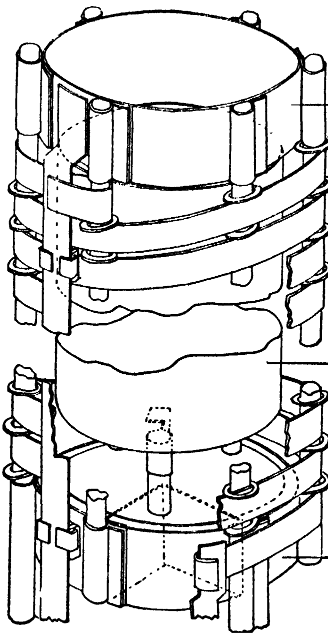


FIG. 133.—Details of heater of vacuum furnace.

A hole for observation and for the introduction of a thermocouple is provided in the top shield. Additional ceramic and mica spacers are fitted where necessary for electrical insulation.

Nickel was used as material for the heater element only because a more refractory material such as tantalum or molybdenum was not available. It has the serious disadvantage of evaporating noticeably *in vacuo*, even far below its melting point, so that the copper screen becomes in time coated with a nickel film the reflectivity of which is much lower than that of copper. As a result the temperature of the screen rises. When the furnace is freshly assembled and the heater loaded so that the charge is furnaced at 900° C., the screen is not glowing visibly. After several runs, however, the screen appears red hot in parts, for the same loading of the heater. Nevertheless, the glass envelope does not get unduly hot, even without special cooling. The copper screen is of course easily cleaned again. A fan keeps the base-plate sufficiently cold.

A good vacuum is readily obtained and the current consumption is moderate. A temperature of 900° C. is reached at 300–400 W., for a useful volume of 200 c.c. An idea of the performance can be obtained from the table, giving a typical record of a degassing process; a mercury pump of moderate speed was used, together with a liquid air trap.

Time	Heater V	Heater current (amp.)	Temp. ° C	Pressure mm. mercury
9.20*	—	—	—	—
10.15	10·5	4·4	560	5×10^{-4}
11.00*	10·5	4·4	570	1
11.50	14·5	5·6	660	2
12.30*	14·5	5·6	670	1
1.00	20	7·5	780	5
2.10*	20	7·9	800	1
3.10*	26	9·4	870	1
4.30	32	13·0	910	2

* Heater voltage increased after taking readings.

There are obviously no elements in the construction described which are difficult either to scale up or to scale down. The power required must be expected to increase with the two-thirds power of the volume. The maximum temperature is limited only by the material used for the heater ribbon and the container. With a nickel ribbon and a nickel container, the limit appears to be well above 900° C.

109. Making Very Thin Vacuum-Tight Glass Windows

By S. Rosenblum and R. Walen

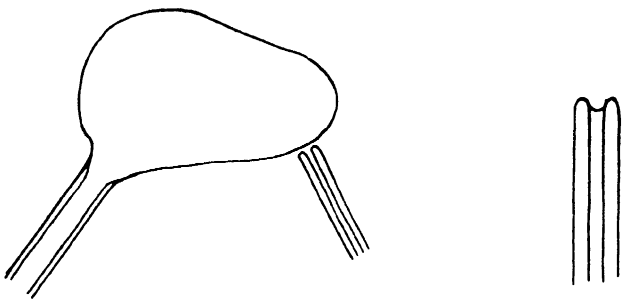
J. Sci. Instrum. **22**, p. 196 (1945)

Recently a method has been described for fusing thin mica windows on to glass or metal.* In certain cases it would be an advantage if a similar result could be obtained with windows of glass instead of mica, and we have recently succeeded in devising a simple method for this

* Donald, T. S., *Rev. Sci. Instrum.* **13**, p. 267 (1942).

purpose. For our experiments it was necessary to obtain windows thin enough to have a stopping power for α-particles equivalent to only a few mm. of air, and yet to be vacuum-tight against a pressure difference of 1 atm. or more.

The method is as follows: a bubble, thin enough to show interference colours, is first blown on the end of a glass tube. A second glass tube is then drawn down to 1 or 2 mm. internal diameter with thickened walls. Whilst the thickened end is still hot it is brought close to an area of the bubble which, judged by the interference colours, is of uniform thickness, and light suction is applied at the cold end of the capillary (Fig. 134 (*a*)). The thin glass wall of the bubble is thus drawn on to the heated end of the capillary and fuses to it. The final result is illustrated



(*a*) (*b*)

FIG. 134.—Making very thin vacuum-tight glass windows.

in Fig. 134(*b*); an advantage of this form is that the fragile window is protected by the robust wall of the capillary.

In this way we have constructed vacuum-tight windows with a diameter of 2 mm. and stopping-power of 4 mm. of air which were able to withstand a pressure difference of more than an atmosphere. When the windows are not subject to a pressure difference on the two sides they have a slightly crinkled appearance, but when a pressure difference is established they are drawn taut, rather like an elastic membrane.

It was found convenient to measure the thickness of the windows by determining their stopping-power directly for polonium α-particles. For this purpose a very simple α-particle counter* working in free air, developed by one of us in the Curie Laboratory in 1934, was employed.

Similar thin windows could be fused on to the end of a platinum tube by a similar method.

* Chang, N. Y., and Rosenblum, S., *Phys. Rev.* **67**, p. 225 (1945).

110. Danger of Explosion of Liquid Air Cooled Charcoal Tubes, and its Prevention

By J. TAYLOR, D.Sc., A.Inst.P.

J. Sci. Instrum. **5**, p. 24 (1928)

It is not generally known that highly activated coco-nut charcoal, as used in physical technique for the clear-up of residual gases, constitutes, with liquid air, a high explosive. Indeed, the method is used in some mines for coal-blasting. Any failure or crack of a charcoal tube immersed in liquid air may, if the charcoal is sufficiently activated, result in a violent explosion.

It is possible to avoid any danger of the liquid air coming in contact with the charcoal by surrounding the charcoal tube with a thin, fairly tightly fitting, metal tube. A few degrees of temperature may be lost in this manner, but there is no great danger in the case of failure of the inner glass.

A still better method is to utilize, instead of the charcoal, silica gel, precipitated from water-glass. This is just as efficient as charcoal when activated, and there is no danger whatever on failure of the container.

111. An Adjustable Resistance

By Sir ALFRED EGERTON, F.Inst.P., F.R.S., and M. MILFORD, M.A.

J. Sci. Instrum. **7**, p. 299 (1930)

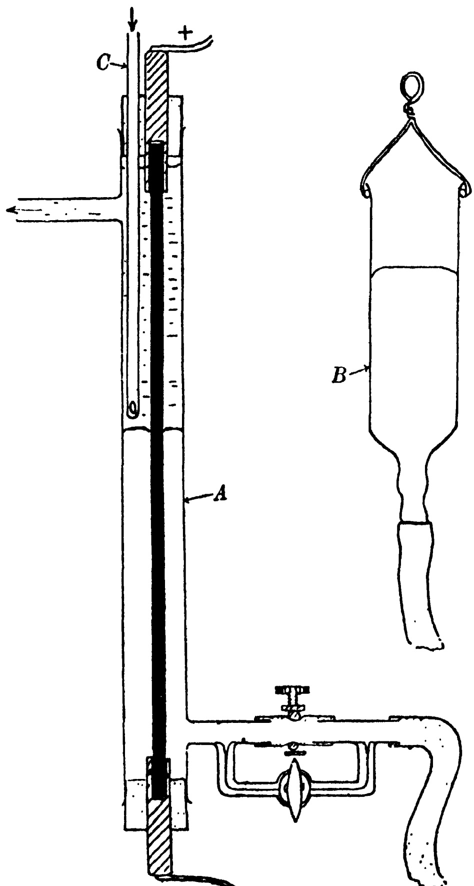


FIG. 135.—An adjustable resistance.

It is often difficult in the laboratory to find a means of regulating the resistance of a circuit carrying large currents. Wire rheostats become heated and change their resistance so that the current cannot be kept constant easily, unless they are made cumbersome and costly. Carbon plate resistances are not easily reset to a former position. Electrolytic resistances suffer from various irregularities. A simple and effective apparatus is here described which has been used for adjusting currents over a range of about 10 to 40 A. (see Fig. 135). It could also be designed for other ranges.

A glass tube *A* (50 × 2 cm.) is provided with two rubber bungs, through each of which pass two closed tubes for connexion to the leads, the lower one in contact with mercury is of iron, the upper of brass. A carbon rod (43 × 0·5 cm.) fits into these tubes; an arc carbon serves very well. The total resistance of the rod is about 0·6 Ω. Mercury can be let into the tube from a reservoir *B* either rapidly or slowly by means of a screw clip or a capillary tap. By this means the effective length of the rod is altered and its resistance can be decreased to about 0·02 Ω. To keep the rod cool, water is passed through the tube *C*, the height of which can be adjusted. The current can thus be changed in a *continuous* manner or maintained constant at any point in the range.

112. A Variable Low Resistance

By W. H. Walton, B.Sc., F.Inst.P.

J. Sci. Instrum. **15**, p. 106 (1938)

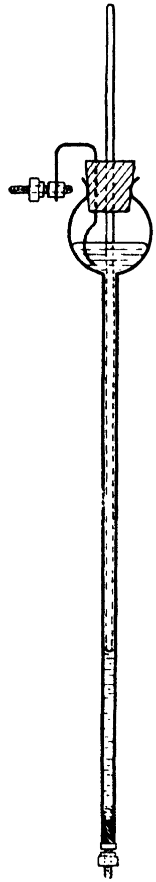


Fig. 136.—Variable low resistance.

The accurate adjustment of an electric current passing through an apparatus such as a potentiometer or a standard lamp often presents some difficulty owing to the lack of smoothness of action which is frequently found with ordinary wire-wound variable resistances which incorporate sliding metallic contacts. These irregularities may be bridged by including in the circuit a variable low resistance described below, having a maximum value of, say, one twenty-fifth of an ohm, provided that this resistance is continuously variable.

A column of mercury, approximately 30 cm. long and 5 mm. diameter, is enclosed in the stem and lower part of the bulb of a thistle funnel (Fig. 136). A terminal, which serves the double purpose of making contact with the lower end of the mercury column and of preventing the escape of mercury, is fastened into the lower end of the tube with sealing-wax. Contact with the upper end of the column is made by a stout wire or strip of metal which dips into the mercury contained in the bulb of the funnel. The resistance of the device is varied by raising or lowering into the stem of the funnel a glass rod, 4 mm. in diameter, which displaces part of the mercury from the column, reducing its cross-section to an annulus between the rod and the tube, and thus greatly increasing its resistance. The glass rod is loosely held in position by a cork fitting into the mouth of the funnel.

113. A Simple Heavy-Current Resistance

By F. A. Cunnold, D.Phil., A.Inst.P., and M. Milford, M.A.

J. Sci. Instrum. **11**, p. 199 (1934)

The authors recently had need of a resistance of about 2 Ω, which would carry a current of at least 60 A. and would remain as constant as possible under any given load. A wire resistance was too cumbersome and an electrolyte too inconstant. For powers of this order, water cooling is almost essential and, accordingly, units were made as shown in Fig. 137. The design has proved both effective and extremely cheap and it requires very little space, considering the large amount of power which can be dissipated.

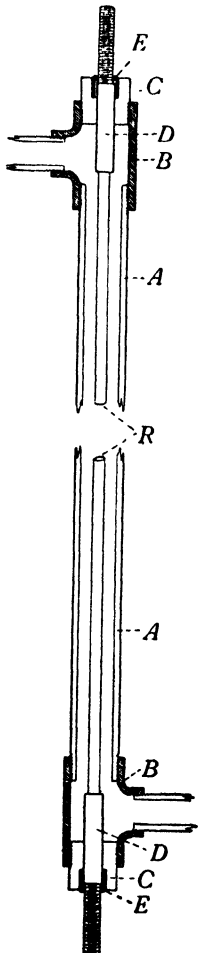


Fig. 137.—A simple heavy-current resistance.

The resistance element is a carbon rod, *R*, $\frac{1}{4}$ in. in diameter and about 18 in. long. This is mounted in a water-jacket built up from $\frac{3}{4}$-in. gas pipe, *A*, with a $\frac{3}{4}$, $\frac{3}{4}$, $\frac{1}{2}$-in. tee, *B*, at each end. The axial ends of the tees were closed by fibre plugs, *C*, screwed into them and these were drilled to take the steel carbon-holders, *D*, which were $\frac{3}{8}$ in. in diameter and were bored to be a tight push fit on the carbon rods. The joints were made water-tight by filling the recesses *E* with bitumen.

Each unit had a resistance of about $\frac{2}{3}$ Ω and three units in series were tested; the water-jackets were connected directly by short lengths of $\frac{1}{2}$-in. rubber pipe. Using a water flow of 16 l./min. (which is less than half the maximum flow possible with ordinary water mains) the figures observed were:

Current amperes	Voltage drop volts	Power kW	Resistance ohms	Temperature rise
31	60	1·8	1·95	1°
45	87½	3·9	1·93	2·7°
60	115	6·9	1·91	5·2°

There was no trouble with electrolysis, the water flow prevented accumulation of bubbles, and the course is sufficiently broken in direction to prevent stream-line flow. A small length—about 2 ft.—of rubber hose connexion was found adequate insulation to stop any appreciable amount of current being conveyed to other pipes or conductors. At a given load the resistance was constant to the accuracy of the measuring instruments used, which was about ½ per cent.

114. Measuring the Length of Resistance Wires

By S. MUNDAY

J. Sci. Instrum. **9**, p. 168 (1932)

When winding a resistance coil which involves the use of more than a yard or two of wire it is rather a problem to know just how much to wind on the spool or bobbin. Direct measurement of length is often impracticable. The approximate length required may be obtained from tables which usually give resistance per thousand yards. An indirect method of measurement is obtained by a very simple apparatus.

A Veeder or similar light type of counter has an aluminium disc attached to the spindle. The disc has a small groove in its edge, the pitch diameter being such that its circumference is 6 in. The wire is fed from the reel to the spool via the disc on the counter. As large an arc of the disc as is practicable should be embraced to prevent slipping.

The necessary number of yards of wire multiplied by 6 will give the difference between the counter readings from start to finish of the winding. It is advisable to allow a small percentage over this length so that adjustment may be made.

115. A Simple Electrical Time-Cycle Process Controller

By K. HOSELITZ, Ph.D., F.Inst.P.

J. Sci. Instrum. **22**, p. 97 (1945)

Time-cycle programme or process controllers for regulating external conditions such as temperature, pressure, etc., to a predetermined programme, usually have serious disadvantages, such as insufficient adaptability for a research laboratory, high cost or complicated mechanism.

A description of the principle and construction of a process controller which was devised to overcome all these disadvantages is given below.

The underlying principle is based on the control of the rectilinear movement of a component such as a slider of a rheostat, a piston or a lever. This linear movement has to be produced by a screw. The description of the apparatus which is illustrated in Fig. 138 is restricted to the control of heat treatment by means of a rheostat.

The moving member is the slider of the rheostat R with screw motion traverse. This screw is driven by a reversible electric motor, M_1; we have used both a reversible a.c. motor and a small d.c. motor. Since the motor M_1 moves the slider of R it is obvious that if it can be governed to go through a prescribed cycle it will control to a predetermined programme. The control of the motor is as follows. The slider carries an arm A, rigidly attached to it, and this arm has a brush-holder B fastened to its free end. The brush-holder B is made

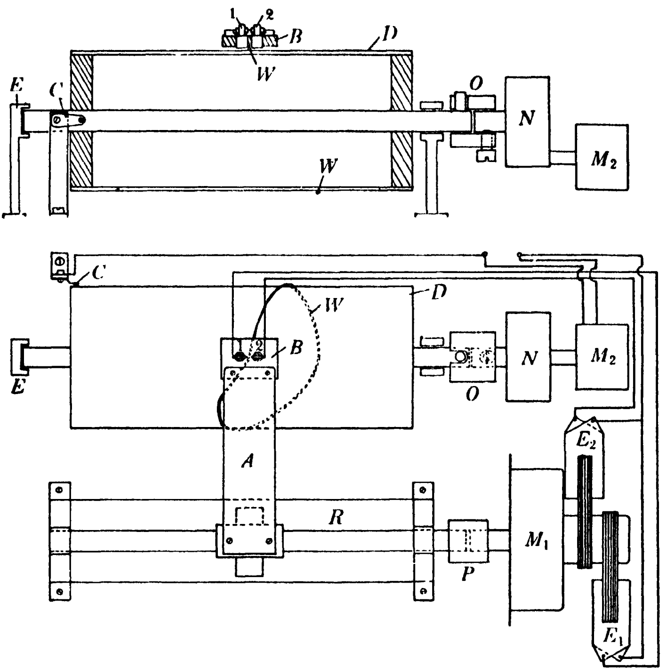


FIG. 138.—Section-elevation, plan and wiring diagram of time-cycle process controller.

of insulating material, such as Micanite or Paxolin, and houses two flat contacts, 1 and 2. The contacts lie in one plane at right angles to the sweep of A as shown in the figure and are about $\frac{1}{2}$–1 mm. apart.

Parallel with the movement of the rheostat slider lies the axis of a rotating brass cylinder B of about 2 in. diameter and of the same length as the travel of the slider. The brushes have to slide with light pressure on the surface of the drum. At one end of the drum a sliding contact C presses against the surface of D. The whole cylinder, which is insulated from the rest of the apparatus by flanges of ebonite (shown cross-hatched in the figure), is rotated by a small motor or clockwork movement M_2. As will be seen below if a periodic cycle is desired, M_2 should be geared (N) to give one revolution per period, since the identical programme can be repeated by further revolutions of the drum. In the case of an ordinary cooling or heating treatment this condition is not necessary. A wire W, of 20–24 s.w.g., is soldered to the drum. The position of this wire determines the programme to be controlled.

The electrical circuit is shown in Fig. 138. The sliding contact C is connected to one terminal of the source of supply, and each of the contacts 1 and 2 is wired to one coil of M_1. The other ends of these coils E_1 and E_2 are joined and taken to the remaining supply terminal. The connexions between E_1 and E_2 and the respective contacts 1 and 2 have to cause the motor M_1 to rotate in such a direction that when the wire makes contact with one of the two brushes the slider will move the corresponding brush away from the wire W and approach the other one. Thus the wire W is always kept sliding on the small insulating gap between the two brushes, and hence the slider will be following the axial co-ordinate of the position of the wire.

If the rheostat be calibrated so that for a given position of the slider a given temperature is maintained in the furnace, the position of the wire can be plotted on the drum for any given programme and the wire soldered accordingly. It is of advantage to make the drum removable by means of a clutch O and a spring bearing E. A number of interchangeable drums can then be kept for a variety of cycles.

If the programme is not periodic, but if, for example, a cooling or heating treatment is required, the wire can be soldered on to the drum in the form of a spiral and several revolutions of the drum can be utilized. One has to make sure, in this case, that the brushes cannot make contact with two adjacent turns of the wire.

Brass contacts and copper wire gave satisfactory service if the contacts and wire were periodically cleaned with fine emery paper. If this is not convenient, silver wire and silver-tipped contacts can be used, and we found this dispensed with the necessity for cleaning. However, on making and breaking contact between brushes and wire, slight arcing takes place which tends to burn the surface of the insulating material of the brush holder. This can be avoided by using hard Micanite or by covering the surface of the brush holder with a thin piece of mica.

The instrument described has been used in this laboratory successfully for the past four months. It controls a linear motion produced by a screw. By means of a screw or gear any linear motion can be converted into rotation and vice versa. The instrument is furthermore simple to construct, since it dispenses with powerful motors, cams and gears, and it can be assembled in any laboratory workshop out of stock materials, and is capable of very wide adaptation.

116. A Simple Power Control Circuit

By J. G. Holmes, B.Sc., F.Inst.P.

J. Sci. Instrum. **18**, p. 49 (1941)

Series-parallel switching is commonly used for a coarse control of electrical energy consumption in heaters, lamps, etc. The degree of control is increased if the usual double-pole, double-throw switch is separated into two single-pole, double-throw switches, but there is a

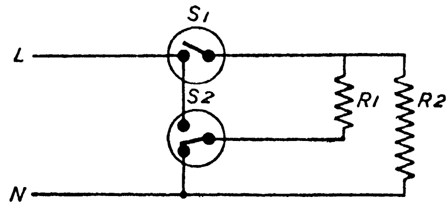


Fig. 139.—Circuit for three values of power and "off".

risk of short circuiting the main supply if the connexions are incorrect. Figs. 139 and 140 show two simple circuits which avoid this risk and which economize in switches. Common 5-A. tumbler switches will control up to 1,000-W. lamps or heaters on 230-V. supply so as to

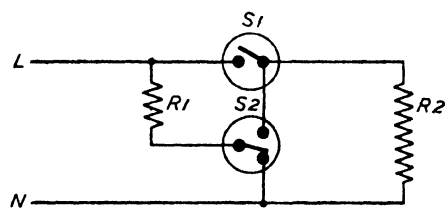


Fig. 140.—Circuit for four values of power.

give three different power consumptions and "off" as in Fig. 139 or four different power consumptions as in Fig. 140.

The following table shows an example worked out for a 230-V. supply in which R_1 is 105·8 Ω and R_2 is 52·9 Ω, corresponding to 500 W. and 1000 W. respectively.

Switch position	Power consumption (watts) Fig. 1	Fig. 2	Circuit
S_1 open S_2 down	Off	500	Off/R_1 only
S_1 open S_2 up	333	333	R_1 and R_2 in series
S_1 shut S_2 up	1000	1000	R_2 only
S_1 shut S_2 down	1500	1500	R_1 and R_2 in parallel

The Institution of Electrical Engineers' regulations require that the switch S_1 in Fig. 139 should be in the live L line of the supply. The live and the earth or neutral lines N can be conveniently identified by connecting each line in turn through a lamp to an earth connexion, when the lamp will light for the live line and will not light for the neutral line.

117. A Wide Range Motor Speed Control

By O. H. SCHMITT, Ph.D.

J. Sci. Instrum. **15**, p. 303 (1938)

In the laboratory the need sometimes arises for a small motor with the intrinsic good regulation of a shunt motor but with speed smoothly adjustable through a wide range. This need can be met very satisfactorily by the arrangement illustrated in Fig. 141. An ordinary shunt motor is reconnected with its armature and field coils in series across the full mains potential, the field being reversed if operation in the original direction is required. The point common to both armature and

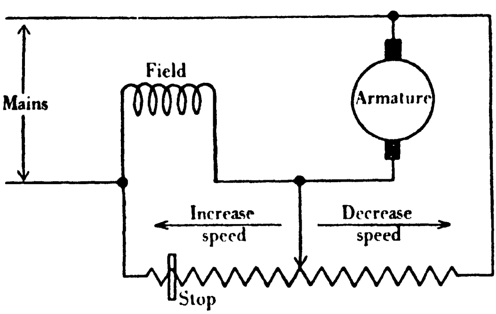


FIG. 141.—Wide range motor speed control.

field is led off to the movable contact of an ordinary slide potentiometer which is also connected across the mains. Upon moving the potentiometer in one direction the field is strengthened and the armature voltage is decreased; this produces a reduction in armature speed until at the extreme end the speed falls to zero. Moving the potentiometer contact toward the opposite end, the field is weakened and the armature voltage increased, giving a greatly increased speed. Either a stop should be fitted to the potentiometer near the high-speed end or a small permanent resistance should be incorporated; otherwise the armature speed may accidentally become excessive. Care should also be taken that the arm is not left too long at the zero speed position as the fields may heat excessively in motors normally cooled by an air impeller.

For best operation the potentiometer should have about the same total resistance as that of the motor when operating normally at full load. For all small 200–250-V. mains operated motors, a 300-Ω unit will serve very well, but should be constructed to carry at least 1·5 A.

While this method of control is admittedly wasteful of power, its several advantages far outweigh this item in small installations. Regulation at low speeds is exceptionally good because of the low armature shunt impedance offered by the potentiometer. This action along with the strong field makes available a strong dynamic braking action when the control is moved toward zero speed. Stable operation is obtained over a ratio of speeds of 100 : 1 in a range from one revolution per second to 6,000 r.p.m.

118. A Simple Method of Making Contacts with Thin Metal Foil

By R. V. Jones, D.Phil., F.Inst.P.

J. Sci. Instrum. **12**, p. 122 (1935)

The problem of making satisfactory electrical connexions to thin metal foil occurs frequently in fine instrument work, e.g. the construction of galvanometers, gold-leaf electrometers, radiation thermopiles and bolometers. The ordinary method of soldering is difficult to apply, because the surface tension of the solder causes the foil to shrivel up, and frequently the foil is soluble in the solder. Moreover, the mass of solder is likely to be greater than the mass of the foil, so that the heat capacity is very seriously increased ; this lengthens the time of response of radiation measuring instruments. Spot welding can be employed with some success, but the welds are generally weak. Recent attempts to construct bolometers have led the writer to develop a convenient technique for joining gold foil of 0·1 μ thickness to stouter pieces of metal. The method has the merit of working best for thin foil, and becomes effective about the point where soldering is impossible ; it will not work satisfactorily if the thickness of the foil is greater than 2 μ. It also provides an efficient way of joining two pieces of thin foil together.

The piece of metal to which it is required to join the foil is cleaned with fine emery paper, and the point of contact is moistened with alcohol applied with an artist's paint-brush. The foil is taken at one end by tweezers, and the other end allowed to fall on to the moistened surface.

The surface tension of the alcohol pulls the foil into intimate contact with the surface, and when the liquid has evaporated it will be found impossible to strip the foil off again. If desired the joint can be further strengthened by laying another piece of foil across the point of contact of the first, while there is still some alcohol left.

Two pieces of thin foil can be joined together in a similar way, but in this case it is better to use a dilute solution of pyroxylin in amyl acetate as adhesive. One piece of foil is laid on a piece of cardboard with its extremity projecting over the edge ; a drop of the solution is placed on some paper, and one end of the other piece of foil is allowed to fall on to the surface of the drop. It is then carefully removed, and transferred rapidly so that the moistened end of the piece of foil held in the tweezers falls on to the projecting end of the other piece. The surface tension of the liquid pulls both foils into good contact, and the solvent evaporates, leaving a minute amount of pyroxylin round the edges of the junction to act as a cement. It has been found that alcohol generally causes the foil to shrivel up, and rarely makes a sound joint.

Wire can be joined directly to foil in a similar way, so long as the diameter of the wire is greater than about 0·05 mm. The ends of wire smaller than this should be rolled into strip, when they can be joined with ease.

It will be seen that the increase in mass due to the junction is negligible, so that the technique is eminently suited to the construction of radiation instruments. The resistances of junctions made in this way have been measured, and it has been found that the resistance of a composite strip of several pieces of foil joined end to end was the same as that of a single strip of the same overall dimensions. The resistance of the contacts is therefore very small. Photographic records of the resistance of junctions made in this way have been taken over periods of days, and the resistances have been found constant within the accuracy of the record—about 0·25 per cent.

119. The Use of Wollaston Strip for Suspensions

By D. W. Dye, D.Sc., F.R.S.

J. Sci. Instrum. **6**, p. 203 (1929)

The finest form in which wire is obtainable is the well-known Wollaston wire consisting, when purchased, of a platinum core within a silver sheathing, used to enable it to be drawn down much finer than would be possible without the covering.

Although it is possible to obtain Wollaston wire as fine as $3\,\mu$ diameter, those who have attempted to use it will appreciate the difficulties associated with the successful suspension of, say, an electrometer needle with it. The use of quartz fibres enables a smaller control force to be obtained than any other known form of suspension, but on certain apparatus the extreme insulating properties of such fibres cause troubles by reason of the charges which accumulate on the suspended portion of the instrument. The use of metallized fibres has not been found satisfactory in many cases, so that a reversion to a metal suspension becomes necessary in such cases. It occurred to the writer that it might be possible to roll down the Wollaston wire in jewellers' rolls before removal of its outer silver coating, in the hope that a very thin platinum strip would result.

Experiments made on some wire with 7 μ core proved fairly successful, but not quite satisfactory. A further supply of wires of various diameters was obtained. The results on this wire were entirely disappointing, since the platinum core appeared to be either quite unaffected or broken into short lengths by the process. Enquiries elicited the information that two kinds of Wollaston wire are made, one kind encased in fine silver and the other in standard silver. It appears that the fine silver casing is so soft that it will not squeeze the core flat in rolling. The standard silver is, however, much harder and does, when rolled out, give a core which is also in strip form.

The technique is very simple. A length of wire encased in standard silver is rolled out in jewellers' rolls, and presents a strip of width from 10 to 15 times its thickness. A length is cut off suitable for the purpose in view. The two ends are soldered on to a little copper wire fork so as to form a U-shaped loop. This is lowered down into diluted nitric acid, leaving a few millimetres at each end above the surface of the acid. When the silver is dissolved away, it will be seen that a beautifully fine and smooth platinum strip is left. The ends can then be unsoldered from the copper fork and attached to the appropriate parts of the apparatus concerned.

In the cases in which most experience has been gained, a wire of 7 μ nominal diameter core has been used. This, when rolled out, gives a strip about 2·5 μ thick and 15 μ wide. The torsional control was found by experiment to be one-eighth part that of the unrolled wire and, therefore, represents a very considerable gain in sensitivity without loss in supporting power of the suspension. The period of a very small electrometer needle of the Compton type, weighing only 4 or 5 mg., was 8 sec. when swinging freely on such a suspension, and was nearly aperiodically damped. The zero keeping qualities were very good, and were much superior to those of a metallized quartz fibre.

A number of electrometers have been suspended at the National Physical Laboratory in this manner, and have given every satisfaction. The strip is much easier to handle at every stage than the corresponding unrolled wire. Successful strip can be rolled from 4-μ wire: although narrower than that given by 7-μ wire, it is not much thinner, so that the gain in sensitivity is not so great. The ratio of control torque before and after rolling is in this case about 5:1.

120. The Manipulation of Wollaston Wire

By H. E. Bennett

J. Sci. Instrum. **19**, p. 168 (1942)

There are many uses in modern scientific instruments for fine platinum wire, among which may be mentioned micro-fuses, special lamp filaments, and devices for measurement of air flow and the heat conductivity of gases. A platinum wire of 10 μ diameter, or less, has also been found to be preferable to the use of a gold leaf on an electroscope, as it provides a fine line for observation. The following hints on the manipulation of this wire may be of use.

Platinum can be drawn directly to a diameter of 10 μ, but the method of Wollaston is employed for producing the finest wires. Wollaston wire is prepared by pressing a rod of platinum into a close-fitting pure silver tube making a sheath, say, ten times the diameter of the platinum, and this composite rod is rolled and drawn to wire. The wire is supplied in this condition and the silver sheath is dissolved in nitric acid by the user, leaving a very fine platinum wire. Wollaston wire can be reduced to a diameter of 1 μ. The technique for handling Wollaston wire presents no real difficulty and in some cases the operation may be simplified by mounting the wire before dissolving the silver sheath. An example may be given of a typical operation for mounting a platinum filament 0·0004 in. diameter to an electroscope. A length of Wollaston wire is straightened by gently rolling with the finger on a flat surface; then a small bead of silver is made at one end by fusion in a gas flame. The bead serves as a weight to produce a slight tension on the final filament. The wire is immersed to the required length in a 30–50 per cent aqueous solution of nitric acid, heated to about 70° C., until the silver sheath is dissolved. The small bead will also begin to dissolve and its final size can be controlled by the period of immersion. It is advisable to use distilled water in preparing the dilute acid, as the use of tap-water may produce a cloud of silver chloride making it difficult to observe the immersed wire. The cleaned filament may then be soft-soldered into position, while handling the wire by the remaining silver sheathing.

In some applications it may be desirable to attach the filament to a platinum wire of larger diameter by welding. This may be done by placing the filament in position across the platinum wire, or preferably by winding it for a complete turn round the thicker wire, and then passing an electric current through the thicker platinum only, to heat it to about 1500° C., when a firm weld will be effected.

Fine platinum wire might find a wider application in micro-fuses. The fusing current of a wire is largely determined by the heat con-

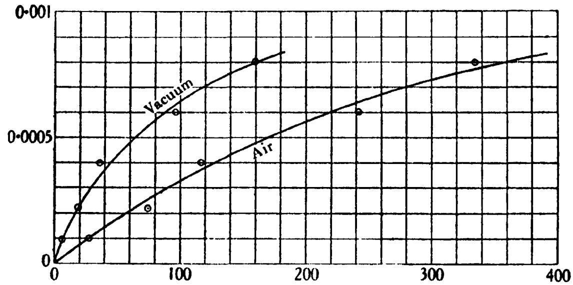


Fig. 142.—Fusing current of fine platinum wires.

ductivity of its surrounding atmosphere, and therefore by mounting the wire *in vacuo* very low-rated fuses may be obtained. Fig. 142 shows the fusing current, in milliamperes, of fine platinum wires, both in air free from draughts and in a vacuum of 0·02 mm. pressure. This graph may be used for selecting fuse wire or as a guide to the current required to produce a heated filament.

121. Cleaning Fine Copper Wire

By D. A. Bell, B.Sc., A.M.I.E.E.

J. Sci. Instrum. 19, p. 79 (1942)

The usual method of cleaning the insulation off the end of a length of Litz wire is to make it red hot and then quench in alcohol; this removes both silk and enamel insulation from the individual strands, and leaves them all bright and in a condition to solder. The method becomes difficult, however, if the whole stranded cable is of very small section (e.g. 3—46's), for two reasons: first, owing to the small ratio of thermal conductivity along the cable to surface exposed to the flame, the wire tends to reach a higher temperature than a thicker cable would, and its temperature rises so rapidly that it is difficult to control, by choice of position in the flame; and secondly, owing to the small ratio of mass of copper to exposed surface, it is impossible to avoid cooling of the wire between the flame and the alcohol bath, and the oxide on the surface of the wire is then not reduced.

The remedy is to wrap the thin wire which is to be cleaned round a piece of solid copper wire, say, 26 or 30 s.w.g., and subject the combination to the usual treatment. The thicker wire provides the necessary thermal time constant and stability, and in practice does not prevent the cleaning of the side of the thin wire which is in contact with it. With this method it is possible to clean even single strand of fine wire by the heat method.

122. Testing Repaired Coil Galvanometers

By S. MUNDAY

J. Sci. Instrum. **20**, p. 32 (1943)

When dealing with repairs to moving-coil instruments the first thing necessary, after repairs are completed, is to test the moving parts for freedom of movement. Where the variable minute amounts of power are not readily available the following method has been found useful.

A thermocouple is connected across the moving coil. This can usually be done by means of spring clip connectors. The application of a little heat to the junction will generate sufficient e.m.f. to send the pointer gently across the scale. Practically any two dissimilar wires may be used for the couple; e.g. copper-iron, copper-Eureka, etc. It is advantageous to use wires of about 22 or 24 s.w.g. as, when the source of heat is removed, the temperature drop of the junction and the consequent return of the pointer take one or two seconds. This very slow movement shows quite clearly whether there is any sticking of the coil or pointer.

When dealing with suspended-coil galvanometers, the heat of one's finger-tips is usually sufficient to give full-scale deflexion.

123. A Simple Clamp for Fine Wires

By L. BAINBRIDGE-BELL, M.A., M.I.E.E.

J. Sci. Instrum. **8**, p. 391 (1931)

The clamp for fixing fine wires, described below, was devised for use in a low-current fuse with an easily replaceable element, but appears to have many applications.

Two terminals *T* are fixed to brass strips *B*, to each of which is soldered the lower part of a small size Newey press fastener (obtainable from drapers). The fuse wire is taken two or three times round the knob of one fastener and the top of the fastener snapped into place;

this operation is repeated on the other fastener. It will generally be found that the wire is thus securely held, but, if the fastener is loose, a soft washer placed over the wire will improve the grip.

FIG. 143.—Clamp for fine wires.

The advantages are: (*a*) no soldering, and (*b*) no securing of the wire by small screws, which on tightening often break the wire.

Fuses of 48 s.w.g. Eureka wire, made in this way, have been in use in the high tension circuits of a sensitive radio receiver for some months and have shown no signs of bad contact. The device has been successfully used to hold spiders' webs.

124. A Connector for Wires—Particularly for the Cold Junctions of Thermocouple Wires

By R. J. M. PAYNE, B.Sc., F.I.M.

J. Sci. Instrum. **11**, p. 231 (1934)

For purposes of temperature measurement in the laboratory, it is usual to immerse the junctions between the ends of the thermocouple wires and the leads of the measuring instrument in melting ice. In order that the thermocouple may be readily detached from the instrument leads, some form of screw terminal is often soldered to the latter. When each thermocouple wire has been secured in its terminal, both thermocouple wires and terminals are pushed to the bottom of glass tubes fitted to the stopper of the vacuum flask containing the ice.

As it is frequently necessary to remove from, or to thread insulators on to the thermocouple wires, and as it sometimes becomes necessary to thread the couple wires themselves through holes in other apparatus, it is desirable that no bending of the thermocouple wires should be involved in the making of the connexion.

A form of terminal which has been found successful, and which may prove useful for other purposes, is shown in Figs. 144–6. Both body and cap of the terminal are machined from ¼-in. diameter round bar. One end of the body is turned down and screwed 3 B.A., the end coned, and then this end and part of the body are split by sawing as shown by the unshaded portion of Fig. 146. The saw-cut is made of such a width that the thermocouple wire used can be easily accommodated therein. The cap is screwed and coned internally to match the body, and is knurled externally to provide finger-grip. End clearance to the conical part of the body is provided so that bottoming

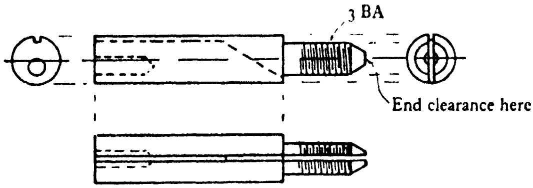


Fig. 144.—Body.

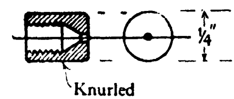


Fig. 145.—Cap.

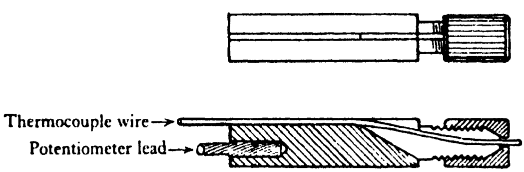


Fig. 146.—Complete terminal and section showing thermocouple wire in position.

does not occur. In using the terminal, the thermocouple wire is laid along the saw-cut and threaded through the hole in the cap as shown. In screwing-up the cap the two halves of the body are pinched on to the wire, making a low-resistance connexion.

The connector may be made of hard-drawn brass rod, but care should be exercised in soldering it to the instrument leads, that the screwed end be kept cool in order to avoid softening of the material.

125. The Assembly of a Sensitive Thermopile

By H. E. Beckett, B.Sc.

J. Sci. Instrum. **6**, p. 169 (1929)

The design of a sensitive thermopile usually permits of the direct attachment of the thermo-elements to a permanent supporting frame. Certain special types, however, require assembly on a temporary base, the removal of which may occasion some difficulty. The thermopile shown in Fig. 147 is illustrative. Small strips of tinfoil attached to the hot junctions are over-lapped slightly, like the slats of a Venetian blind, to form an unbroken receiving surface. This, in the finished instrument, is supported only by the fine bismuth and silver wires, which are bent round and anchored in ridges of shellac on the sides of the mounting-block.

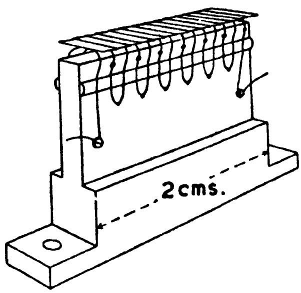


FIG. 147.—Thermopile requiring assembly on a temporary base.

Coblentz, to whom this design is due, recommends that the receiving surface be built on a strip of glass attached to the block by water-soluble glue. When the instrument is complete the glue is dissolved and the glass strip withdrawn.

It has been found almost impossible to perform this last operation without breaking some of the bismuth wires. The following method, which removes the danger of mechanical injury, has proved very satisfactory. Icing sugar made to a stiff paste with water is pressed on to the block, which may be slotted to ensure adhesion. When hard the sugar is pared to shape and the elements are mounted on it with seccotine

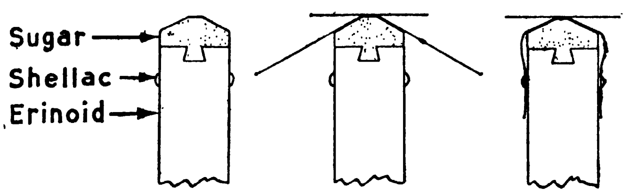


FIG. 148.—The assembling of a sensitive thermopile.

(Fig. 148). Finally both sugar and seccotine are removed by solution in water. In this way a delicate operation is performed with certainty and precision.

126. Low Tension Supply

By A. F. DUFTON, M.A.

J. Sci. Instrum. **9**, p. 265 (1932)

It does not appear to be generally known that small currents, such as are required for the operation of relays, can conveniently be taken from a.c. mains by the use of small condensers.

A 2-μF condenser will pass a current of one-eighth of an ampere on 200 V., 50 c/s, and is found to be generally suitable. Where one main is at earth potential it is preferable to connect the condenser to the other as shown in Fig: 149.

When the operating coil is short-circuited by means of the switch or by the contacts of a thermostat, for example, it ceases to be energized and the current through the condenser is wattless. The operating coils of several relays can be placed in series and fed from one condenser.

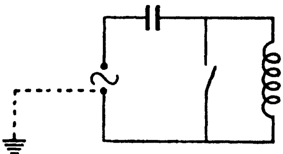


FIG. 149.—Circuit for low-tension supply.

A paper condenser, which is quite satisfactory, is not only lighter and less bulky than a transformer but also cheaper.

127. A Device for Maintaining a Steady Direct Current

By H. H. POTTER, Ph.D., F.Inst.P.

J. Sci. Instrum. **11**, p. 95 (1934)

It is often desirable in research problems and particularly in furnace temperature control to obtain a source of current much steadier than can be obtained from a battery which is being used by others, whereas the cost of a separate battery may be prohibitive if large currents are required. A method is described below whereby the current supplied by d.c. mains or by the main laboratory battery B_1, can be stabilized by taking a small compensating current from a bank of accumulators B_2 of small capacity (Fig. 150).

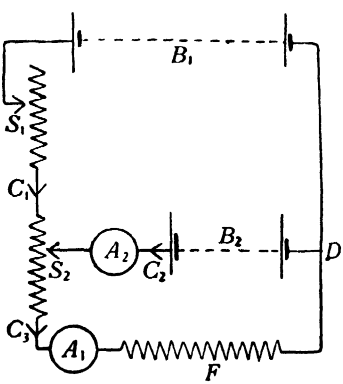


FIG. 150.—Circuit for maintaining a steady direct current.

The current supplied to the furnace F is regulated by the rheostat contact S_1 and measured by the ammeter A_1. The battery B_2 is connected through a sensitive centre-zero current instrument A_2 to a rheostat contact S_2, which is so adjusted that practically no current flows from B_2.

Two methods of using this device can be used, the first of which is perfectly automatic. Let the resistance from the point D to S_2 via B_1 be R_1, from D to S_2 via B_2 be R_2, and D to S_2 via F be R_3. Let the currents in the various parts of the circuit be C_1, C_2, C_3 as indicated, C_2 being very small. Then we have

$$C_3 = \frac{R_2E_1 + R_1E_2}{R_1R_2 + R_2R_3 + R_3R_1},$$

where E_1 and E_2 are the e.m.f.s of the batteries B_1 and B_2. If E_1 changes by a small amount ΔE_1, the corresponding change in the furnace current C_3 is

$$\Delta C_3 = \frac{R_2}{R_1R_2 + R_2R_3 + R_3R_1}\Delta E_1.$$

The success of the method depends therefore on making R_2 as small as possible. This sets a lower limit to the capacity of B_2, since the resistance of a cell is naturally greater the lower its capacity. The resistance of A_2 was made very small by using a heavily shunted micro-ammeter. In the absence of any compensating device R_2 is infinite, then

$$\Delta C_3' = \frac{1}{R_1 + R_3}\Delta E_1.$$

In the actual experiment for which this circuit was devised, the values were approximately $E_1 = 96$ V., $E_2 = 48$ V., $R_1 = 12\ \Omega$, $R_2 = 0{\cdot}7\ \Omega$, $R_3 = 12\ \Omega$. Then for a given change in E_1

$$\Delta C_3/\Delta C_3' = 0{\cdot}104.$$

Thus the compensating device eliminates about 90 per cent of the current changes caused by mains fluctuations.

The device can be used in a second way which theoretically at least eliminates all fluctuations in C_3. By moving the contact S_1 so as to keep the current through A_2 zero, the current in the furnace is kept constant to the same degree that the e.m.f. of B_2 is constant when no current is flowing from it. This is equivalent of course to potentiometer control of current but has the advantage that temperature fluctuations due to delay in adjusting S_1 are greatly reduced by the temporary current supplied by B_2. This method has been used to control the temperature of a furnace of very low heat capacity, working at 800° C. Owing to lack of space the furnace was very ineffectively lagged. B_1 was the laboratory battery of 600 ampere-hour capacity, and B_2 was a battery of 20 ampere-hour capacity. Provided there were no big demands by others from the battery B_1 causing large changes of e.m.f. (due to its internal resistance) the furnace temperature could be kept constant by the first method to about 0·5° C. The accuracy of the second method depends on the closeness with which A_2 is watched, but it was found quite possible for an observer to carry out other detailed observations and yet keep the furnace temperature constant to 0·2° C. for considerable periods.

The main difficulty of the second method lies in keeping clean contacts at S_1 and S_2. It is necessary for this purpose to run the rheostats considerably below their rated value and so avoid undue heating. It is possible that the current through A_2 could be utilized to move the contact S_1, and so make the second method of control automatic, but this has not yet been tried.

128. A Constant E.M.F. Device

By Sir Alfred Egerton, F.Inst.P., F.R.S., and J. M. Mullaly

J. Sci. Instrum. **7**, p. 203 (1930)

It is convenient for various purposes to have a source of small constant e.m.f. against which to balance various e.m.f.s over long periods of time without the difficulty occasioned by the running down of cells. The following scheme has been used for this purpose.

A number of thermocouples are arranged in series so that the cold junctions are kept at the boiling point of a suitable liquid, while the hot junctions are kept at the boiling-point of another liquid with the same pressure - temperature coefficient. (Liquids with the same Trouton constant $\left(\frac{1}{T}\frac{dp}{dt}\right)$ will therefore not satisfy this condition.) Variations of atmospheric pressure do not then affect the difference of temperature between the hot and cold junctions and the e.m.f. should remain constant.

The apparatus which was in constant use for over a year consisted of two glass hypsometers A and A' (see Fig. 151 in which one such vessel is represented). Carbon tetrachloride (b.p. 76·60° C.,

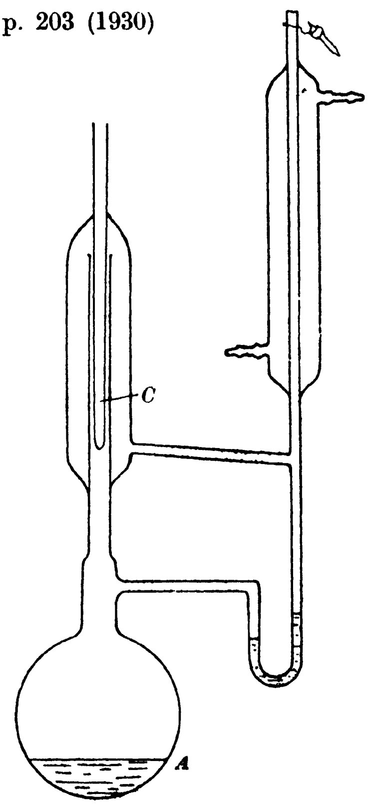


Fig. 151.—A constant e.m.f. device.

$dp/dt = 21{\cdot}6$ mm./°C.) was boiled in the one, and toluene (b.p. 110·69° C., $dp/dt = 23{\cdot}9$ mm./°C.) in the other. The junctions of enamelled copper-constantan thermocouples were immersed in inner tubes C and C'. The height of the flame required initial adjustment to avoid superheating and the apparatus had to be shielded from draughts, but no other adjustments were necessary. If the toluene tends to "bump", a few garnets may be added to assist ebullition. The carbon tetrachloride does not bump.

The following measurements were made with an interval of over a year between them:

Date	mV.	Bar.	Readings over
8. xi. 23	15·308 ± 0·004	747 mm.	2 hours
27. xi. 24	15·322 ± 0·060	739	4

Note. 0·004 mV. equivalent to 1/100° C.

The variation was greater in the second series of measurements, as the apparatus had been set aside for some time uncorked and there was only a little carbon tetrachloride left in the heating bulb. The experiment showed, however, that ageing or other changes in the couples are not serious.

The apparatus was recharged with samples of the same liquids differing very slightly in boiling point from the previous samples and the following results were obtained:

Date	mV.	Bar.	Readings over
8. xii. 24	15·548 ± 0·004	762 mm.	6 hours
9. xii. 24	15·550 ± 0·002	765	6
15. xii. 24	15·500 ± 0·003	744	6

(The large drop in the barometric pressure in the latter case would account for a reduction in the millivolt reading of 0·04 mV. (= 1/10° C.) owing to the small difference in the values of dp/dT for the two liquids.)

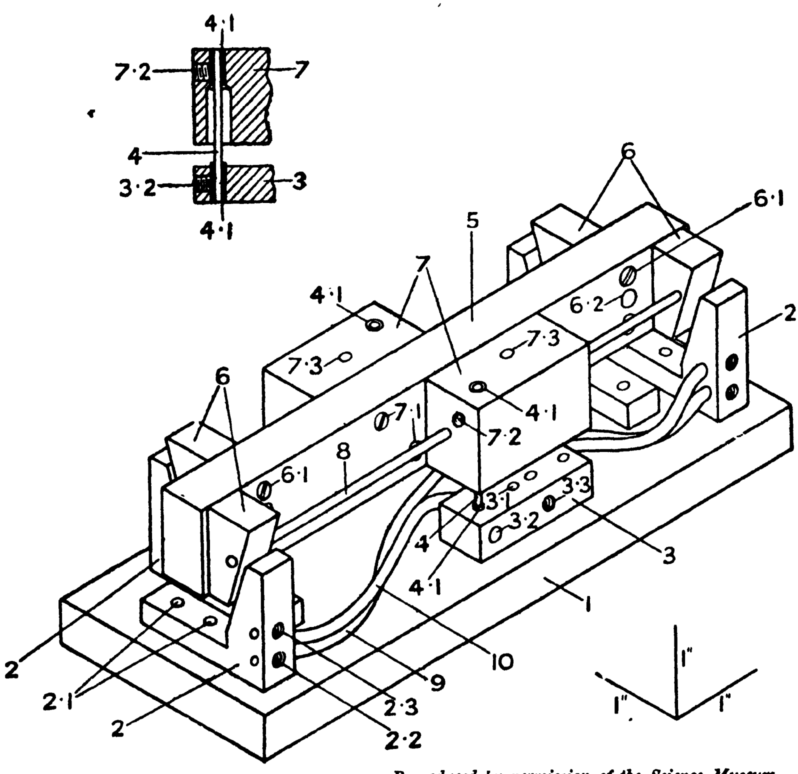
The scheme described will thus produce an e.m.f. of the order of 0·015 V. constant to less than 1 part in 2,000 for many hours at a time. Other ranges are available by altering the number of couples or choosing other liquids. Automatically controlled thermostats could replace the two hypsometers but would not be so independent of troubles. It is possible not only to provide a constant e.m.f. but also a reproducible e.m.f. by this means. Couples of pure copper against pure platinum appear to give an e.m.f. 0·299 mV., reproducible in the case of copper to ± 0·0005 mV. per couple for the difference in temperature between the two vapour baths, and pure silver would probably be even better than copper in this respect.

129. Change-Over Switch with Automatic Release

By O. KANTOROWICZ, Dr.Phil., F.Inst.P.

J. Sci. Instrum. **14**, p. 383 (1937)

When the Peltier Effect was to be demonstrated in the Science Museum, London, during the "Very Low Temperatures" Exhibition in 1936 it was found that commercially available switches with solid contacts did not stand up to the heavy current (15–20 A.) and the



Reproduced by permission of the Science Museum.

FIG. 152.—Change-over switch with automatic release.

rough handling by thousands of visitors for more than a few days. A special switch was therefore designed (Fig. 152) and was made in the Museum workshop; it worked satisfactorily, being used by some hundred thousand visitors without any damage.

The requirements were: (*a*) the switch had to be robust and especially capable of withstanding side thrust on the moving parts; (*b*) it had to pass automatically into neutral when released; (*c*) and it had to have a low resistance, and a high current capacity.

The construction chosen was a modification of Ampère's well-known switch: the rocking arm was hinged on two upright elastic steel rods, and the moving contacts together form a wedge that engages, after a slight rotation of the rocking arm, between a pair of V-cheeks which form the stationary contacts. If side thrust is exerted against the rocker arm, it abuts on one of the stationary V-faces after so small a movement that no damage is done to the hinges.

In normal use, if the operating pressure is predominantly vertical and is applied to either end of the rocking arm, the wedges will contact on a pair of the V-faces with about equal pressure. In consequence of the wedge action, the effective contact pressure is much greater than the pressure applied to the rocker arm; the contact resistance is therefore low.

In order to obtain a rugged design together with ease of assembly, the subconscious desire for symmetric design had to be suppressed and a staggered non-symmetric layout adopted. Great rigidity was aimed at in view of the hard use to which the switch was to be subjected. All the V-faces were generated together in order to ensure equal angles. The inclination chosen was about 1 : 10 from the vertical. It was considered that a more acute wedge angle would have too great a tendency to jam. After assembly a slight camber was produced on all the contact faces by drawing a doubled strip of fine emery cloth to and fro between the slightly closed contacts until the contact faces touch each other at their respective centres. All faces were afterwards washed with paraffin oil, and the contacts were found to be perfect.

Referring to the figure, the base-plate 1 is made from Pertinax. Fixed to it from underneath by the (4 B.A.) screws 2·1 are the four stationary contacts 2 of brass, and by the (4 B.A.) screws 3·1 the central contacts 3 of brass. Fixed into 3 are upright steel rods 4 (piano wire), about $\frac{1}{16}$ in. diameter, which are armed on both ends with slotted sleeves 4·1 of mild steel, that are compressed by (2 B.A.) set-screws 3·2 and 7·2 respectively. Further holes and (2 B.A.) set-screws 2·2 and 2·3 in the V-blocks 2 and 3·3 in the central contacts 3 serve to clamp the connecting wires. The central block 3 is connected to the battery, and the V-blocks 2 connect crosswise with each other and with the apparatus. Clamped to the upper end of the steel rods 4 is the rocker arm 5 of Pertinax (sheets vertical). It carries contact pieces corresponding to those on the base-plate. These are the four wedges 6 of brass, held from the back by (4 B.A.) screws 6·1 and the two central bosses 7 of brass. The central bosses 7 are each held from the back by two (4 B.A.) screws 7·1. The three contact pieces on either side of the rocker arm 5 are joined together by the copper rods 8. These rods are clamped to the wedges 6 by (2 B.A.) set-screws 6·2 which are accessible through holes in the rocker arm 5. The rods 8 are clamped to the central bosses 7 by (2 B.A.) set-screws 7·3.

Some possible alterations are obvious. For instance, the battery leads, if flexible enough, could be fixed to the central bosses 7, and the contact faces could be gold plated for use in inaccessible positions or where very small contact resistance is essential.

130. A Pedal-Operated Switch

By W. Burns, D.Sc., M.B., Ch.B.

J. Sci. Instrum. **19**, p. 63 (1942)

This switch employs door-switch units which can be of the consecutive action or the alternate action type; by using combinations of these, and increasing the number of switches used (this would not alter the basic design described), a variety of switching operations is possible. In the arrangement described and illustrated in Fig. 153, two circuits are switched simultaneously; one circuit is closed and the other broken each time the pedal is depressed. For this two consecutive action door switches are used, one of which closes and the other opens its circuit when their plungers are depressed.

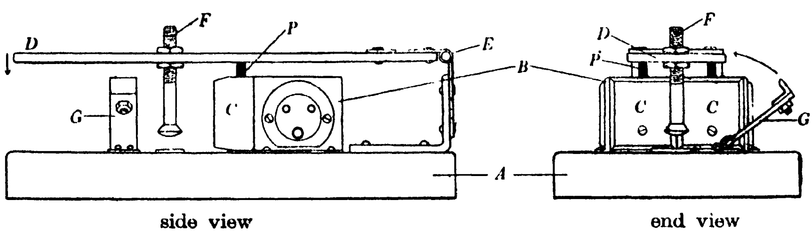


FIG. 153.—Pedal-operated switch.

The construction is simple. On a wooden baseboard A is mounted a box B of light sheet steel; on this are the two switches C; these are vertically adjustable, being mounted with their fixing screws through slotted holes in the box B. They are placed side by side with their operating plungers P projected upwards. These plungers are pressed upon by the pedal D, of mild steel strip, hinged to a piece of angle iron by a door hinge E. The pedal requires an adjustable stop F. An adjustable catch G, for holding down the pedal, may be added; it can be swung back, as shown, when not required. Plugs and sockets complete the connexions to the switches; electrical screening for the latter can be arranged easily if necessary. The switch, as described, has given entire satisfaction during one year's use. It is used in a cathode ray recording apparatus, in which it operates a $\frac{1}{8}$-h.p. camera-motor and turns on the oscilloscope beam simultaneously. This prevents damage to the oscilloscope screen by the stationary spot.

131. Electro-Plating Copper on Manganin

By C. R. Cosens, M.A.

J. Sci. Instrum. **10**, p. 256 (1933)

Resistance coils for accurate work are usually made of manganin (copper 84 per cent, manganese 12 per cent, nickel 4 per cent). The Report of the National Physical Laboratory for 1931 (p. 137), states that "The presence of manganese in alloys of the manganin type renders difficult the adhesion of other metals and alloys, as has been shown by attempts to solder with lead-tin alloys. There is always a risk of the interface separating, and as yet there appears to be no definite means of ensuring complete adhesion and protection, short of using materials requiring a red heat for their application."

Copper plating, followed by soft-solder, is suggested as an alternative to silver-soldering as usually employed, especially for work of the highest class, such as "Standard Ohms". For such work the greatest care is taken when annealing to avoid damaging the surface of the wire by oxidation, by using thick coats of varnish or even annealing in an inert gas, yet silver-soldering inevitably raises the temperature of a considerable length of the end of the wire far above the annealing temperature with the wire fully exposed to the air, which must result in serious oxidation. Such considerations led the writer to attempt electro-plating the ends of the coil with copper, to which soft-solder would adhere satisfactorily. First attempts proved futile: without preliminary preparation of the manganin, it was impossible to secure an adherent coating of copper, presumably due to a film of manganese oxides forming on the wire at room temperature.

Surface "demanganization" in an alkaline bath as a preliminary treatment was found to give quite successful results, the manganin being made alternately anode and cathode in a strong solution of caustic alkali. The chemistry of the process is believed to be as follows. When the manganin is anode, the surface oxidation is to some extent selective, since manganese is much more easily oxidized than copper or nickel; with high current densities the higher oxides of manganese are formed, and dissolve in the electrolyte forming manganates and permanganates; when the manganin is cathode, any oxides of copper or nickel which have been formed are reduced, but the manganates are carried to the other electrode, away from the manganin (since the manganese is now part of a negative ion). While it is probable that the exact strength of electrolyte and current density are not important, in order that the results may be reproducible by anyone interested, details are given of the apparatus and technique employed to deposit a coating of copper 0·13 mm. thick on the end 5 cm. of a 19 s.w.g. manganin wire (1·02 mm. diameter).

Four cylindrical copper electrodes as shown in Fig. 154 are cleaned in hydrochloric acid, washed, and placed in glass jars or beakers *A*, *B*, *C*, *D* about 7 cm. deep. *A* and *B* are filled with 10 per cent solution in tap water of caustic soda ("Pure Stick" as sold for photo-

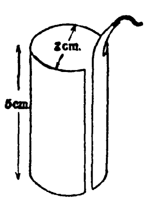


FIG. 154.—Electrode.

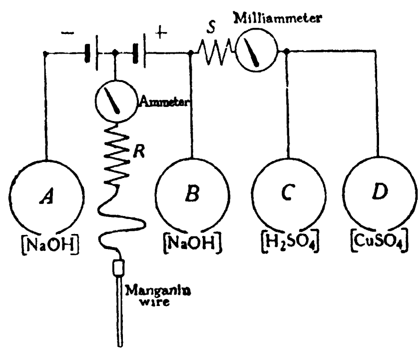


FIG. 155.—Circuit for copper-plating manganin wire.

graphy). *C* is filled with dilute sulphuric acid (1 volume "brimstone acid" of about 1·2 specific gravity as used for accumulators, diluted to 10 volumes with distilled water). *D* contains saturated copper sulphate solution to which 5 per cent by volume of dilute sulphuric acid from *C* is added (commercial "pure" copper sulphate seems satisfactory).

The copper electrodes are connected to two accumulators (Fig. 155) with resistances *R* and *S*, an ammeter reading to 1 A., and a milliammeter reading to 25 mA. The resistance *R* is so adjusted that when the wire is dipped as far as it will go into *A* or *B*, a current of 0·5 A. flows. *S* is then adjusted until when the wire is in *D* to the proper depth, the current is 15 mA. It is found convenient to adjust these with a spare piece of wire in place of that to be plated; it is also desirable to adjust a retort stand to clamp the wire in the proper position in bath *D*, exactly in the centre of the copper cylinder, and with the desired depth of immersion: the depth of solution in the first three beakers should be slightly more than the length to be plated.

The wire to be plated is now substituted for the temporary piece, care being taken to see that it is clamped to the flexible lead in such a way that it can be quickly adjusted in the clamp in place *D*, with the proper depth of immersion. It is scraped clean, without touching the surface to be plated with the fingers, so that no visible tarnish remains. It is now dipped in *A* for about 2 sec., gas is evolved at the wire, and on withdrawal it is seen to be coated with a semi-transparent layer resembling black varnish. It is now transferred to *B* for about the same time, more gas is evolved, and the black coating disappears, leaving the wire somewhat tarnished. On returning the wire to *A*, the black coating reappears, but less deeply coloured than at first, and after repeating the dipping in *A* and *B* a few times, the black coating no longer forms in *A* in say 3 sec., and the "demanganizing" of the surface layer is now complete. After removing from *B* for the last time, the wire is rinsed in distilled water, and then transferred to *C*; the time in this bath must be exactly right (about 1 sec.), the time is judged by the appearance of the wire, which becomes a beautiful highly burnished pale gold. With too short a dip the burnished effect is not obtained, with too long immersion bubbles of gas form on the wire; the right moment for removal is easily judged after a trial or two: at first it is easiest to use a succession of very quick dips, removing the wire just long enough for examination.

As soon as the required appearance is obtained, the wire is immediately transferred to *D* without any washing, clamped in position and left alone for at least 30 min., better for an hour, without removal, after which time a good coating of copper is obtained, and the wire may be removed for inspection, without fear of oxidizing the manganin, which is now protected by copper. The current density may now be increased and the copper deposited to any required thickness.

The process may sound complicated, but in practice it is found quick and easy, the only point requiring care being the removal from the bath *C* at the right moment. After plating some three or four specimens it is found that the whole preliminary process from the initial scraping to transfer to the plating bath *D* does not take more than a minute.

It is essential that the surface of the wire should not become dry during the preliminary process, so that air can get at it, hence the transfer from one bath to the next must be rapid, without too long pauses for examination. At the beginning this is not so important as at the end, but it is essential that the final changes *A*, *B*, *C*, *D*, should be made without any drying of the surface, i.e. the transfer must be as rapid as possible; if any drying should take place it is essential to wash the wire and start again from bath *A*.

Another small difficulty occurs if the time of immersion in *A* is too long, especially at the start; the black coating collects into dark spots on the wire, which do not dissolve in *B*. These spots are only feebly adherent, and can be wiped off with a clean coarse linen rag soaked in the caustic soda solution. The spots can be entirely avoided if the first one or two dips in *A* are made for a shorter time.

The exact reason for bath *C* is not clear, the wire is greyish when it goes into *C*, and golden when it comes out, possibly some nickel is removed here; but it seems essential if a properly adherent coating of copper is to be obtained.

Since the surface of 5 cm. of wire 1 mm. in diameter is about 1·5 sq. cm. it will be seen that the current densities employed at the surface of the wire are $\frac{1}{3}$ A. per sq. cm. for baths *A* and *B*, and 10 mA. per sq. cm. for *C* and *D*

The preliminary treatment appears to remove the manganese by selective oxidation from a surface layer possibly a few molecules thick, and a perfectly adherent coating of copper is then obtainable. Severe hammering fails to strip the copper and one specimen had flats filed on two sides until the manganin showed through; after hammering and breaking the manganin by repeated bending, the copper still adhered, and could not be stripped with a scraper.

A specimen was mounted with soft solder in a well-fitting hole broached in a piece of scrap brass, the end filed flat, polished, etched, and photographed. This showed no sign of any crack or split and a clearly radial arrangement of copper crystals.

132. Cleaning Small Magnet Gaps

By J. G. BEARD

J. Sci. Instrum. 18, p. 50 (1941)

Several methods for cleaning the narrow gaps found in a number of modern permanent magnet assemblies have been tried with varying degrees of success. The rather tedious one of using non-magnetic tweezers requires much time and patience. The use of a high-pressure air blast or good vacuum line is not always practicable, but can be quite effective, as also is the practice of using plasticine, wax, or grease. The latter tend to be rather messy and generally require a second treatment for their removal.

A most effective and simple procedure is the use of a strip of surgical plaster or adhesive paper tape; that known as Durex

Adhesive Tape is very successful. By wrapping a narrow band of this material, sticky side outwards, around a thin strip of steel tape it is possible to introduce the adhesive into very narrow air gaps, then by wiping across or around the pole faces any particles of magnetic dust become embedded in the adhesive and are quickly removed. The annular gaps of small loud-speaker magnets have been successfully treated in this way, even after considerable quantities of magnetic dust had accumulated between the pole faces. The method is particularly applicable to the cleaning of the long narrow air gaps in permanent magnet string galvanometers.

133. Aluminium Panels for Electrical Instruments

By L. B. Turner, M.A., M.I.E.E.

J. Sci. Instrum. **19**, p. 139 (1942)

Aluminium sheet, say $\frac{1}{8}$ in. thick, is often the mechanically and electrically appropriate material for instrument panels, large or small, whether for mounting light components such as valve sockets and potential dividers, or fairly heavy components such as iron-cored chokes and transformers. Attempts to produce an aesthetically satisfactory finish (especially when an engraving machine is not available) are apt to be disappointing. A good treatment, within the scope of any amateur, is the following.

After all drilling, etc., has been completed, the exposed face and edges of the panel are papered smooth. Fairly coarse emery and oil may be used. The panel is washed, and is then etched for 2 or 3 min. in a tray containing a warm solution of commercial caustic soda in tap water. The panel is rinsed with tap water and drained, adherent drops being removed by lightly wiping with cotton wool or a clean cloth. It now has a uniform matt silvery surface, on which legends and scales are readily drawn with Indian ink.

134. A Method of Simultaneously Projecting Two Periodic Curves on a Cathode-Ray Oscillograph

By F. E. Kennard, B.Sc., M.I.E.E.

J. Sci. Instrum. **15**, p. 106 (1938)

In demonstrating the properties of alternating current circuits it is often desirable to show simultaneously two wave forms on the same screen, e.g. current and voltage. This can be done by means of suitable valve circuits requiring apparatus which is not always available, whereas a polarized relay and a ringing magneto are usually to hand in most laboratories. The relay contacts are arranged to act as a two-way switch, one fixed contact is connected to a suitable point in the current circuit and the other to the voltage circuit, the tongue to one of the deflecting plates of the oscillograph, the other plate of the latter is connected to a point common to both circuits. Assuming a 50-c/s supply for the wave-forms, and since synchronism between the action of the relay and the frequency of the circuit is not necessary, the relay may be actuated at any frequency below 25 c/s. This can readily be done by means of a ringing magneto either hand or motor driven.

135. A Device for Winding Small Toroidal Inductances

By C. A. A. Wass, B.Sc., A.M.I.E.E., A.Inst.P.

J. Sci. Instrum. **19**, p. 78 (1942)

In connexion with work on high-frequency communications it is sometimes necessary to wind inductances on ring-shaped cores of outer and inner diameter 40 mm. and 16 mm. respectively. The inductances usually consist of relatively few turns—not more than 200—of No. 46 or 47 s.w.g. copper wire, and they are normally wound by hand, the wire being first wound on to a flat H-shaped spool which can be passed through the central hole of the core. The hand-winding method has a number of disadvantages, and in an attempt to overcome some of these a simple hand tool has been produced. While not being a complete or final solution to the problem, this device is effective and appears to be capable of development into a satisfactory automatic machine.

The main features of the winder are shown in Fig. 156. Two arms *A*, *A* are connected by a hinge *H* and are normally held apart by a spring *S*. At the ends of the arms are devices D_1, D_2 for holding a bobbin *B* on which the wire is wound. These holders are so arranged that when the arms are squeezed together until they meet, the bobbin, originally held in D_1, is transferred to D_2, and is carried by D_2 when the arms are released. When the arms are squeezed together again the bobbin moves back from D_2 to D_1. Thus if the tool is held in the right hand and the core in the left hand the bobbin can be passed from D_1 to D_2 inside the core and from D_2 to D_1 outside the core as shown in Fig. 157, and so the wire can be wound on to the core.

D_1 and D_2 are shown in detail in Fig. 158. D_1 consists of a block L with two flat springs K_1, K_1, shaped as shown, screwed to it. The

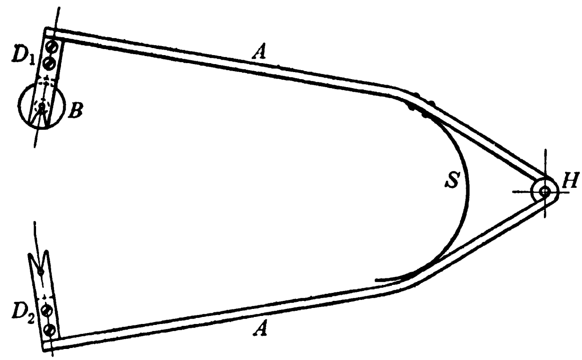


FIG. 156.—Device for winding toroidal coils.

bobbin, the shape of which is also shown in Fig. 158, is held between the springs and the points of its conical sides fit into holes M, M in the

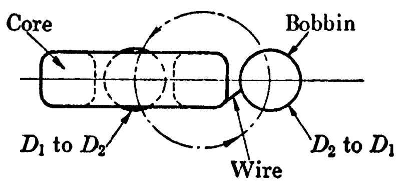


FIG. 157.—Method of winding coil.

springs so that the bobbin can rotate fairly freely; the springs are forced apart from their normal position when they are holding the

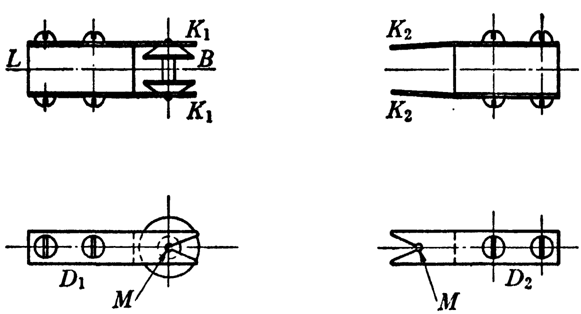


FIG. 158.—Details of devices for transfer of bobbin.

bobbin. D_2 is similar to D_1 but the springs are labelled K_2, K_2 for convenience. If the bobbin is held in D_1 and D_2 is moved towards it, each K_2 spring can be forced between one side of the bobbin and the adjacent K_1 spring, and if pushed far enough the holes M, M in K_2, K_2 will fit over the points of the bobbin. While this is being done the bobbin touches the inner end of the block L which prevents it moving away from D_2, and the notches in the ends of K_2, K_2 prevent any sideways motion. When D_1, D_2 are drawn apart the bobbin will be carried by D_2, and when the holders are clear of each other the springs K_1, K_1 will return to normal, while K_2, K_2 remain farther apart because they are holding the bobbin. If D_1, D_2 are brought together again the bobbin will be transferred back from D_2 to D_1, and similarly every time the arms A, A are squeezed together the

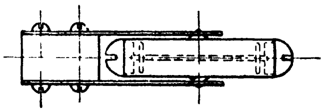


Fig. 159.—Modification suggested for winding larger coils.

bobbin will move from one holder to the other, so that the wire can be wound in the manner described above.

The wire capacity of the bobbin is limited, but it is sufficient for the original purpose. If required, the capacity could probably be increased by using, instead of a bobbin of the shape shown in Fig. 158, a long shuttle carrying a long thin bobbin as indicated in Fig. 159. The shuttle would be held by a modified form of the holder described above, and would be passed through the central hole of the core and transferred from holder to holder in the same way as the bobbin in the original machine.

Other modifications and improvements are possible, and it is thought that the method of transferring an object from one holder to another might find application in other mechanical operations in addition to toroidal coil winding.

[*Note.*—For principle of operation and construction of automatic machines for applying wire or tape on to toroidal or other types of cores in which winding material cannot be fed past the winding axis and where the core has to remain stationary with regard to this axis, *see* Planer, F. E., *J. Sci. Instrum.* **20**, p. 185 (1943).]

136. A Simple Device for Securing Rigidity of Electrodes in Conductometric Work

By B. N. SASTRI, M.Sc., A.R.I.C., A.I.I.Sc., and M. SREENIVASAYA

J. Sci. Instrum. **12**, p. 167 (1935)

The conductometric titration of feebly conducting systems necessitates the use of electrodes with a large surface area placed close to each other, a circumstance which renders the system measurably susceptible to vibrations caused by the stirring necessary in conductometric work. The distortions thus caused can be avoided by employing expensive stout platinum strips, gauzes and wires, but these are not easily obtainable in all laboratories.

A satisfactory and economical device, which can be adopted with

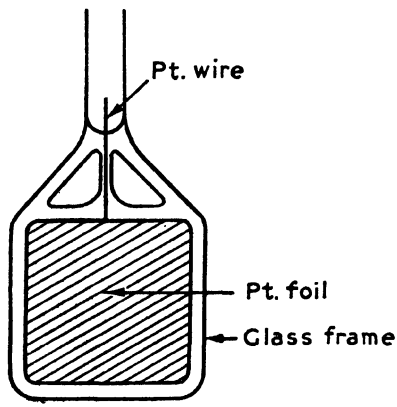


FIG. 160.—Device for securing rigidity of electrodes.

materials readily available in any laboratory, consists in housing the platinum electrode (12 mm. square) cut out from a foil 0·08 mm. thick in a framework of Pyrex glass (Fig. 160), one side of the frame being sealed on to the glass stem into which the platinum wire is fused. The sealing of the framework is facilitated by a preliminary edging of the foil with a thin layer of platinum-sealing glass. The electrodes thus prepared can be coated with platinum black, heated for purposes of greying and treated in just the same manner as any other electrode in vogue.

137. Optical Levers

By B. H. C. MATHEWS, C.B.E., Sc.D., F.R.S.

J. Sci. Instrum. **16**, p. 124 (1939)

A high sensitivity can be obtained from any reflecting instrument by utilizing a long light beam ; but a long beam of light is often inconvenient, and great loss of light occurs, which is undesirable if photographic recording is employed. The same high sensitivity can be obtained, compactly, and with far less loss of light, by utilizing an optical system magnifying only along the axis of motion.

The simplest arrangement is that shown in Fig. 161. The slit *A* is illuminated by the lamp *L*, light reflected from the moving mirror *M* strikes the cylindrical mirror *C* and is reflected on to the scale or camera slit *S*. A small change in the point of incidence on *C*, caused by the

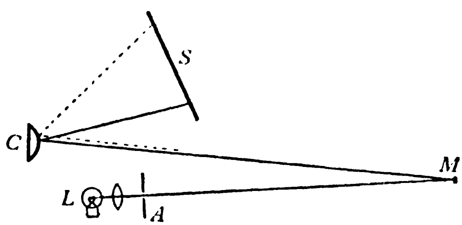


FIG. 161.—Optical lever.

rotation of *M*, results in a large change in the angle of reflexion. In order that a sharp image of the slit shall be focused on *S*, the mirror *M* is of such a focus that it forms an image of the slit at a point a little behind the surface of *C* ; the cylindrical mirror can then be made to focus a magnified image of this at *S*.

As magnification occurs in only one plane, the intensity of the image falls off with the effective length of the beam, instead of with the square of this distance, as it would if the same magnification had been obtained with a simple long beam.

This arrangement is in use with the author's oscillograph* to give the magnification of a 5-m. beam, the overall space occupied is 45 cm.

* Mathews, B. H. C., *J. Sci. Instrum.* **6**, p. 220 (1929).

The approximate values of the constants are as follows: *AM* 18 cm.; *M* + 8 D. spherical; *MC* 38 cm.; *C* + 80 D. cylindrical; *CS* 17 cm. A very narrow slit (0·1 mm.) is employed as its width is magnified some 25 times. A 3-W. Pathé projector lamp gives sufficient illumination for recording on P 20 bromide paper up to a speed of 20 cm. per sec. using a cylindrical lens 5 mm. wide, parallel to the camera slit, to condense the light on the paper.

A similar arrangement has been found very convenient for use with a mirror galvanometer (Fig. 162); in this case the scale is placed behind the cylindrical mirror; part of the light passes over the mirror to form an image I_1, part is reflected from it to the plane mirror *m* and so back to the scale at I_2. By suitable arrangement of the components both images can be focused on the scale. The direct image gives a low sensitivity and the image reflected via the cylindrical mirror a much greater sensitivity, and this can be made a simple multiple (10 or 20 times) of

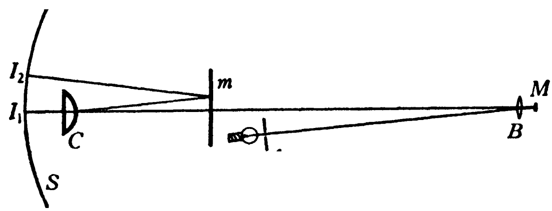


FIG. 162.—Optical lever for use with galvanometer.

the lower sensitivity. For null-point measurements it is unnecessary to read the scale, the two images are simply brought into coincidence.

The whole is enclosed in a box 25 cm. × 15 cm. × 15 cm., with a transparent paper scale at the end, a 1·5 W. lamp supplied from a dry battery gives ample illumination for use in a well-lighted room.

The constants of the arrangement in use are: *AB* 12 cm.; *B* + 7 D. cylindrical; *BM* 3 cm.; *M* plane; *BC* 15 cm.; *C* + 30 D. cylindrical; *CM* 8 cm.; *mS* 10 cm. Magnification ratio I_1 to I_2 × 10.

Similar results can be achieved by the use of negative cylindrical lenses, but to obtain images suitable for photography achromatic lenses are necessary; these are not readily obtainable while cylindrical mirrors can easily be made by surface silvering or metallizing the curved surface of positive cylindrical lenses which are readily obtainable, or can be turned and polished in any suitable metal.

Optical levers with an effective length of 10–20 m. can thus be obtained in small compass; but for levers above 5 m. length good optical surfaces are necessary to obtain good definition of the final image.

138. An Optical Multiplier

By W. I. Place, M.Sc., M.I.E.E., F.Inst.P.

J. Sci. Instrum. **3**, p. 229 (1926)

A magnetic testing apparatus for *B–H* tests on sheet steel at low inductions has recently been made in which, *H*, the intensity of the magnetizing field, is measured by means of a search coil connected in series with a ballistic galvanometer of the moving-coil type. A galvanometer was selected which gave approximately the maximum attainable sensitivity, in millimetres per line-turn at one metre, under certain conditions as regards period, etc., chosen for convenience. The deflection was increased by making the galvanometer scale distance two metres and fitting an optical multiplier which doubled the deflexion, giving an effective radius of four metres. This type of multiplier was invented by F. L. O. Wadsworth and described in the *Philosophical Magazine* for 1896.

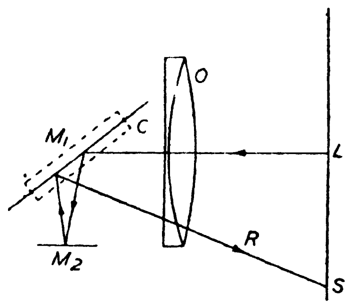


Fig. 163.—An optical multiplier.

In Fig. 163 *O* represents an achromatic object glass (2 cm. × 1 cm. × 0·7 cm. thick) of two metres focal length. M_1 and M_2 are plane mirrors, silvered on their back surfaces and placed close together. M_1 is 1 cm. × 1·35 cm. and is attached to a stiff wire joining the suspension strip to the moving coil. M_2 is a fixed mirror 1 cm. square. The mirrors are held in light copper frames. When the galvanometer coil *C* is at rest, M_1 is inclined at an angle of 45° to the incident light, and its plane is also at 45° to that of the mirror M_2. Light from the condensing lens *L* of the lantern passes through *O*, falls upon the moving mirror M_1, is reflected on to M_2, thence back to M_1, passes out through the lens *O* and forms an image of *L* on the scale at *S*.

Owing to the double reflexion at M_1, the reflected beam *R* turns through an angle equal to four times the angle turned through by the galvanometer coil *C*, whether the spot moves to right or left of zero. The scale employed is of translucent celluloid, 75 cm. long, and the design of the object glass makes it possible to read the position of the cross wire to 0·1 mm. at all points on the scale.

139. Magnesium Oxychloride for Photometer Screens and Test Plates

By J. S. Preston, M.A., M.I.E.E., F.I.E.S., F.Inst.P.

J. Sci. Instrum. **12**, p. 197 (1935)

Magnesium oxychloride of composition Mg_2OCl_2 is formed when magnesium chloride is heated in air. If, however, calcined magnesia is mixed into a thick paste with a strong solution of magnesium chloride, the paste sets hard in some hours owing to the formation of an oxychloride. The composition of this oxychloride corresponds to a union of about five molecules of MgO to one of $MgCl_2$, with an indefinite amount of water. This material is known as Sorel's cement.

The whiteness of the hardened cement, together with its high mechanical strength, suggested its suitability for photometer screens and for test plates for use in illumination measurements. It has in fact proved very suitable for both, though its property of absorbing moisture limits its usefulness in the latter field.

The material is prepared as follows. Equal weights of MgO (preferably the calcined variety) and of $MgCl_2.6H_2O$ are taken and the latter is dissolved in a minimum of water. The oxide is then added and mixed in very thoroughly, water being added drop by drop until the consistency of ordinary plaster is reached. Care should be taken not to add too much water, because vigorous mixing appears to thin the mixture somewhat.

The mixture may be used to form a simple disc of the cement in the following way; a teaspoonful or more is placed in the centre of a clean dry lantern slide cover-glass and worked into the shape of a Bath bun with the end of the spoon, attention being paid to the removal of bubbles. A second cover-glass is then lowered on to the cement which is thus pressed to the desired thickness, which its consistency should maintain without additional support to the upper glass. The whole is left for, say, 20 hours, when the cover-glasses can be split away by twisting them slightly at the corners. The disc so made has glazed surfaces. To form a matt surface the disc may be rubbed down with suitable grades of glass paper, or with Sira abrasive on a ground glass plate or another disc of oxychloride. Carborundum powder may be used, but in this case, to prevent the hard particles from becoming embedded in the disc, the disc should be soaked in water until saturated and the grinding should be done in the wet state. Embedded particles may then be removed with a strong jet of water or a light brush and the plate dried slowly to avoid cracking. Alternatively a more matt surface may be obtained by casting the disc between ground glass plates.

These may also be removed by twisting, though slight difficulty may be experienced. Grease should not be used to facilitate removal of the glass as it appears to interfere with the setting of the cement and also may discolour it.

To form a photometer screen of the usual type, shown in Fig. 164 (*a*), the two halves are cast separately. A piece of ground glass is held firmly against the outer surface of one metal frame (e.g. with stout bull-dog clips) and supported horizontally, frame uppermost. The cement is then placed in this mould and worked to a uniform thickness slightly less than that of the frame. A few sharp taps from below on

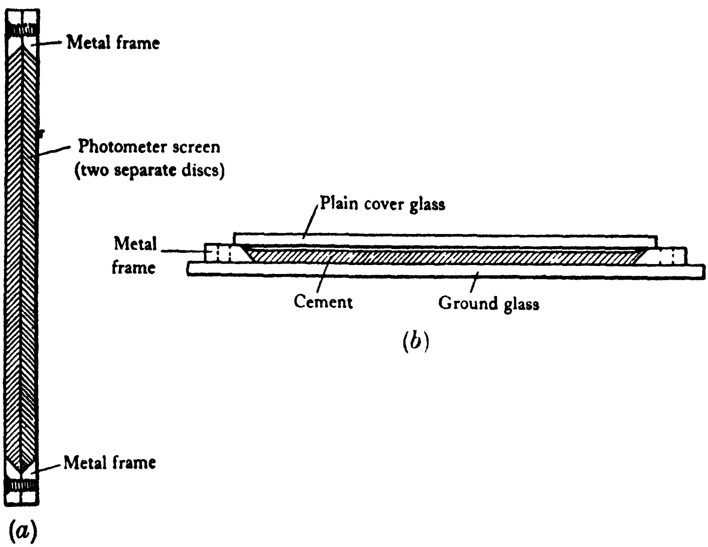


FIG. 164.—Oxychloride photometer screens.

the glass plate will greatly assist in spreading the cement. The whole is left in a saturated atmosphere to set, or the open upper side of the disc may be covered with another glass plate, which should not, however, touch the cement. These precautions are necessary to prevent the water from drying out. The other half of the screen is made in the same way and the two are then mounted with a disc of clean white blotting- or filter-paper between them, after removal of the glass plates. The appearance of one-half when left to set should be as in Fig. 164 (*b*).

This cement is translucent in thickness of a few millimetres. The translucency is increased by the use of more water than necessary. The cement can be cast into any shape desired and does not apparently shrink or expand appreciably on setting.

140. A Fluorescent Medium for Use on Surface Plates

By H. D. GRIFFITH, B.A., and A. M. FRASER

J. Sci. Instrum. **18**, p. 9 (1941)

When a surface plate is coated with Prussian blue or some similar medium and the work is pressed on to it, the position of the high spots on the work can be recognized by the areas where pigment has been picked up: the only difficulty arises from the poor visibility of the thin pigment layer, which generally shows small optical contrast against the adjacent clean metal. We have developed an improved technique which gives brilliant contrast and which enables scraping to be done with greater speed and confidence.

The medium used is a suspension of powdered anthracene in medicinal paraffin oil, sufficient anthracene being stirred into the oil to give the consistency of thin cream. A very small quantity of the medium is spread on the surface plate and employed just as the Prussian blue medium when using the old technique, but the high spots are observed by the light of an ultra-violet lamp. As viewing lamp, any quartz mercury arc fitted with a nickel glass (Wood's glass) screen can be employed: such as an Osira lamp. The work is placed below the lamp, the direct light being screened from the observer's eyes, and the high spots where the anthracene has been picked up are then seen to glow brilliantly with green fluorescent light, bright enough to be easily visible in a normally lighted workshop. The surfaces can be wiped clean with a rag moistened with benzene.

141. An Improved Method of Illuminating Resolution Charts

By H. K. BOURNE, M.Sc., M.I.E.E., F.R.P.S.

J. Sci. Instrum. **21**, p. 162 (1944)

When camera lenses are tested by photographing a resolution chart, the problem arises of obtaining an even illumination over the area of the chart while avoiding specular reflexion. In order to show the finest detail, these charts are often printed with a glossy surface so that specular reflexion is difficult to eliminate. Any such reflexion produces misleading results because part of the image will be over-exposed and the fine detail will be lost completely. The whole area of the chart must be illuminated uniformly so that any variation in the illumination produced by the lens over its field can be measured.

A simple and effective solution has been obtained by making use of the principle of the light integrator. The resolution chart is placed inside a box whitened on the inside with zinc oxide paint. The chart is illuminated indirectly by light reflected from the walls of the box from fluorescent lamps placed behind the board on which the chart is mounted.

An arrangement used in this laboratory is shown in Fig. 165. The box is a cube with each side 30 in. long, and two discharge lamps 24 in.

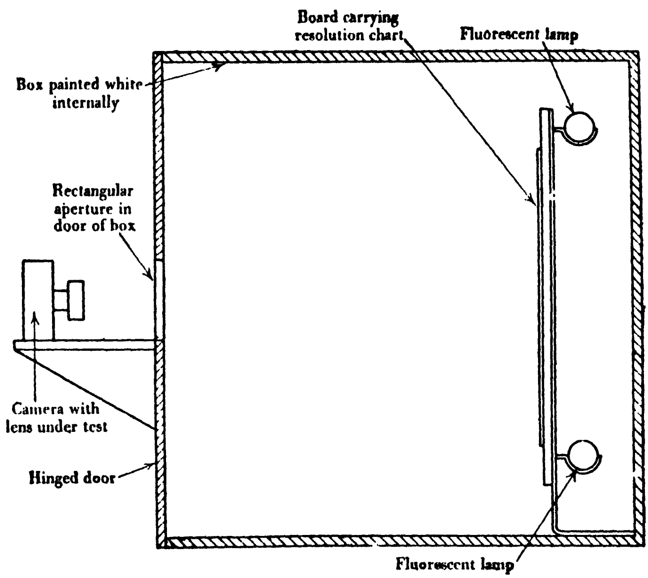


FIG. 165.—Method of illuminating resolution charts.

long, of approximately 40 W., provide the illumination. The resolution chart is mounted on a board, the back of which is whitened, placed near the back of the cube and the lamps are situated behind this board. Illumination of the diagram is thus indirect, and even though a glossy finish is used the surface of the chart appears to be quite matt when it is placed in the cube. The illumination (approximately 40 f.-c.) is uniform over the whole of the chart.

The resolution diagram is photographed through a rectangular aperture cut in the front of the box. No direct illumination from the lamps falls on the lens as they are shielded from the camera by the board carrying the chart.

Tubular fluorescent lamps are used for two reasons: (1) they are excellent low brightness sources of diffused light. (2) They give a colour which approximates closely to daylight so that the probable performance of the lens in daylight may be tested. If the effect of chromatic aberration is to be studied, then lamps of suitable colours may be used. These lamps can be switched on and off as desired without appreciable delay in obtaining full brilliancy. Their efficiency is high, so that if necessary a number may be used in a bank to provide a high illumination with little heating. In larger illuminating boxes the standard form of 5-ft. fluorescent lamp may be employed successfully.

142. A Counting Lamp for Colonies of Bacteria

By A. E. Crisp, M.A., M.I.C.E., M.I.W.E., F.G.S.

J. Sci. Instrum. **17**, p. 70 (1940)

It has been found difficult to make accurate and rapid counts of colonies of bacteria on Petri dishes with the lamp described in the Ministry of Health Publication No. 71 (Revised 1938) and a new design

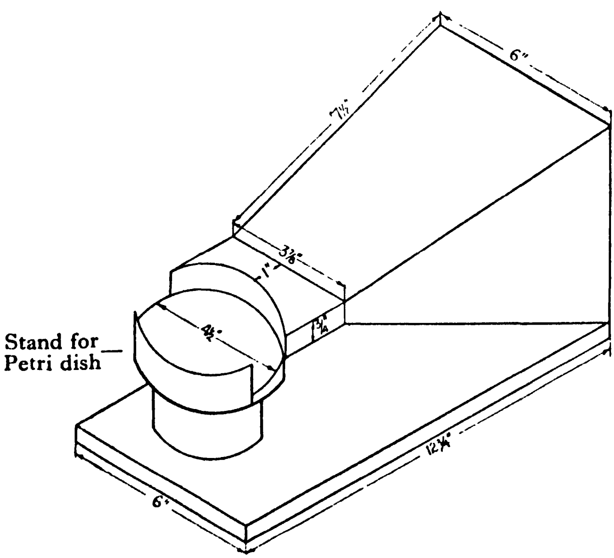


Fig. 166.—Counting lamp for colonies of bacteria.

has therefore been developed in which the light from a 60-W. lamp, after passing through a colour filter, falls in a horizontal direction on the colonies, which are then shown up in relief by their shadows;

minute air bubbles are thus also easily distinguished from the colonies by the bright reflexions from their surface.

The general construction of the lamp is clearly shown in the accompanying isometric projection (Fig. 166). The lamp is mounted on the (detachable) end plate of the pyramidal case. Blue, orange, or yellow filters are found best. A black with white-lined Pake's paper counting disc is placed below the dish.

143. A Simple Bacterial Colony Counting Device

By A. L. SIMS and R. C. JORDAN, Ph.D.

J. Sci. Instrum. **18**, p. 243 (1941)

The laborious work of counting large numbers of bacterial colonies has been greatly eased by the use of a simple automatically registering counter made from three purchasable parts (Fig. 167). A Burgess micro switch *A* with a leaf spring *S* as its operative element, and on to which a Stylo pen-nib *B* is soldered, is connected in series with the a.c. mains supply and an electro-magnetic counter.

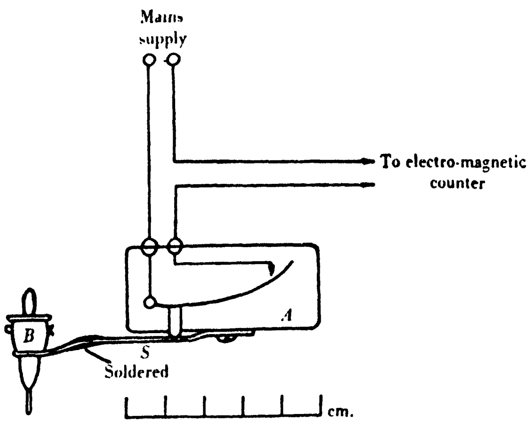


FIG. 167.—Bacterial colony counting device.

The Stylo nib is filled with fairly viscous Indian ink and, holding the switch (suitably insulated) in the hand, the nib is pressed lightly on to the Petri dish surface over each colony. The resultant pressure makes the contact in the switch and the counter is thereby activated, while simultaneously a small drop of ink marks the counted colony. With this simple device a plate containing 200 colonies can readily be counted in a minute with the minimum of mental effort.

144. Fitting Spider-Threads in Eyepieces of Optical Instruments

By F. H. Rolt, O.B.E., B.Sc., M.I.Mech.E., M.I.P.E.

J. Sci. Instrum. 7, p. 172 (1930)

The " cross-wires " of optical instruments often consist of two spider-threads either parallel or inclined at an angle to each other. Unless interfered with they last almost indefinitely, but occasions do arise when it is necessary to replace broken threads or to fit new ones at a different angle from those already in position. The following method allows this operation to be carried out with very little trouble.

It is usual for the " cross-wires " to be mounted on a ring or fitting which can be detached from the instrument. If it is a case of replacing broken threads, the positions for the threads will be identified by slight cuts visible on the upper face of the fitting. With new fittings it is necessary to make such cuts at the positions required.

The next step is to select a spider-thread of the desired thickness; this should be done by viewing with the eyepiece of the instrument concerned. If possible, the selection should be made from spiders' webs out of doors as they are not only usually free from dust but also stretched taut ready for mounting.

To mount the thread, bring the fitting up behind the web and, with the help of an eyeglass, hold the frame so that the particular thread selected lies in the cuts provided. A small drop of shellac-in-ether varnish applied to the cuts will quickly fix the thread in position, and it may then be severed on each side of the fitting with a pair of scissors.

As it is not possible to find webs out of doors at all times of the year, it is desirable to have some threads stored away in reserve. Such threads can be obtained by making a spider hang by its thread from a suitable frame which is gently revolving so as to wind the thread on to it. The frame should be stored in a dust-tight box.

[*See Notes* 145 *and* 146.]

145. A Simple Method of Fitting Fine Cross-Wires in an Optical Instrument

By D. G. Drummond, Ph.D., F.Inst.P.

J. Sci. Instrum. 10, p. 258 (1933)

It is a common observation that liquid glues such as are sold in small tubes can readily be drawn into thin fibres. I have recently made use of this fact in fitting fine cross-wires in optical instruments.

The technique of fitting the cross-wires is simple, consisting in placing a small dab of glue at the required point of the cross-wire ring, drawing out a fibre with the tip of a pin and then, after allowing it to harden for a moment, lowering it across the aperture and fixing the other end with a further dab of glue.

The nature of the fibre obtained depends upon the brand of glue used and upon various other factors such as temperature, humidity (possibly), rate and extent of drawing, and the time interval between taking the glue from the tube and drawing the fibre from it. I have not conducted any extended investigation into the separate effects of these factors and for the purpose in hand it is probably most satisfactory to experiment for a few minutes when required. In general, a glue in a fluid state is likely to yield a thinner and more uniform fibre than the same glue in a more viscous condition. This seems to be not an invariable rule, however, and certainly if the glue is too fluid it is not possible to draw fibres at all.

I have tried several kinds of glue and append a few notes on the behaviour of some common brands when used for this purpose. It is rather difficult to make comparisons because of the number of variable factors which are involved and these notes are, therefore, to be taken only as a general indication of the outstanding characteristics of the various brands.

Kirkor: fibres of indefinite length can be drawn immediately after taking the glue from the tube. These are very easily produced, are strong and flexible and tend to be rather thicker than those given by the following brands. Thicknesses from 0·04 mm. to 0·002 mm. are obtainable.

Croid No. 3: this is not so readily drawn until it has been exposed to the air for a few moments. It gives exceptionally smooth, straight fibres of thicknesses 0·01–0·002 mm. which are strong and resist draughts and shocks to the cross-wire ring but are rather brittle to the touch.

Seccotine: this tends to give rather lumpy and short fibres which are, however, strong and easily fitted as cross-wires. It readily gives fibres of diameters 0·004–0·002 mm.

Certofix: from this, fibres of a wide range of thicknesses down to 0·001 mm. are obtainable. It is not quite so easily worked with as the above brands and the fibres are less robust.

It will be seen from the foregoing that fibres of thicknesses from 0·04 to 0·001 mm. are obtainable by this method. For comparison, the single fibres taken from a silkworm cocoon are of thicknesses from 0·02 to 0·01 mm., are not straight and are comparatively irregular.

In estimating these diameters I have adopted the rough and ready method of laying a portion of the fibre in question on the surface of a celluloid grating replica and examining it under a microscope using a $\frac{1}{8}$-in. objective. The relation between the diameter of the fibre and the grating interval (0·0017 mm. approx.) is then judged visually.

In conclusion I may say that I have successfully used a pair of such cross-wires of thickness 0·005 mm. under the increased magnification obtained by substituting a low-power microscope for the usual eyepiece of a telescope.

[*See Notes* 144 *and* 146.]

146. A Simple Method of Fitting Fine Cross-Wires in an Optical Instrument

By R. W. LAWSON, D.Sc., F.Inst.P.

J. Sci. Instrum. **10**, p. 395 (1933)

Referring to Dr. D. G. Drummond's Note (*above*), I have obtained much better results with Rawlplug Durofix than with Seccotine. It is easily drawn into fibres of 10 μ or less in thickness, and does not show the "lumpy" structure of Seccotine fibres, referred to by Dr. Drummond. Durofix fibres are very uniform in thickness, and often seem to adhere where they cross, which gives added strength. Their toughness is shown by the fact that we have not yet succeeded in breaking such a cross-wire (ca. $1\frac{1}{2}$ cm. long, 9 μ thick) by blowing strongly at it at close range. Should a break occur, the fibres do not tend to curl up as do silk fibres ; in one instance I detected a break in one of the fibres of a cross-wire system by means of a lens, though to the naked eye there was no sensible displacement of the broken ends, and the break was not obvious.

[*See Notes* 144 *and* 145.]

147. Treatment of Discoloured Quartz Windows

By A. G. GAYDON, D.Sc., F.Inst.P.

J. Sci. Instrum. **19**, p. 123 (1942)

Windows of fused quartz become discoloured on prolonged exposure to short-wave ultra-violet light. The effect is particularly marked with windows on powerful discharge tubes used for producing the continuous hydrogen spectrum for absorption work in the ultra-violet. The windows become coloured a purplish hue, and the transparency falls off considerably. The colour is often restricted to the inner surface of the window, and several cases have been encountered in which the colour has been attributed to sputtering from the electrodes, and unsuccessful attempts have been made to remove the supposed surface deposit by chemical means or by abrasives.

The purple coloration can easily be removed by heating the window to about red heat, when it phosphoresces bright green for a few moments and then becomes quite transparent again. This effect has long been known,* but has received chiefly theoretical attention and appears to be unknown to many to whom it might be of practical interest. The treatment would not, of course, be suitable for windows of crystalline quartz, which are apt to shatter on heating. The simple heat treatment appears completely to restore the transparency in the visible and near ultra-violet, at least as far as 2300 A., and thus renders it suitable for use again for spectroscopic work with ordinary quartz spectrographs. As to the far ultra-violet (1800–2300 A.), the fact that some forms of quartz, mercury arc, which normally run too hot to develop the purple colour, lose their transparency to the mercury line at 1849 A. on prolonged running, seems to indicate that the effect of the heating may not extend to these very short wave-lengths.

148. Unscrewing Lens Mounts

By D. A. Cameron

J. Sci. Instrum. **20**, p. 32 (1943)

In dismantling an eyepiece or photographic objective for cleaning it sometimes happens that a lens mount or knurled retaining ring is not readily unscrewed. The application of a light oil may be effective if time is allowed for the oil to creep into the screw threads; but if after this force has to be applied, it is best to cut either key slots or holes in the mount or ring, rather than to attempt to grip it in its original state. Where the knurled edge protrudes, two cuts may be made with a hacksaw at opposite ends of a diameter, and an old hacksaw blade held in a vice makes a good key. Where the ring is recessed, two holes may be drilled (if key slots are not provided) and a suitable key made by cutting an iron washer in half and filing to shape.

* E.g. Baly, E. C. C., *Spectroscopy* **2**, p. 101 (London: Longmans, Green and Co., Ltd. 1927); Bailey, A. C., and Woodrow, J. W., *Phil. Mag.* **6**, p. 1104 (1928).

149. Transparent Scales on Glass Supports

By E. A. Baker, D.Sc.

J. Sci. Instrum. 13, p. 234 (1936)

Scales on celluloid or ivory are easily cut, and even the finest cuts are readily blackened; but the methods of filling fine cuts on glass are not so well known. The following method of obtaining finely divided scales or graticules on glass supports has been found effective.

The divisions are cut in the undeveloped emulsion of a "lantern" plate, which of course must not be exposed to bright light during the process. The plate is then developed, when the cuts appear as narrow black lines. By using very little pressure lines suitable for eye-piece scales are readily secured. The emulsion requires protecting by a cover-glass or by varnish. It may be noted that "lantern" emulsion is obtainable on plates of sizes other than those normally used for projection.

150. Making Thermometer Graduation Marks Permanent

By D. Northall-Laurie, F.R.I.C., M.I.Chem.E.

J. Sci. Instrum. 9, p. 96 (1934)

A method of making thermometer graduations permanent, so that they will not become faint after immersion in water for some time, is to make a stiff paste of silicon ester paint medium, a commercial preparation with a good fine quality of lamp black and, after cleaning the thermometer thoroughly, to rub the paste into the graduations, lightly cleaning off the excess with a rag. If the thermometer is warmed or left for some days, the silicon ester sets hard with the formation of colloidal silica which latter will not shift in water or be dissolved by any reagent other than hydrofluoric acid. Silicon ester when prepared for use by the makers will not keep in a suitable condition for more than two months and eventually sets to a gel. In this condition it is useless.

151. Stick-Slip Phenomena in a Lens-Centring Device

By L. B. Banks, A.M.I.Mech.E.

J. Sci. Instrum. **23**, p. 160 (1946)

An interesting but troublesome phenomenon has been encountered in connexion with a device for centring a lens on an optical bench. The set-up is shown in Fig. 168, and the difficulty that arose was that when the adjusting nut was turned in the direction to release the pressure in the spring a shuddering or "stick-slip" action was felt and a severe oscillation of the lens mount was set up, such as to make accurate adjustment impossible. When the nut was turned downward, so as to tighten the spring, the action was as smooth as could be wished.

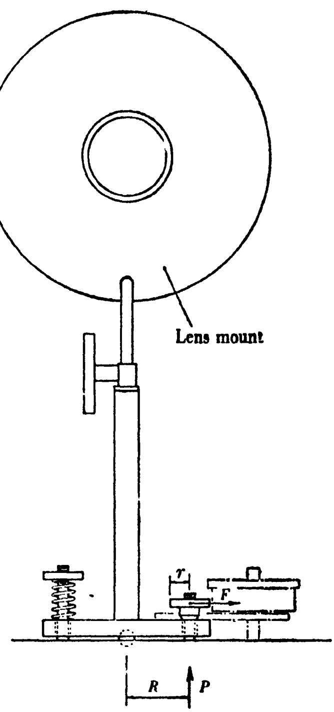


Fig. 168. — Modification (shown dotted) to lens centring device to counter "stick-slip" phenomena.

An analysis of the factors involved showed that the phenomenon originated in the friction of the nut and the angular accelerations of the nut and the lens mount. When the nut is turned, increasing force is exerted until the force of friction is overcome. Failure of the lens mount to follow the motion of the nut will lead to a sudden reduction in the friction immediately after the nut begins to turn, and the nut will be given an acceleration dependent upon the force applied to it and its moment of inertia. Shuddering will then occur. The condition for smooth adjustment, assuming a satisfactory pivot, is therefore:

angular acceleration of mount $\geqslant$ angular acceleration of nut.

If P is the force due to the spring acting upward on the nut,
R the radius at which P acts,
I_m the moment of inertia of the lens mount about its pivot,

F the force acting on the nut,
r the radius about which F acts,
I_n the moment of inertia of the nut,

then $$PR/I_m \geqslant Fr/I_n.$$

For any given coefficient of friction and thread form, $P = kF$, where k is a constant depending on these two quantities. The inequality can therefore be written

$$kR/I_m \geqslant r/I_n.$$

A cure in a given case can be effected by appropriate change in one or more of the four variables, viz. (*a*) increase R, (*b*) decrease r, (*c*) decrease I_m and (*d*) increase I_n. In the actual case considered it was decided to adopt (*a*) and (*d*), and this gave a complete cure of the trouble. The amendment to the design is shown chain dotted in the figure.

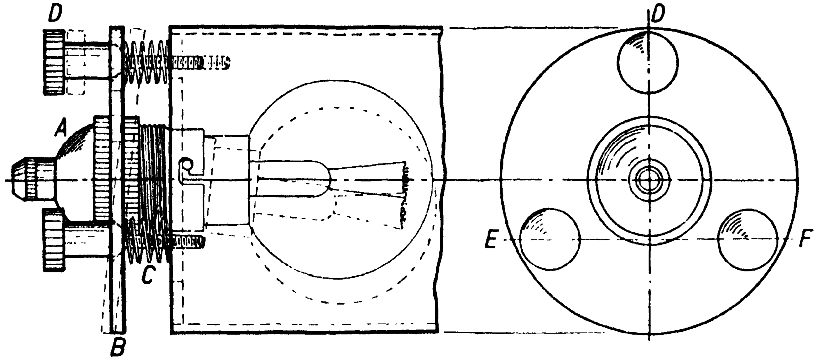
It will be obvious that similar trouble is likely to arise wherever a screw motion is used for adjustment of a mass which is compelled to follow by spring, or gravitational force. It has apparently been experienced in the worm drive of the elevating gear of gun turrets and has been analysed at some length in an article by S. J. Mikina in *Machine Design* for March 1945.

152. A Device for Centring a Microprojector Lamp

By R. Harries

J. Sci. Instrum. **12**, p. 393 (1935)

Most optical projection apparatus requires some form of device for centring the projection lamp. The writer devised the arrangement shown in Fig. 169 for adjusting the lamp of a microprojector, and the same idea could doubtless be employed on other pieces of apparatus. The lamp-holder A is secured to a brass plate B which has three equidistant conical holes drilled in it as shown. Each hole receives the hemispherical end of its adjusting screw, and the plate B is kept in contact with the screws by means of the springs C. The adjusting screws pass into the end-plate of the lamp house. The action of turning the adjusting screw D, for example, is to tilt the lamp about the line EF into the position shown dotted. When a large rocking movement is needed it is suggested that the plate B be modified, and instead of conical holes, slots with sloping sides should be employed. The screws can also be used to correct small errors in focusing, if so desired.



Side view of centring device End view

FIG. 169.—A device for centring a microprojector lamp.

153. A Continuous Record for Recording Drums

By R. E. CLARK, A.M.I.E.E.

J. Sci. Instrum. **11**, p. 267 (1934)

The usual chart for recording drums, where the record is made either by an ink-pen on white paper or a scratcher on smoked paper, is in one piece wrapped once round the drum and joined either by a clamp or by sticking the overlap. When the drum makes only one revolution this is quite satisfactory, but if the length of the record is increased by causing the drum to make several revolutions, and the pen or scratcher to spiral down the chart, the record obtained is more difficult to measure, because when removed from the drum it is no longer continuous and there is little or no space to write notes close to the record. These disadvantages may be overcome by winding on the drum a strip of paper in the form of an overlapping spiral of the same pitch as that of the marker. For a smoked chart the whole *outside* surface of the paper is smoked in the same way as the usual chart. The record thus obtained is continuous and has, when removed from the drum, a white margin for writing data close to the record.

The length of chart paper can be wound on to the drum at the right pitch by hand after marking with a pencil the overlap required; or the paper can be printed with a continuous line to indicate the overlap. Where a number of drums are constantly in use, a winding jig is an advantage. In this the drum of the recording instrument is placed upon a spindle secured to a winding handle; the portion of the spindle passing through a boss secured to the base is threaded to the required pitch and advances the drum as the winding handle is turned ; the roll of chart paper is maintained in one position and fed from a loose drum secured to the base.

154. A Simple Spark Recording Apparatus

By E. H. DOCK, M.Sc., F.Inst.P.

J. Sci. Instrum. **13**, p. 370 (1936)

One difficulty with pen recorders used for recording the movement of a stressed specimen is that of adjusting the pen so that just the right pressure is maintained, and a suitable trace produced without the pen digging into the paper. In the spark method no contact is made with the paper, and this difficulty does not arise. The paper, on which it is desired to make the record, is attached to a metal sheet or drum, and the metal is connected to one secondary pole of an induction coil or magneto. A light wire is fixed to the specimen, or other moving element, and this is connected to the other pole of the coil. A spark is produced, when desired, either by hand or by means of a timing device. The record is not easily visible to the naked eye unless it is held up to a strong light, or unless the metal has a distinctive colour which shows through, but it is particularly useful when subsequent measurements have to be made with a travelling microscope. The diameter of the hole depends on the intensity of the spark used, and it should not be too large. No special paper is required ; permanent records can be made on relatively cheap paper. A small coil may be used, but attention must be paid to the moving discharge point. The coil in use gives dots having a mean diameter of about 0·1 mm., and this of course limits the separation of distinguishable points. When using a measuring microscope it is easy to set the cross-wires on the centre of a hole, and measurements of the distance between two holes can be repeated to 0·05 mm. The method has been used satisfactorily with a large induction coil by having a subsidiary spark-gap in series with the one actually recording.

155. The Recording of Stationary Patterns on the Cathode-Ray Oscillograph

By E. T. S. WALTON, Ph.D.

J. Sci. Instrum. **22**, p. 54 (1945)

The method described here avoids the disadvantages of the use of photography, and gives a simple means for obtaining within a few minutes a permanent record of any stationary oscillograph pattern.

The principle is essentially the same as is used in the shadow projection method of showing convection currents due to heating. A piece of cellophane is held flat against a sheet of glass which is clamped close to the end of the cathode-ray tube. The curve seen is traced on the cellophane, using a pin point held in a pin chuck. This tracing is difficult to see in ordinary light, but if it is illuminated by a point source of light, the depression in the cellophane made by the pin point acts like a concave lens, causing the rays of light which strike it to diverge. A sharp shadow of the tracing is thus cast on a piece of paper held behind it, and the details may be drawn in readily by a pen or pencil.

An 18-W. motor-car headlamp bulb placed about a metre above the cellophane and suitably orientated forms a convenient point source of light. The cellophane should be placed between two sheets of glass at a distance of about 8 cm. above the paper. This leaves adequate room for drawing in the diagram.

Methods of holding the glass in front of the fluorescent screen may easily be devised to suit the oscillograph used. A brass ring clamped against the sheet of glass has been found satisfactory for holding the cellophane in position. A quick-release mechanism should be incorporated so that the cellophane may be changed rapidly.

The method is cheap to use and it has the advantage that records may be transferred rapidly to a notebook and studied during the course of a series of observations.

156. Corrector Bar Mechanism Applied to a Densitometer

By G. F. G. KNIPE, B.Sc.

J. Sci. Instrum. **20**, p. 64 (1943)

In photoelectric densitometers which have been used in this laboratory for some considerable time, the light used for measurement of the density is controlled by a neutral wedge with a nominally linear scale. For the highest accuracy, precise calibration of these wedges is necessary, and it has been found that the calibration changes are appreciable when the wedge ages, or if the lamp or photocell is changed. Originally when recalibration became necessary a new scale was made, but this has now been made unnecessary by using a corrector bar.

The mechanical arrangement is shown in Fig. 170. The main slide holding the optical wedge carries a bracket holding the density scale. This scale is printed photographically on a glass plate, and an enlarged image is projected by a fixed prism and lens on to a ground-glass screen for ease in reading. The bracket also carries the corrector bar which

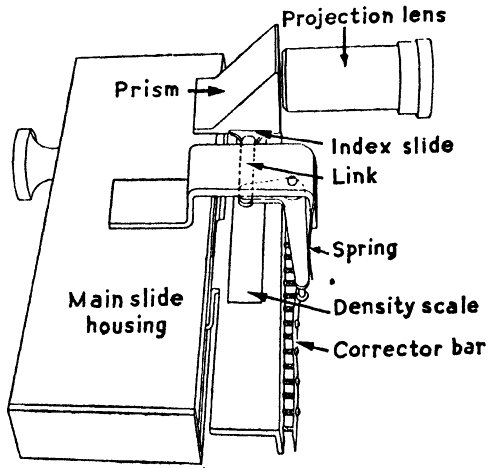


Fig. 170.—Corrector bar mechanism applied to a densitometer.

is supported by a row of adjusting screws, and is flexible so that adjustments can be made to correct for errors. Thus the optical wedge, the density scale, and the corrector bar all move together.

The reading of the density scale is indicated by an index line ; this index line, however, is not an ordinary fixed line, but is engraved on a glass plate mounted in the index slide just above the density scale, the index line being projected with the density scale. The index slide is connected by a link and crank to a roller which is pressed against the corrector bar by a spring, so that by adjustment of the bar the index line can be moved until the densitometer reads correctly.

By its use the densitometer can be made to read correct to $\pm$ 0·005 over the range of density of 0–4·0, within an hour, which, as can be imagined, is very much less than the time necessary to make a new scale.

157. A Gravity-Controlled Sight to Assist in Height Measurements

By S. L. Anderson, B.Sc., A.Inst.P.

J. Sci. Instrum. **19**, p. 186 (1942)

This device, of use in finding the extension of materials under load, is intended to assist in eliminating the effect of parallax when determining the height of a line by means of a scale which is at a short distance away from the line, either in front of or behind it. As can be seen

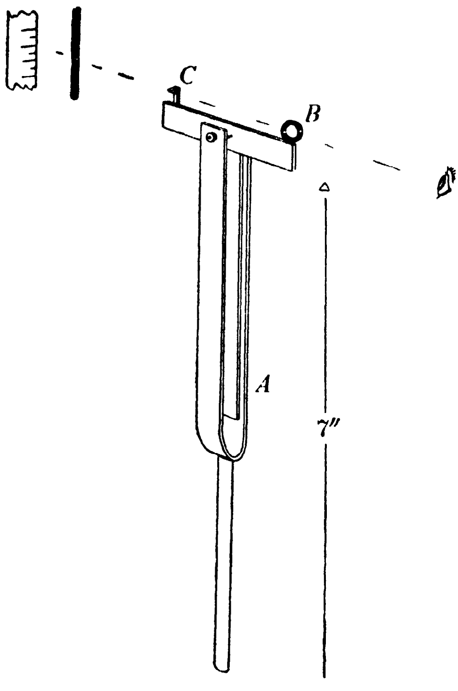


Fig. 171.—A gravity-controlled sight to assist in height measurements.

from Fig. 171, it consists of a **T**-piece pivoted in a fork with a handle *A*. A 4 B.A. brass washer forms the back-sight, while the fore-sight consists of a short brass wedge; these are maintained in a horizontal line by the weight of the vertical arm of the **T**. The device is held in the hand, and standing at a little distance the sights and the line of which the height is required are lined up upon the scale. The back-sight is painted black with a white line across its horizontal diameter, the fore-sight is painted white. There is a clip (not shown) upon the fork to hold the T-piece when not in use.

158. Adjustable Telescope Holders

By S. MUNDAY

J. Sci. Instrum. **14**, p. 414 (1937)

When using a telescope in a laboratory stand it is a difficult matter to focus the cross hairs on to a definite mark, e.g. a scale, owing to the fact that the final clamping invariably tilts the telescope. This difficulty has been overcome by fitting a fine adjustment on existing telescope holders. Two methods have been adopted ; one using comparatively long radial bars with a tangent screw, the other with worm-gear drive. The former type is simpler to make, but its range of movement is small and it has not the " mechanical " appearance of the latter.

The usual laboratory stand telescope holder consists of a light casting

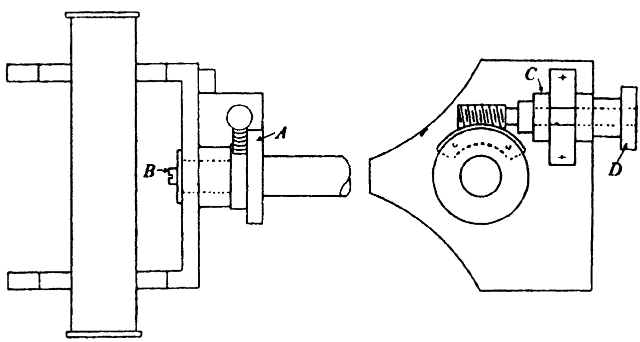


FIG. 172.—Worm-gear adjustable telescope holder.

in the form of two parallel vees in which the telescope is held. Rigidly attached to the casting is a steel rod, the axis of which is at right angles to the axis of the telescope. The steel rods were removed from the castings and the latter rebored and faced up on both sides of the boss.

In the case of the worm-gear type, referring to Fig. 172 which shows side and end views of the holder, bosses *A* were silver-soldered to the rods. These bosses, together with the small end of the rods, were turned in the lathe, thus ensuring that the smaller diameter of the boss upon which the worm-wheel is mounted, and the rod end upon which the casting turns, were concentric. The rod is prevented from moving axially by a shoulder screw and washer *B*. A worm-wheel was made and cut into three parts, so serving for three telescope holders. These sectors were fixed to the boss *A* by two screws. The worm-shaft bearing *C* was built up from brass bar and fixed to the back of the casting by two screws. Some fitting was necessary here as the backs of the castings were not readily machinable. The worm is revolved by the knurled head *D*.

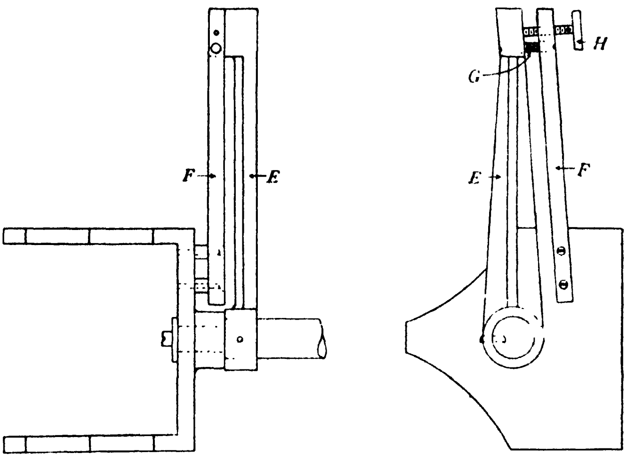


FIG. 173.—Radial-bar type of telescope holder.

For the radial-bar type shown in Fig. 173, the same procedure in the case of the castings was adopted, but no bosses were fixed to the rods. A bar casting *E* was fixed to the rod and a steel bar *F* to the back of the telescope-holder casting. The two bars are pulled together by the spring *G* and separated by the tangent screw *H*.

The movement of the telescope holder relative to the rod is limited in this type by the permissible extension of the spring.

159. A Method of Constructing Slits of Fixed Width

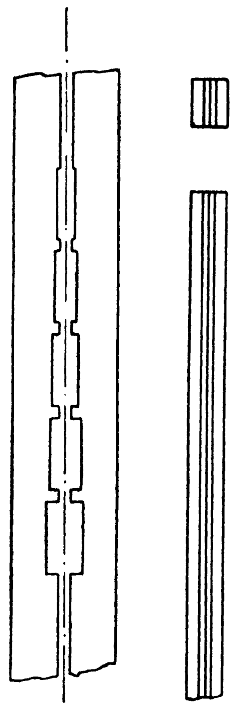
By W. L. BUXTON

J. Sci. Instrum. 9, p. 297 (1932)

In certain optical systems it is convenient to incorporate slits of fixed predetermined widths. For example, a certain piece of apparatus which the writer had to construct required a series of eleven slits 12 mm.

in length, varying from 0·1 to 2 mm. in width, arranged vertically above one another.

If we split the slits along their common axis (Fig. 174 (*a*)), we have two strips, along the edges of which there is a series of rectangular notches of varying depths. These depths are equal to half the widths of the respective slits. Therefore, if we machine strips along their edges, and cut a series of rectangular notches, of length equal to the length of the slit required, and depth equal to half the width of the slit, and place the strips edge to edge, so that the notches coincide, we have the required openings.



(*a*) (*b*)

FIG. 174.—Constructing slits of fixed width.

A description of the procedure adopted may serve as a guide to anyone who intends making slits of this description. Two pieces of brass about 12 mm. wide, 0·5 mm. thick and of the required length were carefully flattened, tinned and sweated together with protecting pieces of the same width but ⅛ in. thick on either side (Fig. 174 (*b*)). Both edges were then machined up, and a final cut, with a high-speed vertical mill of the same diameter as the length of the slits, was taken. This gave the zero setting of the vertical movement of the machine table. By raising the table half the slit width and taking a cut across the strips, a rectangular notch was formed. The table was next moved along by an amount equal to the length of the slit plus the distance of the space between the slits, and another cut taken whose depth was equal to half the width of the next slit, and so on until the complete series was finished. The strips were then unsweated and all surplus solder carefully removed. Next the notches were backed off by hand so that they had nearly a knife edge. Finally they were mounted, notch to notch, on suitable strips having openings running nearly their entire length and a little wider than the widest slit.

The writer has found it possible to produce slits as narrow as 0·05 mm. without difficulty, and by employing suitable means and exercising reasonable care even narrower ones could be produced. It is hoped that in the near future an attempt will be made to construct slits of stainless steel on this plan.

160. Reproduction of Graphs by Industrial Photo-Print Methods

By O. Kantorowicz, Dr.Phil., F.Inst.P.

J. Sci. Instrum. **23**, p. 131 (1946)

The reproduction of graphs drawn on commercial graph papers by blue or dye line printing is difficult, and the resulting prints are often patchy. Clean and clear prints can be obtained by the method here described. This method also results in a reduction of drawing-board work if several sheets of graphs which differ in detail only are to be reproduced (e.g. standard test results on similar objects).

The reproduction process is in two stages: first, a master sheet is prepared by drawing on a commercial graph paper with Indian ink the design common to all graphs (e.g. trimming lines, captions, scales, etc.). A typewriter can also be used on the master sheet provided the ribbon is fresh and a virgin piece of carbon paper is inserted behind the master sheet with the waxed surface in contact with the back of the master sheet. The master sheet can now be " oiled " (from the front side only if a carbon paper has been used), but such " oiling " is necessary only if the paper base of the master appears " cloudy ". Secondly, the prepared master sheet is contact printed on translucent sensitized material like Ozalid cloth. For this printing process the master sheet is reversed (back to front) so that the side carrying the design and the graph grid is in direct contact with the sensitized layer of the translucent material. After developing, the copy in its turn is inverted and placed on white paper. The design is fairly easily recognized from the back, and the individual detail features of the graph are now added on the non-treated side of the copy with Indian ink. Erasures of this detail can easily be made without damage to the master design and grid lines. The copy is finally printed with the treated side in contact with the treated side of the print.

It is believed that the success of this method is due to the intimate contact of treated sides. Diffusion of light in the thickness of paper, inherent in the usual method of printing, is thereby avoided.

161. A Device for Visual Observations at Low Temperatures

By A. SCHALLAMACH, Dipl.Eng., F.Inst.P.

J. Sci. Instrum. **19**, p. 169 (1942)

Faced with the task of making a great number of visual observations over a wide range of fairly low temperatures, the author designed a device which, because of its simplicity, may be found useful for other purposes. A cross-section through the apparatus is shown in Fig. 175. The object, or object carrier *A*, is cooled by conduction along the copper rod *B* which dips into a cold medium, such as liquid air, contained in a suitable Dewar flask *C*. The object is insulated by the small Dewar vessel *D*, the inner part of which is continued outwards into a collar which slips over the upper part of the copper rod *B*. A rubber sleeve *E* makes a sufficiently airtight connexion between this rod and the vessel *D* even when immersed in liquid air. As rubber in contact with copper perishes rather quickly, it is highly advisable to place a steel ring *F* over the copper where the sleeve makes contact. The heavy black line in the centre hole of the copper rod represents a Paxoline sleeve which holds the leads of a thermo-couple attached to *A* and which is brought out in the manner shown. The hole is closed by a countersunk screw with a small hole drilled through it just large enough to take the Paxoline sleeve. If need be, the lead-in can be made tight with a thin application of cellulose acetate (film base) varnish. The apparatus is supported by a steel wire *G* held in a retort stand, or in something similar.

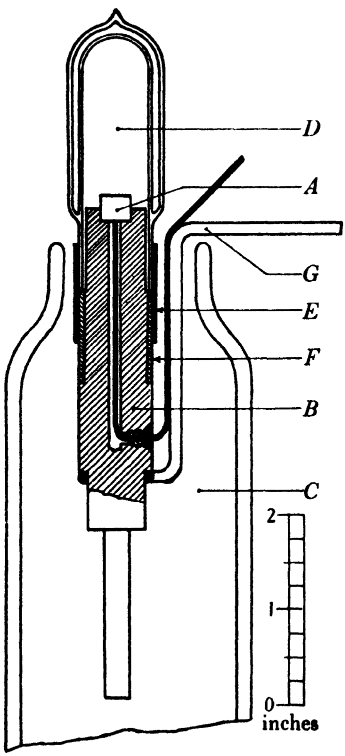


FIG. 175.—Cross-section of device for visual observations at low temperatures.

The final temperature taken up by *A* depends, of course, on how far the device is lowered into the cold bath. A further measure of control is afforded by turning the lower end of the copper rod to a smaller diameter. Another purpose is served thereby; when the apparatus is gradually lowered liquid air will not boil up so rapidly at first, as only the thin part is immersed. This apparatus has been in use for a considerable time and has proved very economical in the consumption of liquid air.

162. The Observation of Reflecting Galvanometer Deflexions

By R. V. Jones, D.Phil., F.Inst.P.

J. Sci. Instrum. **11**, p. 233 (1934)

Much of the fatigue caused by determining a series of reflecting galvanometer deflexions can be eliminated by inserting a green filter in the optical system. This increases the sharpness of the image, as chromatic aberration is reduced, and the zero line appears more distinct. It also changes the colour of the background from an unpleasant yellowish white to green; this decreases the strain caused by looking at the patch of light. The writer has found the Wratten No. 52 to be the most satisfactory filter tried; a deep yellow filter gave very good contrast, but was most tiring. The reduction in fatigue when making fifty or more successive observations is very marked.

163. Oscillograph Film Camera for Brief Records

By A. J. Small, Ph.D., A.M.I.E.E.

J. Sci. Instrum. **15**, p. 238 (1938)

When oscillograph records are required of the wave form of regular cyclic variations, the ordinary film camera is very wasteful of film.

On a length of old or scrapped film a piece of recorder photographic paper or unexposed film, 5 in. long, is mounted at a sufficient distance from the leading end, say 2 ft., to ensure that the film speed shall be uniform when the sensitive paper passes through the camera window. If the strip of film carrying the sensitive paper is used in the camera as supplied, the small diameter of the spindle and the acute angle of approach of the film to the upper sprocket wheel would cause the paper to become detached from the film. Consequently, it was found necessary to fit to the spindle of each pulley a hardwood disc, about 4 in. diameter, the disc on the driving spindle being provided with a brass fitting by which one end of the length of old film could be attached to the disc.

The method of mounting the piece of paper is shown in Fig. 176. A narrow slot is cut across the film with a sharp knife to within ¼ in. from the sprocket holes at each side. The film is reinforced by a piece of thin adhesive paper gummed on the under side of the film in such a way as to leave a pocket behind the slot. One end of the sensitive recorder paper is slipped through the slot into this pocket and the other end is slipped under a second piece of thin paper gummed at the edges to the top side of the film. The thin adhesive paper serves to facilitate the passage of the sensitive paper and film through the camera window.

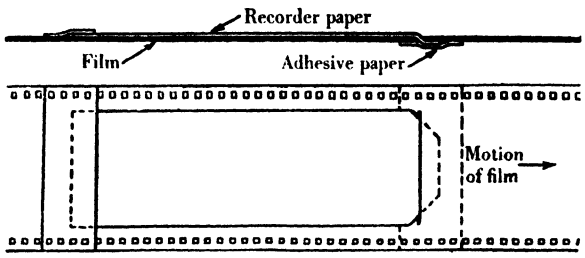


FIG. 176.—Method of attaching recorder paper to film.

The same piece of film can be used satisfactorily for at least 100 records, after which wear of the sprocket holes usually necessitates the film being replaced.

In addition to recording recurrent phenomena the foregoing modification of the film camera can be used during preliminary adjustments of the oscillograph or of the electrical circuits, before recording transient phenomena in the usual way. The brief record thus obtained enables the synchronizing of the various elements, the position of the traces on the film, the time scale, etc., to be checked without exposing a long length of film with its accompanying inconvenience in development.

164. A Siphon Head for Dewar Flasks

By G. C. ELTENTON, B.A., A.Inst.P.

J. Sci. Instrum. **16**, p. 28 (1939)

During some work which required the maintenance of a constant level of liquid air it was found that the usual siphon heads tended to leak and necessitated a number of heads to cover the range of Dewar flasks required. The head illustrated in Fig. 177 provides a solution of the problem. By making the rubber seal *R* re-entrant the head becomes self-sealing for a large range of neck diameter *d*. For the usual

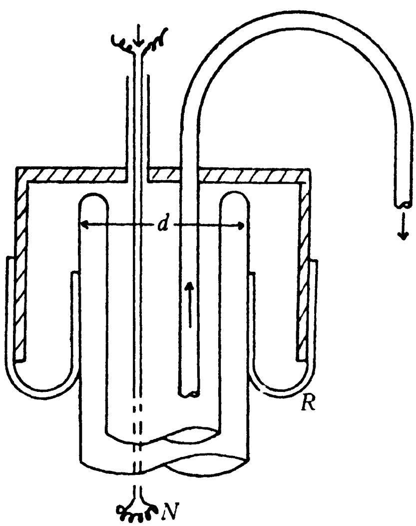


FIG. 177.—A siphon head for Dewar flasks.

Dewar flask capacity (2–5 l.) a 3-in. inner tube is suitable. The excess pressure in the flask can be obtained either by blowing or by evaporation. The latter method is much more convenient when a constant level has to be maintained in a subsidiary vessel. A float in the latter can then operate a relay in a circuit supplying energy to a small nichrome spiral *N* immersed in the liquid air of the main Dewar flask. It was found possible in this way to maintain a level constant to within ± 0·5 mm. over a period of hours, without attention.

165. A Simple Safety Siphon

BY R. READMAN

J. Sci. Instrum. **8**, p. 331 (1931)

The well-known form of siphon illustrated in Fig. 178 has the disadvantages of requiring suction for filling; of affording insufficient safeguard when used with acids or poisonous liquids; of drawing air into the liquid during operation; and of having to be refilled afresh for each vessel from which liquid is to be drawn.

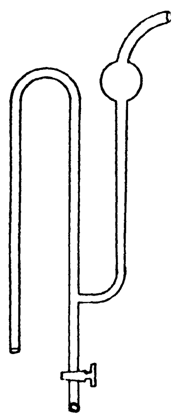


FIG. 178.—Well-known form of siphon.

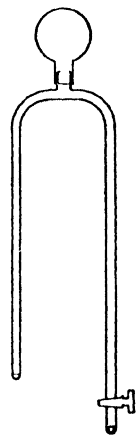


FIG. 179.—Simple safety siphon.

The simple form shown in Fig. 179 was made up for emptying a number of battery jars. It is filled by closing the tap and by pressing and releasing the bulb, which is of a type used with certain photographic studio shutters. On closing the tap the siphon remains filled, while in use no air is drawn in.

166. An Automatic Siphon

By H. TOMPA, Ing.Dr.Tech., A.Inst.P.

J. Sci. Instrum. **21**, p. 88 (1944)

The siphon shown in Fig. 180 has been found very useful for siphoning liquids where sucking to start the flow is impossible or inconvenient. It consists of a bent tube whose shorter limb is surrounded by a bulb with a constricted opening; the bulb communicates with the tube by a small hole at the top. If the shorter limb is plunged into a liquid so that the bulb is fully immersed and the bend is not too high above the surface, liquid rises at once up the inner tube and slowly into the bulb; it pushes the air there through the hole into the tube, where it rises and, acting as an air lift, carries the liquid over the top of the bend. Once started, the siphon acts as an ordinary siphon. The dimensions given in the sketch have been found satisfactory, though they are probably not an optimum. A glassblower of average skill should be able to construct the siphon; it is only important to keep the opening at the mouth of the bulb small, so that it takes 3–5 sec. to expel the air.

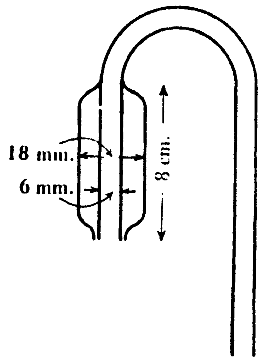


FIG. 180.—An automatic siphon.

[*See following Note.*]

167. Modified Construction of an Automatic Siphon

By V. A. YARDLEY, A.M.I.Mech.E., A.M.I.Chem.E.

J. Sci. Instrum. **22**, p. 115 (1945)

The self-starting siphon described by H. Tompa in the above Note is formed at the base with an annular opening which if made too large cannot easily be made smaller: the limit appears to be reached when the walls of the annulus are about 0·5 mm. apart. In a modified design, devised by the writer, the annulus is replaced by a small hole in the base of the bulb which is otherwise sealed (see Fig. 181): besides simplifying construction this method enables the opening to be made a definite size and renders the device more certain in action.

For mobile liquids such as water, paraffin, ammonia and the usual acids the apparatus functions readily with a hole no more than 1·5 mm. diameter, but for less mobile liquids, such as oils, it is preferably increased to, say, 2 mm. In this case it is convenient to have a tube of larger bore inside the bulb so that the liquid can rise fast enough to trap the air within the bulb.

The depth of immersion of the air hole must also be considered.

Even for small lifts a submergence of about 5 cm. is needed for oils of medium viscosity, although for mobile liquids this depth can be reduced to about 1·5 cm. With a 5 cm. depth of immersion in water, the glass siphon described by Tompa will start with a lift of 15 cm.; to obtain the necessary depth of submergence in shallow conditions the bulb shape can be made rather wider and flatter. The simplified construction now suggested permits of easy fabrication in metal with consequent less risk of breakage; moreover, by directly attaching a rubber

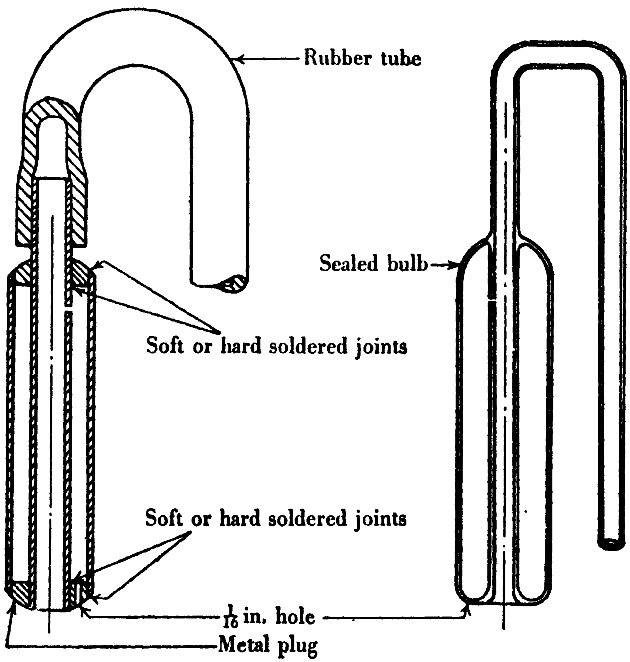


FIG. 181.—Modified automatic siphon.

tube to a short extension of the bulb, greater flexibility in use is obtained. One method of construction in metal is shown in the sketch.

The arrangement has been very convenient for obtaining samples of liquid from depths of a metre or more. Rubber tubing, however, has a greater frictional resistance than glass or metal, and consequently more energy has to be expended by the air in overcoming this; hence the lift must be kept low and the length of the outer limb short, say no more than 30 cm.

[*See previous Note.*]

168. A Buoyancy Manometer for Use with Corrosive Gases

By R. S. Bradley, M.A.

J. Sci. Instrum. **15**, p. 338 (1938)

A simple pressure gauge, illustrated in Fig. 182, operating over a range of about an atmosphere has been made by observing the change of buoyancy of a light glass bulb suspended from the end of a quartz spiral spring. The bulb was blown from Pyrex tubing which was rotated rapidly in a " soft " blow-pipe flame. In this way a uniform symmetrical bulb was obtained of sufficient strength for use up to pressure changes of one atmosphere, though it required careful handling. One of 10 ml. capacity weighed approximately 0·25 g.; it was found impossible to increase the ratio volume to weight much over 40 owing to uneven thickness of the bulb. A greater ratio could no doubt have been obtained by a professional glass-blower.

The spiral spring was made by winding, in a blowpipe flame, a quartz fibre on to a quartz tube. The sensitivity was 140 cm./g., i.e. the bulb extended the spring by 35 cm. This gives a displacement of about 1 cm. per atmosphere in air, and about 2·5 cm. in chlorine. As the motion of the bulb can be read to 0·004 mm. by means of a travelling microscope, pressure changes of an atmosphere can be read to 1 part in 250 in air and to about one-third of this in chlorine. Greater sensitivity could be obtained by the use of a bulb with a larger ratio of volume to weight or by the use of a longer spring. There will be a slight departure from linearity due to compressibility of the bulb, so the apparatus should be calibrated against a manometer for accurate work. It also should be used in a thermostat if great accuracy is desired.

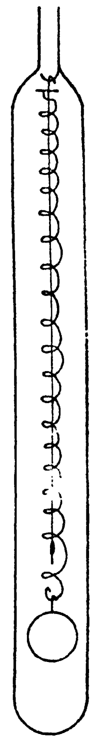


Fig. 182.—Buoyancy manometer.

The manometer may be housed in a tube with ground joints greased with metaphosphoric acid, or more conveniently in a glass tube sealed at the lower end as in the sketch. The upper end of the spring is engaged in a support fixed in the tube. For a reference point, a fibre passing down the axis of the spiral may be suspended from the same support. The lower end of this fibre will then hang in approximately the same plane as the point of the hook at the bottom of the spring to which the bulb is attached and their relative heights can easily be read.

169. A Safety Device for a Differential Oil Manometer

By W. W. BARKAS, D.Sc., F.Inst.P.

J. Sci. Instrum. **16**, p. 162 (1939)

A differential U-tube manometer containing oil affords a sensitive method of measuring small differences in gas pressure, but if the pressures cannot be applied simultaneously to the two sides of the manometer, some means must be devised for preventing the oil from blowing through the tube before the pressures have been approximately equalized. The simple method adopted at this laboratory has proved suitable for absolute pressures of the order of half an atmosphere (500 cm. of oil). It is illustrated in Fig. 183.

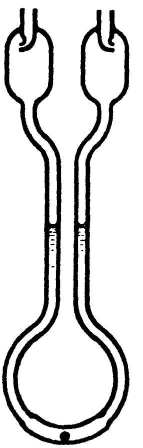


FIG. 183.—Safety device for a differential oil manometer.

The bottom of the U-tube is made of rather wider diameter than the rest, and a steel ball-bearing is trapped in this portion. Any sudden difference of pressure drives the ball up against one or other of the narrower ends, thus closing the tube, but when the pressures are nearly equal, the ball rolls to the centre and offers no hindrance to the true manometer equilibrium. In the type used a $\frac{3}{16}$ in. ball is inserted in a $\frac{1}{4}$-in. tube. No grinding of the constricted necks is necessary unless the pressure difference has to be held for long periods. If the ball becomes jammed in the neck due to a too sudden movement of the oil, it can be loosened by tapping or with a magnet once the pressure difference has been relieved.

170. The Determination of Volumes by the Use of Carbon Dioxide

By W. W. BARKAS, D.Sc., F.Inst.P., and J. M. PATON

J. Sci. Instrum. **20**, p. 163 (1943)

In the course of an investigation at this laboratory it was found necessary to determine the volumes of various portions of a complicated and irregularly shaped apparatus. Direct determination by filling with water and weighing was ruled out, and determination by the method of measuring the pressure changes on expanding air from a known volume did not give results of sufficient accuracy. The method finally adopted was as follows.

The apparatus, kept at a constant temperature, is evacuated and filled with carbon dioxide to a known pressure less than atmospheric. The carbon dioxide from each volume is then allowed access to two previously evacuated and tared vessels containing soda asbestos and phosphorus pentoxide respectively. The carbon dioxide is absorbed by the soda asbestos according to the equation

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O.$$

The water set free during the reaction is absorbed by the phosphorus pentoxide. The volumes under determination varied from 100 ml. to 200 ml., and with these 1 hr. is sufficient for almost complete absorption. At the end of this time the absorption vessels are closed, the pressure of the residual carbon dioxide is measured and the absorption vessels removed and weighed. From the data obtained, and taking 1·977 g./l. at N.T.P. as the accepted value for the density of carbon dioxide, the required volumes are calculated. If the final pressure is not zero a correction is applied to allow for the expansion of the residual gas into dead spaces.

Let W_1 = the sum of the inital weights of absorption vessels in grammes.
W_2 = the sum of the final weights of absorption vessels in grammes.
P_1 = the initial measured pressure in centimetres of mercury.
P_2 = the final measured pressure in centimetres of mercury.
V = the required volume in millilitres.
V_a = first approximation to required volume in millilitres.
T = temperature in degrees Centigrade.

$$V_a = \frac{W_2 - W_1}{1{\cdot}977} \times \frac{273 + T}{273} \times \frac{76}{P_1 - P_2} \times 1000.$$

But the residual gas has expanded from V into the dead spaces V_d and the correct value for V is given by

$$V = \frac{W_2 - W_1}{1{\cdot}977} \times \frac{273 + T}{273} \times \frac{76}{P_1 - P_2[(V_a + V_d)/V_a]} \times 1000.$$

Note.—V_d does not include the absorption vessels, but may contain the manometer, in which case it is corrected for the depression of the mercury in the open limb at pressure P_2 as in the following example :

$$W_1 = 89{\cdot}1267 + 83{\cdot}2440 = 172{\cdot}3707 \text{ g.}$$
$$W_2 = 89{\cdot}1815 + 83{\cdot}2591 = 172{\cdot}4406 \text{ g.}$$
$$P_1 = 17{\cdot}390 \text{ cm.} \qquad P_2 = 0{\cdot}050 \text{ cm.}$$
$$T = 23^\circ \text{ C.} \qquad V_d = 180{\cdot}8 \text{ ml.}$$

V_m = volume due to depression of mercury in manometer at P_2.

$$V_a = \frac{W_2 - W_1}{1{\cdot}977} \times \frac{273 + T}{273} \times \frac{76}{P_1 - P_2} \times 1000$$
$$= \frac{0{\cdot}0699}{1{\cdot}977} \times \frac{296}{273} \times \frac{76}{17{\cdot}390 - 0{\cdot}050} \times 1000$$
$$= 168{\cdot}0 \text{ ml.}$$

and

$$V = \frac{W_2 - W_1}{1{\cdot}977} \times \frac{273 + T}{273} \times \frac{76}{P_1 - P_2[(V_a + V_d + V_m)/V_a]} \times 1000$$
$$= \frac{0{\cdot}0699}{1{\cdot}977} \times \frac{296}{273} \times \frac{76}{17{\cdot}390 - 0{\cdot}050\,(248{\cdot}86/168{\cdot}0)} \times 1000$$
$$= 168{\cdot}2 \text{ ml.}$$

The following shows a comparison of the results obtained on a volume which had been calibrated with water :

By weighing with water ml.	By absorption of carbon dioxide ml.
139·5	139·4
	138·8
	138·8

Three complete sets of results for the various portions of the apparatus are

Exp.	Portion 1 ml.	Portion 2 ml.	Portion 3 ml.	Portion 4 ml.	Portion 5 ml.
a	136·0	132·7	116·9	113·1	169·5
b	135·4	132·4	117·8	113·2	168·8
c	135·8	132·4	117·2	113·3	168·2

In the more usual gas-expansion method the accuracy of the result varies with the ratio of the volumes of the known and unknown vessels, whereas in the present method the absolute accuracy is the same whatever the volume, depending only on the initial and final pressures of the carbon dioxide and the accuracy of weighing.

171. Two Constant Pressure Devices

By A. Clow, D.Sc., A.R.I.C., and G. Shand, B.Sc., B.Sc.(Eng.)

J. Sci. Instrum. **16**, p. 354 (1939)

The action of the all-glass manostat is shown diagrammatically in Fig. 184. Purified gas under pressure enters the system at *A*, and is stored in a reservoir *B*, having a capacity of about 6 l. at a pressure which can be read on the manometer *C*. A two-way tap D_1 normally allows the gas to pass by way of the tap D_2 and the capillary *E* to the all-glass valve *F*. This valve, which is controlled by the relay *R* and solenoid *S*, is shown in greater detail in Fig. 185, and is described below. From the valve the gas passes through the tap D_3 to the pressure regulator *G–H* in which a column of mercury makes and breaks an electric current; depending on the variations in pressure, which operates the

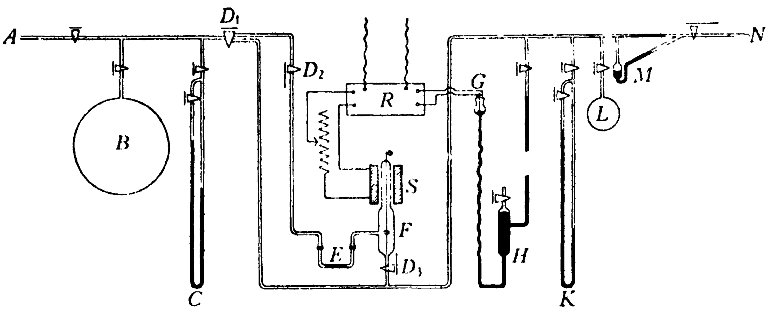


Fig. 184.—Flow diagram of all-glass manostat.

relay controlling the current through the solenoid. The resultant pressure is read on the manometer *K*. Small variations in pressure produced by the opening and shutting of the valve are smoothed out by the reservoir *L* of 250 ml. capacity. *M* is a flow-meter and the gas is delivered at the end *N*. The two-way tap D_1 is used to by-pass the valve when pumping out the system.

The valve *F* consists of three parts of simple construction, details of which are given in Fig. 185. The concave half of a spherical standard joint *A* is sealed off and fused to a length of 7-mm. tube. A small asbestos pad *B* protects this joint from the jar of the falling armature *C*. After this soft-iron armature has been inserted in the 7-mm. tube, the tube is drawn down to as good a cone as possible and sealed off at about 4 cm. above the end of the armature, thus allowing the armature room to fly up and jerk the valve from its seating. The upper end of the moving part of the valve fits loosely into the roughly ground glass cone D, the amount of freedom of movement at this point being critical, of the order of 1 mm., a gap which can be adjusted when making the final joint of the valve at J. The valve is connected to the exit tube by a standard joint K (B 19 B.S.S.) which must be large enough to pass the spherical joint which forms the valve.

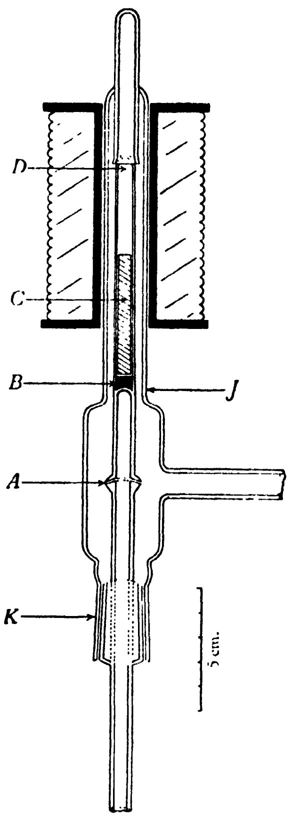


Fig. 185.—All-glass valve.

When supplied by the makers the spherical standard joint is ground to the degree of fineness for joints intended for use with vacuum grease and it must be polished with "ninety minute" rouge until it does not pass more than 10 c.c. of gas per hour, when the clean dry surfaces are merely placed in contact without any grease whatsoever, and one side evacuated. The success of the device depends on the perfection of this polishing.

It was found in operation that the settings of D_2 and especially that of D_3 were critical: both of these were therefore fitted with extension handles and had scores made half round their barrels with a triangular file. The height of the circuit breaker controls the pressure at which the device operates; any variation in the atmospheric pressure during a run being corrected at this point.

Fig. 186 illustrates the second device which manostats by admitting air to the connected system when the vacuum exceeds a predetermined limit. It consists of a mercury reservoir connected through a tap or rubber tube and screw clip to a column of mercury supported by a rubber diaphragm which, while maintaining contact with a capillary nipple, closes the system to the atmosphere. When the degree of vacuum exceeds the limit the weight of the atmosphere lifts the diaphragm admitting air to the system, thus restoring the predetermined pressure. The diaphragm is made by cementing with rubber solution a piece of sheet rubber to a rubber plug cut from a rubber stopper. The nipple against which it presses is made from 7-mm. tubing which has been thickened up until the internal diameter is less than 1 mm. and ground flat so as to present no sharp edges to the diaphragm. The nipple is adjusted to take up a position 1 mm. below the diaphragm by other rubber plugs.

The pressure at which the device operates is a function of the height of the mercury column and this is adjusted to the required pressure by admitting mercury from the reservoir through the tap t_2, or through

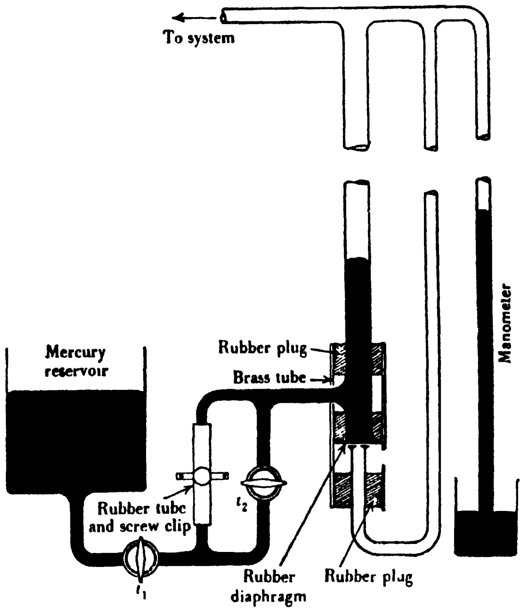


FIG. 186.—Alternative type of manostat.

the rubber tube and screw clip. In operation a rapid oscillation of the diaphragm is set up, the actual movements being very slight.

As in the previous device, changes in the pressure of the atmosphere must be allowed for, but, provided that this is done, both devices have been shown to be capable of maintaining a system of quite small volume to within 0·1 mm. of the required pressure, without any mechanical attention whatsoever.

172. A Device for Producing a Slow Constant Flow of Liquid

By R. J. Davies, M.Sc., F.Inst.P.

J. Sci. Instrum. **8**, p. 110 (1931)

In many experiments it is necessary to have a slow flow of liquid, the rate of flow to remain constant over long periods. The device (Fig. 187), which may be used for any liquid, has been found very satisfactory.

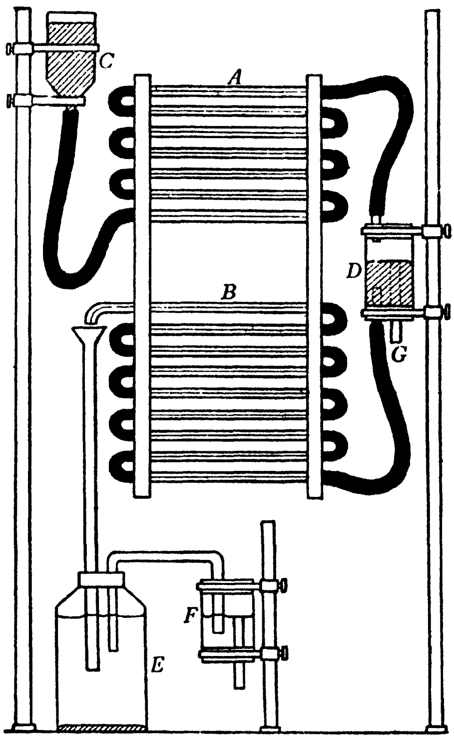


Fig. 187.—A device for producing a slow constant flow of liquid.

A number of capillary tubes of small bore are connected together by means of high-pressure rubber tubing as shown in Fig. 187 at *A*. A reservoir *C*, containing mercury, is connected by pressure tubing to the bottom capillary tube and may be raised or lowered, thus producing a variable pressure head. By means of the upward flow of mercury through the tubes thus obtained, air bubbles, which are found to occur in the rubber tubing if a downward flow is adopted, are eliminated. From the exit tube of the set *A*, mercury drops into a constant-level reservoir *D*, which is again of variable height. In this reservoir the level is maintained constant by means of the open tube *G*, which tube also provides an outlet for the excess inflow of mercury over that which flows through the set *B*. The tubes *B* are 20 per cent to 30 per cent longer than those of *A*, and are connected together in precisely the same manner, the flow being again by upward displacement. The mercury from the exit tube of *B* drops into a funnel-shaped tube, and thence into a large glass vessel containing the liquid to be used. This liquid is displaced by the mercury and flows into the constant level trap *F*, from which it drops at a steady rate.

The whole apparatus is rigidly mounted on a large vertical wooden panel firmly attached to a heavy wooden base. The latter supports the vessel *E*, and holds the supports for the reservoirs *C* and *D*. The capillary tubes are mounted 3·5 cm. apart by being passed through holes in strips of wood attached to the panel as shown

In the construction of the apparatus it is important to ensure that the capillary tubes are carefully cleaned, the rubber tubing free from sulphur, and the mercury free from impurities. The capillary tubes were cleaned by passing successively through them nitric acid, distilled water and pure alcohol, and the rubber tubing was boiled in caustic soda solution.

The length of capillary tubing used clearly depends on the rate of flow desired, less tubing being necessary for a faster flow, and vice versa. By using capillary tubes of different bores, it was found that 0·25-mm. bore is the most satisfactory. With smaller tubes the rate of flow becomes erratic, and with larger tubes the viscosity effect is so much reduced that very long lengths of tubing are necessary. Using seven capillary tubes of 30 cm. length and 0·25-mm. bore in *A*, and nine of the same size in *B*, a steady flow of 25 c.c. to 150 c.c. a day may be obtained. In this manner a flow of 50 c.c. a day was attained without appreciable variation for several weeks.

173. A Motorless Circulator for Liquids

By C. Record

J. Sci. Instrum. **5**, p. 299 (1928)

The apparatus illustrated (in three forms, Figs. 188, (*a*), (*b*) and (*c*)) has been devised by the writer for continuously circulating or agitating liquids without the use of a motor or moving parts; the power being supplied by an ordinary water-jet pump.

The tubes *B* and *C* are placed in the liquid to be circulated, the end of *B* being lower than that of *C*. On aspirating through *D*, by means of the pump, the liquid rises in *B* and *C* till its surface in the vessel is lowered to the bottom of *C*, the chamber *A* being partly filled. Air then enters through *C*, and continues to carry liquid up with it, the liquid returning down *B*. Liquids may easily be raised several feet to the chamber *A*.

Fig. 188 (*a*) shows a generally useful form made in glass, *B* being connected to any apparatus through which the liquid is to circulate before returning to its source. The form shown in Fig. 188 (*b*), while

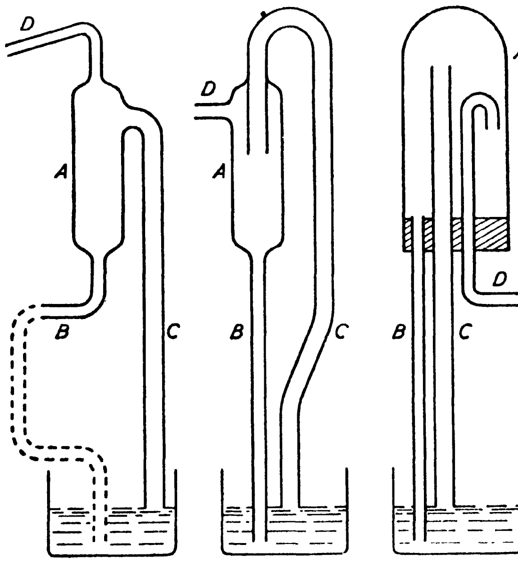


FIG. 188.—A motorless circulator for liquids.

rather less efficient than the former, was suggested by Mr. F. Hobson, of Huddersfield Technical College, as more suitable for circulating liquids which froth, as in the first form froth may suck into the pump, resulting in a slight loss of liquid. Fig. 188 (*c*) shows a form which can be put together in a few minutes without glass blowing, or can be made in metal, and which is more suitable than the other forms for circulating any liquid containing solid matter which is liable to choke the circulator, as it can be readily opened for cleaning. The tube *D* is hooked at the top so that liquid ejected from *C* shall not fall into it. The tube *B* is only made in one straight piece, as shown in Figs. 188 (*b*) and 188 (*c*), when the apparatus is required for agitation only. For this purpose it can be got into vessels where there is no room for the usual motor driven stirrer.

If the tubes B and C are of equal bore the action is intermittent, the chamber alternately filling and emptying. This is satisfactory for agitation, but not efficient for one-way circulation; but if C has a bore of 8 or 10 mm., and B 5 or 6 mm., perfect one-way circulation is obtained, the level of the liquid in A remaining constant. The chamber may of course be of any size, and, if large, will hold a reserve of liquid and automatically maintain a constant level in the vessel from which the liquid is circulated. Evaporation by the air pumped through may be prevented, if necessary, by arranging for the air supply to bubble through similar liquid before reaching the surface of that circulated, but for most purposes this evaporation is, of course, negligible.

174. Rapid Filtration of Viscous Liquids

By E. B. Moss, B.Sc., A.F.R.Ae.S., M.I.M.E., F.Inst.P.

J. Sci. Instrum. **11**, p. 372 (1934)

The filtration of viscous liquids such as oils or varnishes is usually a slow process, as well as a messy one.

If only a small quantity has to be filtered the liquid may be poured into a test-tube of such a size that it is not more than three-quarters full, and a tight wad of cotton wool pushed into the open end. This plug is then forced down through the liquid with the aid of a rod. Any suspended solid matter is carried before the plug while the clear liquid passes through it. The filtrate may be stored in the tube or transferred to another.

175. A Device for Bottling Viscous Liquids from Bulk

By E. Simeon

J. Sci. Instrum. **14**, p. 349 (1937)

The cock shown in Fig. 189 is proportioned to suit a liquid like glycerine, and has an outlet ⅜ in. diameter. Movement of the plunger to the left opens the way for the liquid, and simultaneously expedites the flow; movement to the right closes the cock and then produces a "suction" which stops the flow for a second or two, long enough to place the next bottle underneath. The long-drawn drip is avoided, which makes for clean work and saves time.

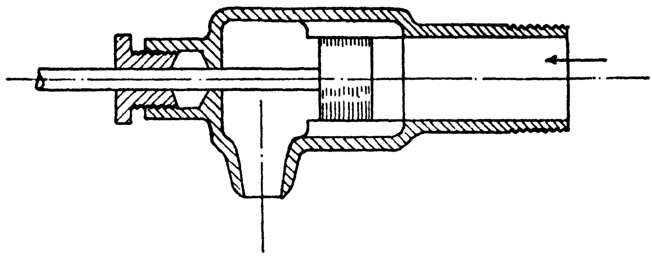


FIG. 189.—Device for bottling viscous liquids from bulk.

The action is spoilt if the outlet has a damaged edge, or is too large; the flow can be speeded up by putting on 3 or 4 ft. of pressure head.

176. A Variable-Slit Filter for Liquids

By E. SIMEON

J. Sci. Instrum. **14**, p. 315 (1937)

The small filter shown in Fig. 190—in mild steel—was designed to remove dirt particles from mercury, on its way to a small high-pressure jet. An outer case encloses eight rings made from steel tubing, the

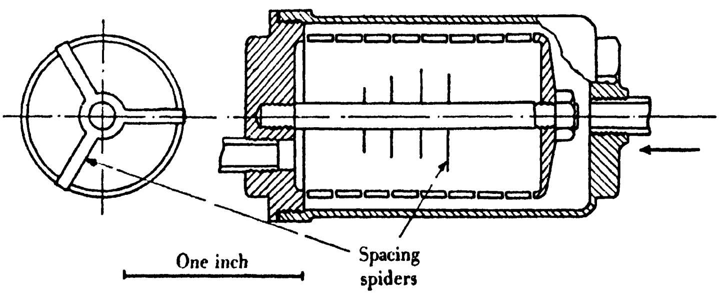


FIG. 190.—A variable-slit filter for liquids.

edges being ground flat. These are assembled on a central stud with thin spacers, to give the desired width of slit. The filter is easily cleaned, and if it becomes choked would be unlikely to collapse under pressure.

177. A Sensitive Relay Operated by Fluid Flow

By J. H. J. Poole, Sc.D., M.A.I., and J. C. Gilmour, B.A.

J. Sci. Instrum. **20**, p. 49 (1943)

The necessity of designing an easily constructed sensitive relay to be operated by cessation of the flow of fluid in a system has often been experienced. We have used the model, described in this article, to break an electric circuit when the flow of water through a cooling system fell below a certain value. It was found to function satisfactorily and to be easily modified so as to operate on very different minimum flows. The design has also the advantage that it can be used on completely closed water circuits. With suitable modification it should also be possible to use it for gas flows.

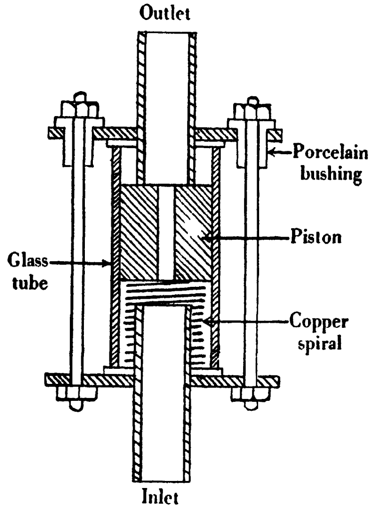


Fig. 191.—A sensitive relay operated by fluid flow.

The construction of the relay is shown in Fig. 191. The essential part of the relay is a metal piston (length L) which moves freely in a vertical glass tube, the system being made liquid-tight by means of rubber washers held in place by two circular end-plates which also carry the liquid inlet and outlet pipes. The piston has an axial hole (diameter $2a$) drilled through it, and is connected electrically to the lower plate by means of a spiral of light copper wire. The current of liquid rising through the device raises the piston until it comes against the outlet tube, thus completing the electrical circuit with the top plate. Suitable terminals (not shown in diagram) are soldered to the end-plates and, to ensure electrical insulation, the liquid is led in and out of the relay through rubber-hose connexions. From a number of experiments it has been found that the volume of liquid V which has to pass through the apparatus per second to cause it to operate is given roughly by the empirical formula

$$V\eta = \alpha + \beta L a^4(\rho - \sigma),$$

where η = coefficient of viscosity of fluid, σ = density of fluid, ρ = density of piston material, all in c.g.s. units. Experimentally it was determined that $\alpha = 0{\cdot}044$ and $\beta = 7{\cdot}0$ for values of a from 0·1 to 0·3 cm.

One advantage of this type of relay is that it is operated directly by the fluid flow and does not depend on the pressure of the liquid in the system, so that if the system becomes choked the relay will operate. For liquids containing solids in suspension it would, however, be necessary to use suitable filters to ensure that the hole in the piston did not clog up, but this is a problem that seldom arises in an ordinary laboratory.

Another point that leads to ease in construction is that the only insulation required, other than the glass tube and the hose-pipe connexions, is afforded by the small porcelain bushings in the upper plate. The device has been found to be very sensitive to small changes in flow and to give quite a fine control. We have found it operates best if the piston has its length equal to its diameter, and is as good a fit as possible in the glass tube. The length of the latter should be chosen to give a suitable travel in the make and break.

178. A Water-Tight "Lead-In" to an Enclosed Chamber suitable for Ordinary Temperatures

By W. F. Cope, M.A., A.M.I.C.E., A.M.I.Mech.E.

J. Sci. Instrum. **11**, p. 198 (1934)

The author has had occasion to measure, by the well-known differential method, the temperature difference between the wall of a pipe and the fluid flowing inside it. The cold junction had to be mounted in a closed box which had to withstand the pressure and velocity of the water surrounding it, and it is believed that the method adopted for carrying the leads through may be of use in other connexions. A full description of the experimental technique used is published elsewhere.*

Through the end flange of the apparatus (Fig. 192) are drilled clearance holes for the glass tubes. These holes are deeply countersunk on the inner face. A second flange is provided having corresponding holes countersunk on its outer face. A rubber ring is threaded over the glass tube and the joint is made by clamping the plates together with the bolts thus gripping the ring between the opposing countersunk faces and forcing it into contact with the tube. The thermo-elements are threaded through the glass tubes, the junctions projecting about ⅛ in., the interstices are filled with a bituminous compound and a coating of

* Aeronautical Research Committee, *Reports and Memoranda Series*, No. 1560 (London: H.M. Stationery Office).

the same compound is liberally applied to the junctions. The end flange is detachable so that the couples can easily be calibrated *in situ.*

This type of joint has withstood pressures of two atmospheres

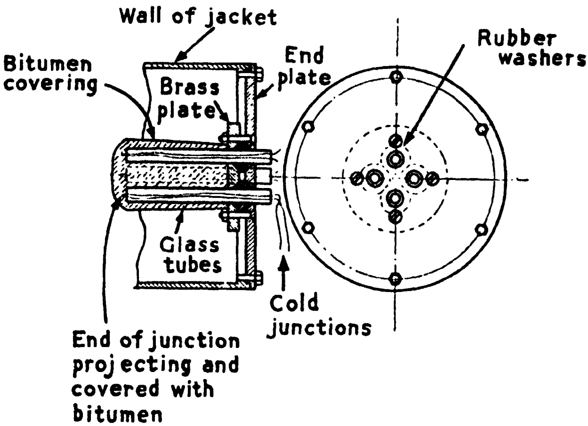


FIG. 192.—A water-tight " lead-in ".

and water velocities of 200 cm. per sec. without deterioration. The accompanying sketch shows four tubes but as many as eight have been accommodated in one plate without trouble.

179. Glass Spirals for Use in Sensitive Pressure Gauges

By S. G. YORKE

J. Sci. Instrum. **22**, p. 196 (1945)

The mechanism here described has been designed with a view to increasing the efficiency and sensitivity of glass spirals and, at the same time, overcoming many of the difficulties in their making and reproduction. The spiral mounted as a pressure gauge is useful in chemical kinetics research with corrosive gases. It is very superior to the " spoon " and diaphragm gauges, since it will withstand pressures of the order of 3 atm., and sudden change of about 1 atm. A similar quartz spiral has been described by M. Bodenstein and W. Dux.*

A slightly tapered $\frac{5}{16}$-in. diameter carbon rod *A* (Fig. 193), on which the glass is wound, has a $\frac{5}{64}$-in. hole drilled through the smaller end. The other end is held in a steel socket *B* attached to 3 in. of $\frac{3}{16}$-in.

* Bodenstein, M., and Dux, W., *Z. phys. Chem.* **85**, p. 300 (1913).

diameter steel rod. The latter is fixed into a steel rod *C*, $3 \times \frac{3}{8}$ in., on which is cut a right-handed thread, ten threads per inch for half of its length, to provide an automatic feed. The other half is drilled $\frac{13}{64}$ in. and slotted to form a cylinder with a $\frac{1}{16}$-in. key-way to allow $1\frac{1}{2}$-in. travel along a $\frac{3}{16}$-in. driving rod carrying a $\frac{1}{16}$-in. key-pin. A $2\frac{1}{2}$-in. pulley wheel, *E*, having a length of carpet thread wound round it, and weighted, drives the spindle. The speed is controlled at 15–20 rev./hr. by connecting to the winding spindle of a metronome, *D*, the spring of which is removed and the ratchet reversed for resetting the machine. An iron shield, *F*, $\frac{1}{8}$ in. thick, 3 in. wide, covers the carbon, extending for 1 in. down the front and 2 in. down the back, leaving $\frac{1}{4}$ in. space between the carbon and shield. A vertical supporting rod, $\frac{1}{4}$ in. in

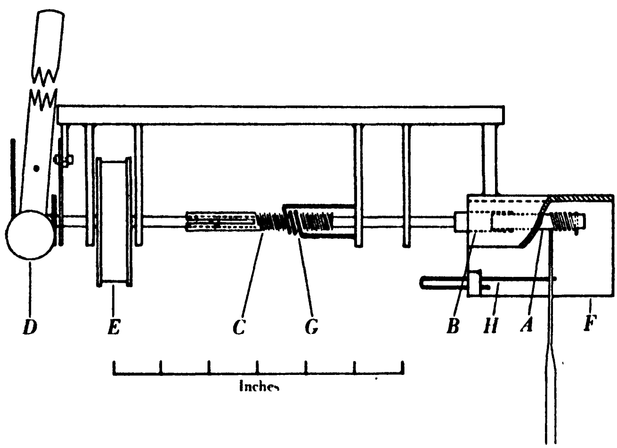


FIG. 193.—Machine for winding glass spirals.

diameter, is welded to the top of the shield, and an adjustable guide wire, *H*, slides in a block welded on to the botton of the rear portion.

Four pieces of bright mild steel, $2\frac{1}{2} \times \frac{1}{2} \times \frac{1}{8}$ in., each having a $\frac{3}{16}$-in. hole near one end, are used for bearings as indicated in the diagram. Another short piece of bright steel is bolted to the frame of the metronome. When the complete assembly is in alignment, a $\frac{3}{8}$-in. diameter steel rod is welded to the four bearing strips, to the strip holding the metronome, and to the supporting rod on the shield. Thus, with very slight adjustment, the complete spindle will revolve freely in the bearings.

The guide, *G*, consists of three turns of $\frac{1}{16}$-in. iron wire wound into the thread of the rod C and fixed to a bearing strip, causing the carbon to travel to the right as it revolves.

The spirals are made from tubing prepared from 6-mm. diameter

Hysil tubing which is softened and drawn, whilst blowing, to approximately 1·25-mm. diameter parallel up to 30 mm. from the parent tubing. The wall must be thin enough to crumble easily when gently squeezed between finger and thumb. A length of 25 cm. of this tubing, joined to approximately 8 cm. of 6-mm. tube to act as a weight whilst winding, and also for mounting, is required for a spiral of 7 or 8 turns. 1 cm. of the thin end is bent through 90° to put through the hole in the carbon.

A coal-gas air-oxygen blowpipe flame is directed on the back portion of the iron shield, opposite the hole in the carbon, heating an area of approximately 1 sq. in. to a cherry red. The bent end of the tubing is anchored through the hole in the carbon, and the wire, H, is adjusted to guide and steady the glass. The carbon and glass are protected from the direct flame by the shield, which also serves as an oven to distribute the heat for even softening of the glass. The machine is set in motion. When the spiral is wound, the mechanism is stopped and, after cooling, the end through the carbon is broken off with forceps. By reverse turning of the spindle and a gentle side movement of the spiral, the glass will slide from the carbon.

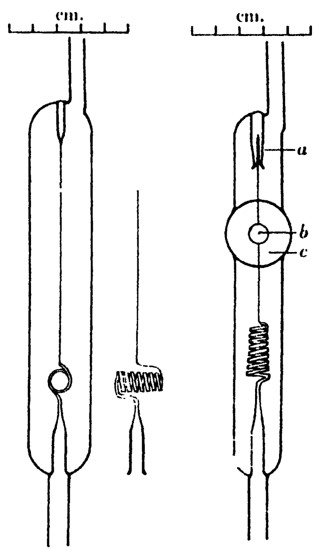


FIG. 194.—Methods of mounting spirals for use as pressure gauge.

Two methods of mounting the spirals are shown in Fig. 194. In the one on the left, the spiral has a pointer sealed to the end at 90° to the axis of the coil. The deflexion of this pointer can be measured directly or against a fixed zero pointer as shown.

A more accurate instrument, shown on the right of Fig. 194, has the spiral mounted vertically with a spindle sealed to the end along the axis of the coil supported at the top in a bearing of capillary tubing (a). The rotation of the spindle is measured by a beam of light reflected from a galvanometer mirror (b) waxed to the spindle. To avoid distortion of the light beam, a plain optical window is fused on to the outer jacket. The recorded deflexion of the light beam of an instrument of this design is at one metre, of the order of 4–5 cm. for 1 cm. of mercury pressure.

[*See following Note.*]

180. Improved Method of Winding and Mounting Glass Spirals for Sensitive Pressure Gauges

By S. G. Yorke

J. Sci. Instrum. **28**, p. 16 (1948)

Several advantages were found in using an electrical heater for softening the glass when winding spirals for sensitive pressure gauges, as compared with using a coal-gas air-oxygen flame. The softening temperature for forming the glass spiral was more easily controlled and could be reproduced, whilst a rheostat in the circuit permitted the slight adjustment to the temperature required to allow for the variation in the thickness of the wall of the individually drawn glass tubing. An

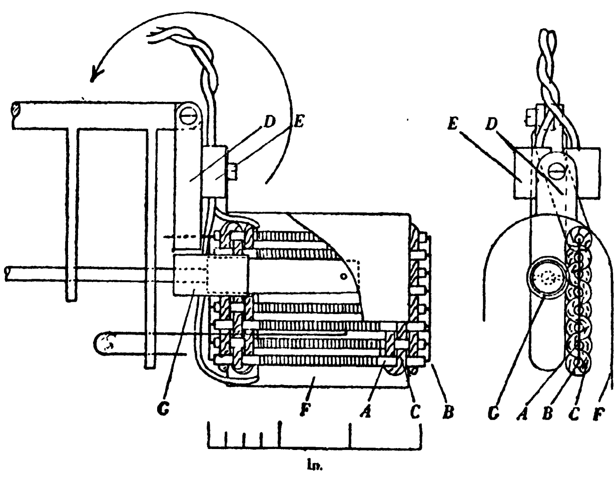


Fig. 195.—Improved apparatus for winding and mounting glass spirals for sensitive pressure gauges.

aluminium reflector covering the heater and the carbon rod on which the spiral was wound, both concentrated the heat on to the carbon and shielded the softened glass from air draughts.

A 210 V. 1 kW. electrical heater was used on a spiral winding machine described in previous Note, to form fragile glass spirals up to ½ in. in diameter (Fig. 195). The heating element was 11·5 ft. of 28 s.w.g. Brightray wire wound on to eight 3 × ⅛ in. refractory sleeves *A*, spaced ¼ in. apart on a spot-welded frame of 18 s.w.g. nickel wire *B*. Asbestos cord *C* was woven over the ends of the sleeving to ensure insulation between the heater wire and the frame which was earthed. The heater was supported in a vertical position behind the carbon rod from a strip of metal *D* which could be hinged into a position over the winding machine as indicated by the arrow in the diagram. Porcelain insulated binding screws *E* connected the Brightray wire to electrical flexible leads. A 5-A., 50-Ω rheostat in series completed the circuit. Conveniently attached to the hinged support was an aluminium reflector *F* (section cut away). Interchangeable steel sockets *G*, to hold various diameter carbon rods, were made to fit on to the spindle of the machine. The spiral was formed of very thin-walled tubing, approximately 1·25 mm. diameter 400–450 mm. long drawn on the end of a short piece of 6–7 mm. diameter Hysil glass tubing. The heater current was switched on ; the end of the small tubing was then attached to the end of the carbon rod through a small hole. The machine was next set in motion. On completion of the spiral the machine was stopped and the current switched off. The heater unit with the reflector was hinged up over the machine to avoid breaking the spiral against the heater when it was removed from the carbon rod. It is advisable to use protective goggles against the radiated heat whilst manipulating the machine.

Owing to difficulties in reproducing diameter and wall dimensions of individually hand-drawn tubing, no definite comparative values are prepared for the separate diameters of the spirals ; however, the $\frac{7}{16}$- and $\frac{1}{2}$-in. diameters gave greater sensitivity than the earlier $\frac{5}{16}$-in. diameter spirals. Larger diameters were less robust and fractured more readily with sudden changes of pressure.

The convenient method of attaching a mirror with wax to the spindle of the spiral, for optical recordings, was unsatisfactory when working at higher temperatures. Consequently, an optically polished Hysil glass plate 14 × 5 mm. by 0·75 mm. thick, having a 0·5-mm. diameter spindle fused coaxially to each end, was plated with aluminium by evaporation of the metal *in vacuo*.* One spindle was then fused to the glass spiral and the other spindle formed the bearing for the vertically mounted gauge, thus dispensing with the use of the wax and enabling the gauge to be used within, or in close proximity to a heated reaction vessel.

An alternative mirror used with corrosive gases was made by coating with a platinum film from colloidal platinum dispersed in volatile oils, the latter being evaporated by gentle warming.

[*Note.*—For details of the manufacture of helical silica springs, see King and others, *J. Sci. Instrum.* **12**, p. 249 (1935).]

[*See previous Note.*]

* Strong, J., *Phys. Rev.* **43**, p. 498 (1933).

181. Prevention of Capillary Disturbances in Electrolytic Field Plotting Troughs and in McLeod Gauges

By O. Klemperer, Ph.D.

J. Sci. Instrum. **21**, p. 88 (1944)

Appreciable simplification of electron-optical field plotting for rotational-symmetrical electrode arrangements has been obtained by the method of Manifold and Nicoll.* There a trough with sloped bottom was used to produce a wedge-shaped sector of electrolyte. The thin edge of the wedge represented the axis of the electrode arrangement. The bottom of the trough was made from glass so that a co-ordinate system could be placed beneath it and seen from above. The accuracy, however, of such a field plot depended largely upon the degree of perfection to which the shape of an ideal sector could be approximated by the thin edge of the liquid wedge of electrolyte. In the ideal case, a straight line should be produced by the intersection of the trough bottom with the surface of the liquid which should be absolutely plane up to the intersection line.

In practice it was difficult to keep the glass bottom of the trough and the electrolyte itself perfectly free from traces of grease. The edge of the electrolyte which therefore did not wet the glass completely, often appeared to form crinkles, and the top surface of the liquid wedge showed near its thin edge noticeable deviations from a plane, being at some places concave, at other places convex.

We have now been able to produce perfectly clean edges without any particular precautions to avoid traces of grease. In the critical region, where the glass bottom of the trough contacts the surface of the electrolyte, the glass surface was slightly ground, thus providing a number of microscopic capillary grooves running in perpendicular direction to the glass-to-liquid contact line. The grinding was produced by moving a wet rag, covered with finest emery compound, a few times at right angles to the above contact line. The glass surface was ground so little that the capillary grooves were hardly visible and did not interfere in the least with the clear visibility of the co-ordinate system beneath the glass bottom. The capillary grooves, however, were quite sufficient to facilitate complete wetting, so that perfectly straight edges of the liquid wedge could be obtained without difficulty.

The grinding of a glass surface to prevent the sticking of liquids has been recommended by Rosenberg† for the capillary tubes in McLeod

* Manifold, M. B., and Nicoll, F. H., *Nature* **142**, p. 39 (1938).

† Rosenberg, P., *Rev. Sci. Instrum.* **9**, p. 258 (1938).

manometers. It may be interesting to note in this connexion that in the case of water, the grinding provided complete wettability of the glass surface and the capillary elevation appeared to be the same both for ground and for clear tubes, as long as the tubes were completely clean. In the case of mercury, however, the capillary depression appeared to be increased after the grinding of the tubes, even if the tubes before the grinding were cleaned from all traces of grease by prolonged treatment with chromic acid. For instance, Pyrex glass capillaries of 1·0 mm. diameter which are quite usual for McLeod gauges, showed mercury depressions of 9 and 6 mm. respectively for ground and for untreated surfaces. Using Quincke's value 547 dyne/cm. for the surface tension of mercury and introducing the above depressions in the usual formula,* the contact angles 124° and 112° were calculated for the ground and for the untreated surface respectively. Compared with Quincke's value of 127° or with Young's value of 140° for the contact angle,† this seemed to indicate that the mercury showed the true depression in the ground capillaries, while in the untreated capillaries the depression was reduced —perhaps due to films of moisture which adhered firmly to the glass surface. For the practice of McLeod measurements it would seem necessary to have the pressure-indicating capillary and the zero-level indicating capillary either both ground or both clear.

* Adam, N. K., *Physics and Chemistry of Surfaces*, 2nd ed., p. 10 (Oxford: Clarendon Press, 1938).

† Adam, *loc. cit.* p. 186.

INDEX