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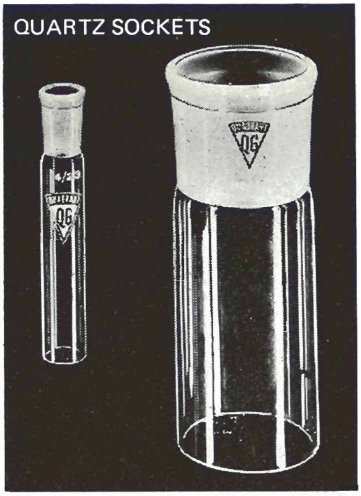
No. 1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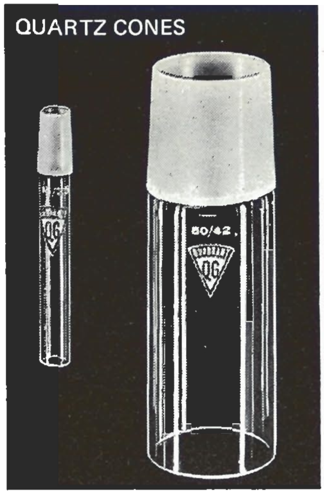
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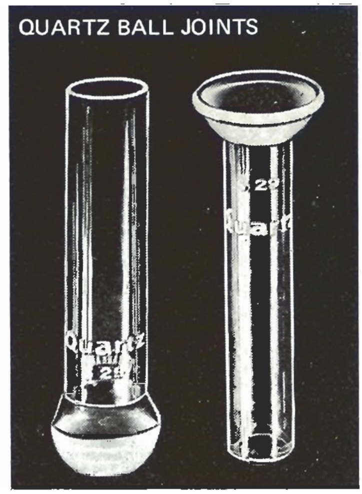
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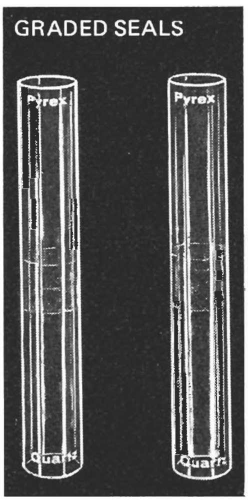
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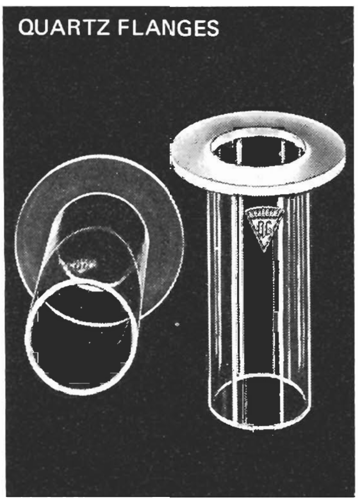
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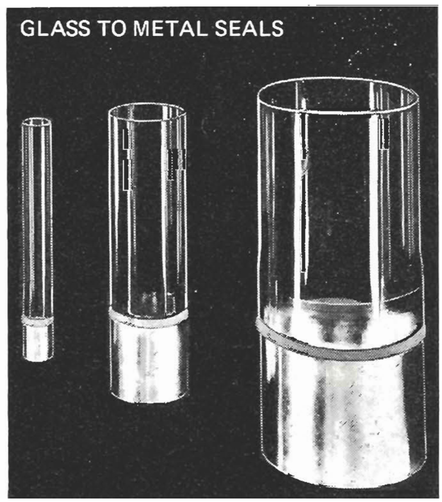
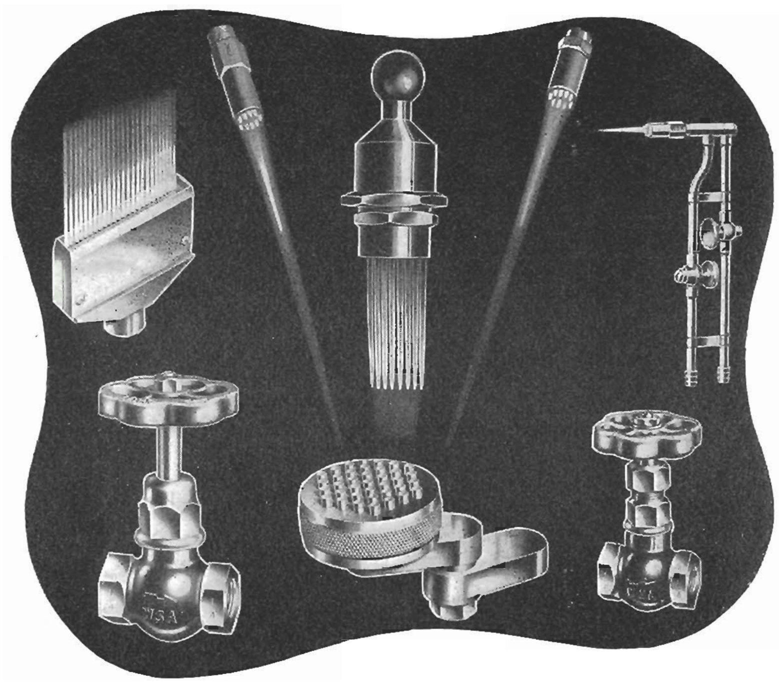

GLASS TO METAL SEALS



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ADVERTISERS

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IMAGE INTENSIFIERS AND PHOTOMULTIPLIERS

By R. P. Randall, B.Sc., D.I.C. F.R.A.S. and C. Wade, B.Sc., A.R.C.S., D.I.C E.M.I. Electronics Ltd., Ruislip, Middlesex

The sense of sight – vision – and the observation of events that occur from day to day play an important part in our understanding and appreciation of the environment we live in. In particular, our visual senses have played a vital role in the development of science and technology – where certain phenomena have been observed to occur, man has always tried to explain their cause.

This discourse will introduce some devices which enable our visual senses to be extended and therefore aid in the current growth of scientific endeavour and its application in technology. The principle advantages in the use of these devices stem from their ability to provide accurate information about optical signals which can be carefully measured and permanently recorded by electrical or photographic methods. The eye in this respect is at a disadvantage and can often produce erroneous responses – for example when judging colour or brightness, or when viewing canals on Mars and Loch Ness monsters.

The meaning of the term 'optical signals' can be clarified by reference to Figure 1 which illustrates the various guises that the phenomena of electromagnetic radiation can present itself, charted here in terms of changing wavelength, one of its characteristics. A precise account of the true nature of electromagnetic radiation is not possible, and even a partial explanation is beyond the scope or needs of this discussion.

The arrows at the ends of the scale in Figure 1 merely indicate that there are no limits to the extension of the scale, although radiation in these extremes is difficult to detect. It will be seen that the band of wavelengths that the eye can respond to is comparatively small. The dotted lines define a band of wavelengths a little wider than the visual band and for this discussion radiation in this band will be considered as optical signals. The scale of optical signals is shown expanded below (microns are one million times smaller than meters and are used to give convenient figures), and this shows colours are related to wavelength.

Optical signals are usually sensed by the eye in the form of images having shape, colour and contrast. Many events occur where optical signals are merely the emission of light and much can be learned about an object by a study of the characteristics of the light it emits, without having any knowledge of what the object might look like.

Photons, Electrons and their reactions with solids.

In photomultipliers and image intensifiers optical signals generate electrical signals and these are used to help us in the detection of the optical signal that caused them.

To understand how this is possible we must first appreciate that both light and electricity are composed of very small discreet units, just as solids are made of a large accumulation of atoms. The unit of electricity is called an electron, and its size can be judged by the fact that in a current of one amp over a million million million electrons pass along a wire every second. In a similar manner the unit of light is called a photon, and although the eye will respond to the action of just a few of these, millions normally pass through the lens of the eye to form a normal picture.

Although these particles seem so insignificant

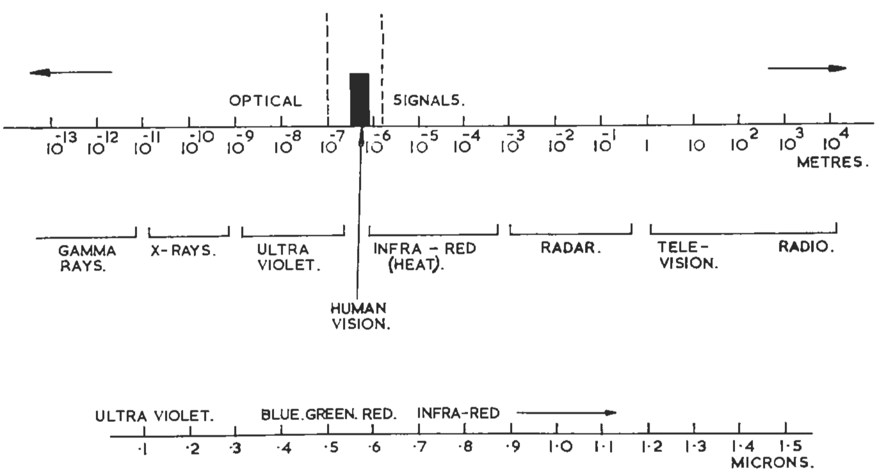


Fig. 1
The spectrum of electro-magnetic radiation.

they play a very prominent part in the function of photomultipliers and image intensifiers, and the way these work can only be understood by examining what happens when light photons or electrons react with solid matter, such as metals, insulators, or some particular chemical compounds which have been developed especially for their sensitive reaction to photons or electrons.

Fig. 2 shows the various reactions that can occur when a photon or electron reacts with a solid. A photon can be considered as a small package of energy, and photons of the same wavelength contain the same amount of energy. The energy content of a photon gets less as its wavelength gets larger. Electrons can also be made energetic, but only as a bullet from a gun, i.e. it must be moving, and the faster it goes the more energy it has. The four reactions shown in Fig. 2 arise due to the conversion of the energy of the photon or electron into other forms.

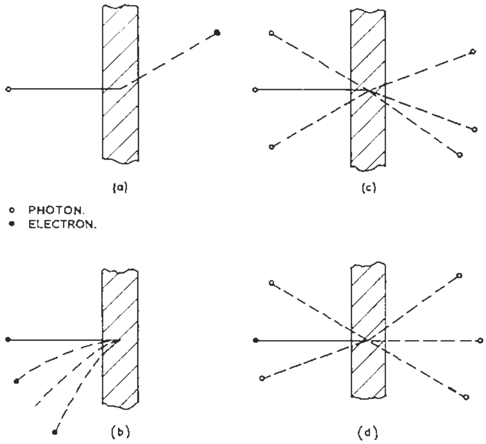


Fig. 2

Examples of the reactions of photons and electrons with matter.
(a) Photocathode.
(b) Secondary electron emission.
(c) Phosphors.
(d) Phosphors.

In Fig. 2 (a) a photon loses its energy to an electron that was in the solid, and in this case, the movement imparted to the electron because of the energy transfer is sufficient for it to leave the solid. Obviously the solid must be very thin so that the electron does not hit any atoms on the way out, and the energy of the photon must be large enough to make the electron move fast enough to escape.

Now just as a radio can be tuned to receive a station to best volume, it is possible to make chemical compounds that allow the reaction shown in (a) to occur efficiently, i.e. electrons in the compound are tuned to react with the wavelength of the incoming photon. By a proper balance of thickness and constituents it is possible to make solid layers which can allow as many as 30% of all photons entering the material cause the ejection of electrons.

These compounds are called *photocathodes*, and the energy conversion process is *photo-electron emission*, and the electrons emitted in this way are *photo-electrons*.

It should be noted that one photon produces one electron, *never more*.

In diagram (b) a high speed electron collides with a comparatively thick solid. In this case the energy of the electron is transferred to one or more electrons which move fast enough to leave the solid. The combined energy of the electrons leaving is never more than that of the one that went in.

This process is called *secondary electron emission*, the electron entering the solid is the *primary electron* and the ones leaving are *secondary electrons*. The secondary electrons are shown leaving on the same side as the incident primary electron as this is the more common case.

The number of secondary electrons produced by the primary electron hitting the solid is called the *secondary emission ratio of the solid*, or more exactly of its surface as the state of its surface can greatly affect this process. Surfaces can be made where the secondary emission ratio is 6 or 7.

The materials involved in the last two reactions are called *phosphors*. In case (c) the energy of an incident photon causes the emission of several photons of lesser energy (longer wavelength), and although this effect is not used in the construction of photomultipliers it is useful because it enables us to convert high energy photons outside the range of optical signals, into optical signals that can be detected by photo-electric devices.

The high speed electron in case (d) has also transferred its energy to form several photons. The wavelength or colour of these photons is dependent on the type of solid struck by the electron, and it is possible to make compounds which cause blue, green or red light to be emitted by this reaction.

The number of photons released can be very high (if the electron energy is high enough) and can exceed 1,000. Usually only about 1/10th of the energy of the incident electron is converted to photons.

Controlling Free Electrons.

In case (a) we have shown the emission from a solid of a solitary electron. What happens to it now? If it enters air, it would rapidly be lost probably being absorbed by a gas atom in the air. To prevent this, it is necessary to ensure that no air is present in the volume to which the electron escapes, i.e. there must be a vacuum on that side.

This is usually achieved by forming the photocathode inside an airtight bottle of glass, from which all the air has been pumped out, leaving a good vacuum inside.

Now we have an electron floating freely about in a vacuum and unless it is controlled it will eventually hit the glass walls and be absorbed. This is prevented quite easily.

An important property of electrons is that they can't stand each others company and always move away from one another. If we place a metal plate

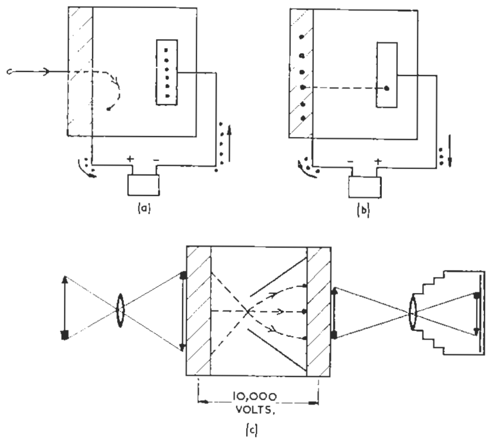


Fig. 3

Controlling free electron paths in the vacuum of a simple photo-electronic tube.

(a) Tube with photocathode and negative potential on collecting plate.

(b) As (a) but positive potential on plate.

(c) Example of simple electron optical system used as a single stage image intensifier.

in the vacuum (Fig. 3 (a), and pump electrons into it by wiring it to the negative terminal of a battery, the free electron will move away from the plate and will eventually start to move towards the photocathode. If we reverse the wires (Fig. 3 (b), the electron is repelled from the cathode as electrons are pumped into it by the battery and is attracted by the absence of electrons in the plate. Eventually it will strike the plate and its arrival could be seen as a very small electrical current passing through the tube. Normal lighting on the photocathode (instead of as in this case, one photon) would produce a measurable current.

By the use of properly shaped metal plates – electrodes – it is possible to steer electrons wherever we wish them to go provided the right voltages (negative or positive) are placed on the electrodes. In fact it is possible to arrange electrodes in rings so that electrons pass through the holes in them just as light does through a lens, (Fig. 3c). Thus electrons leaving a photocathode can be imaged on to another surface some distance from the cathode.

The use of electrodes with specific voltages on them to guide the movement of electrons is called *electron optics*.

As electrons are attracted towards electrodes at positive voltage they move faster. In this way the electron can gain energy so that the energy conversion processes occuring in secondary emission, and phosphors can occur.

A glass bottle containing a photocathode, electrodes, or secondary emitting surfaces and phosphors is usually referred to as a photo-electronic tube.

Image Intensifiers

The image intensifier is a member of a wider family of photo-electronic devices called Image Convertors. This name has arisen principally because these devices can be made to respond to light images over the whole range of optical signals, a proportion of which cannot be seen by the eye, and convert them to images that are visible. Television is also an example of image conversion, the conversion occuring in this case is the change in location of the image projected by the camera lens, and its multiplication by often many millions of times. The conversion process in the image intensifier causes the projected image to be increased in brightness, and this can help in the observation or photography of dimly illuminated objects.

The basic operating principles of the image intensifier are very simple and can be demonstrated in diagram of Fig. 3c. Let us examine the case where a small amount of light – say 10 photons pass through the lens and fall on the photocathode in the tube. Not all of these photons will release electrons, and in normal practice we might expect 2 photo-electrons to be produced. These are ejected into the volume of the tube and are immediately acted upon by the voltages on various electrodes in the tube which form an electron optical lens, which will cause these electrons to be focussed onto the phosphor. At the same time a high positive voltage has been placed on the phosphor, 10,000 volts, and this causes the electrons to hit the phosphor at very high speed. Some of their energy is converted by the phosphor into light, and with this voltage on the phosphor we can expect at least 400 photons to travel out of the phosphor, so that an observer would see this image in the phosphor.

Now, we started with 10 photons arriving at the cathode of the tube, and produced 400 at the phosphor. The tube has therefore multiplied the number of photons in the image 40 times. It follows that if we were to consider the lens to be imaging on the photocathode a normal picture composed of many thousands of photons, the tube will produce an image on its output phosphor 40 times brighter.

A first sight this looks marvellous, but the diagram will help illustrate that such a tube can be of little value. The illuminated object is imaged by the lens onto the photocathode of the tube. The image projected by the lens will be dimmer than the original object, in fact it is very difficult to design lenses which cause the image brightness to be more than 1/40th of the object brightness. The gain of 40 times in brightness obtained by passing the image through the intensifier therefore only compensated for the light loss imposed by the imaging lens. The camera thus sees an image which has the same brightness as the original object, so we might as well remove the first lens and image tube.

It is obvious therefore that to make a useful image intensifier several units like the one we have just considered must be joined together so that higher levels of image intensification can occur.

An example of a tube that employs this principle is shown in Fig. 4.

Fig. 4 (a)
Commercial Image intensifier
(a) Photograph of E.M.I. 9694 tube.

Basically this tube consists of four units of the type described above, connected together in one vacuum envelope to form a single electron tube. The four separate stages comprising a photocathode, electron optical section, and phosphor are easily identified in the diagram. The output phosphor of one stage is optically coupled to the photocathode of the next by mounting these components on very thin mica discs (.004mm thick) so that the light image on the phosphor passes to the photocathode without degradation of detail. Thus all the light from the phosphor passes to the photocathode. The last phosphor is on a glass plate and is viewed as the output. Each stage of the tube can produce a gain of 30 in image brightness, so that with four coupled stages the resultant gain becomes 30 x 30 x 30 x 30 or approximately a million. Thus one photo-electron leaving the first photocathode produces a flush of a million photons on the output phosphor which can easily be seen by the eye, or recorded on film. As this photo-electron was initially produced by a single photon such tubes enable extremely faint optical images to be observed.

Tube Construction

The vacuum envelope of this tube is formed from four sections fabricated from two metal flanges (5) and two rings (3) sealed together by glass rings. The metal components enable electrical contact to be made to the photocathode/phosphor units (6) and the focussing electrodes (4). This type of tube employs magnetic fields to preserve image focus from stage to stage which dictates the shape of electrodes used. The end windows (1 and 2) carrying the input photocathode and output phosphor are also sealed to metal flanges, and the whole assembly is joined as a single unit by argon arc welding of the window flanges and body flanges at five points, on the periphery of these flanges (5). This type of body fabrication is very flexible and reliable and many image tube types follow this principle of construction.

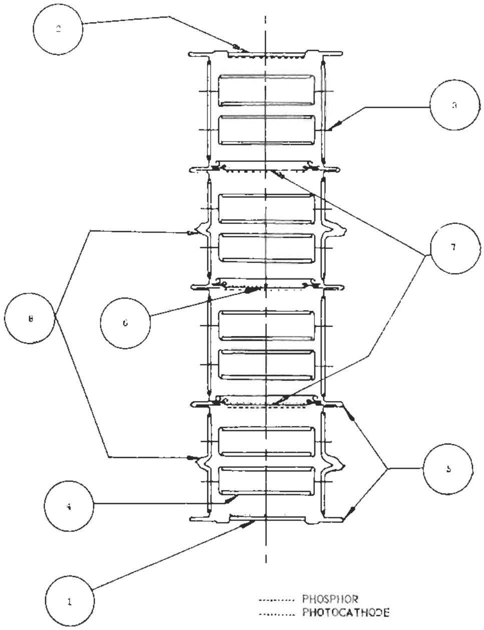


Fig. 4 (b)
Example of multi-stage image intensifier.
(b) Diagram of 9694 tube.

Applications

These devices have an obvious application in the military field, small compact units can be made which enable a soldier to have almost day-like vision during the hours of night time. Similarly they can be useful for security purposes or as aids to night binoculars, particularly for maritime use.

The imaging qualities of tubes for this purpose do not have to be particularly good, usually they are only required to enable an observer to recognise some object that he can't see with his eye.

For most scientific purposes, tubes of the type shown in Fig. 4 are required because they are capable of intensifying the image without distorting it, or adding spurious information. Principally they are employed in applications where photography is the usual means of examining the result of some specific operation. In these cases a photograph can only be obtained after perhaps hours of exposure, and an instrument worth many thousands of pounds can be quite unavailable for use by other operators during the process of exposure. The image intensifier enables the photographic exposure time to be reduced by over a thousand times so that hours of exposure can now be accomplished in seconds, so allowing more use to be made of costly apparatus. Another factor here, is that the experimental conditions could change during long exposures resulting in useless photographic results.

PHOTOMULTIPLIERS

Operation

A photomultiplier consists basically of a photo-cathode, secondary emitting dynode system and current collector arrangement enclosed in a glass envelope in a vacuum approximately 10^{-6} torr. The photo-cathode is normally deposited on the end window of the tube and the dynode system is a number of secondary emitting surfaces mounted between the cathode and the collector (anode). In the operating condition, a voltage of approximately 1 KV is applied across the tube between cathode and anode with the dynode stages at increasing voltages and the anode positive with respect to the cathode.

When light is incident upon the photo-cathode, electrons are emitted into the cathode first dynode region and are accelerated towards D_1 by the potential difference applied between cathode (K) and D_1. This K – D region is designed so that the majority of the electrons leaving the cathode arrive in D_1 and have the correct energy to give rise to secondary emission at D_1. Generally about 200 – 300 volts are applied between cathode and first dynode, giving rise to a secondary emission yield of approximately 4. These secondary electrons leave D_1 and are accelerated towards D_2 when again secondary emission occurs and the whole cascade process continues to the anode where the electrical signal is collected. For standard tubes, with inter-stage voltages approximately 100V, a gain of the order of 10^6 - 10^8 is achieved, i.e. one electron leaving the cathode gives rise to 10^6 electrons reaching the anode, and the tube as a whole converts a light signal incident on the photo-cathode into an electrical signal at the anode. Tube sizes range from $\frac{1}{2}''$ to $12''$ cathode diameter.

Limitations

Photo-cathodes have a spectral response, i.e. they are more sensitive to light of one wavelength than another and their quantum efficiency is defined as the number of electrons emitted per incident photon at a certain wavelength, typical values being 20 – 30%. The wavelength region covered in photomultipliers is 1,100Å – 11,000Å. The cathode materials employed being Cs (Te) and Cs (I) at short wavelengths. Sb Cs, Na_2K Sb Cs, Bi Ag O Cs and K_2Cs Sb in the visible region and Ag O Cs at long wavelengths. "Cut off" in the short wavelength region is due to window transmission, hence the use of Lithium Fluoride and Calcium Fluoride, and at long wavelengths by the work function of the photo-cathode.

The dynodes are generally either "venetian blind" or "box and grid" structures with Sb Cs, Ag Mg or Be Cu as the secondary emitting substance. The maximum voltage that may be applied across the tube being limited by "breakdown." Transit times through the dynode systems are 50^{-100} nano seconds, and rise times 2 – 20 nano seconds, and for a gain of 10^6 and a rise time of 2.5 nano seconds a peak anode current of 5 mA is obtained for one electron leaving the cathode.

When a photomultiplier is operated in complete darkness electrons are still emitted from the cathode. This "dark current" is amplified by the dynode system and sets a lower limit to the intensity of light that can be detected. These electrons are thermionic in nature and their emission rate may be reduced by cooling. Another contribution to the dark current is afforded by the potassium content present in the glass window, hence potassium free glass (e.g. silica) is used for certain applications.

Another limiting factor is "noise" which is due to the statistical fluctuations in the photo-emission from the cathode, and in the secondary emission process. This "noise" may be limited by having a high gain first dynode. Photomultipliers performances are adversely affected by the environments in which they operate such as magnetic and electrostatic fields, radio-activity and vibratory conditions

Construction

A form of assembly containing the dynode system is mounted on a valve base and this arrangement is then sealed into the glass envelope. For pyrex or silica window tubes a graded seal is employed between the window and the pinch. The assembled valve is then processed in vacuum (approximately 10^{-5} torr). When the cathode substrates are deposited the alkali metals are admitted in the correct proportions. The photomultiplier is then sealed from the processing system ready for testing and subsequent use.

Applications

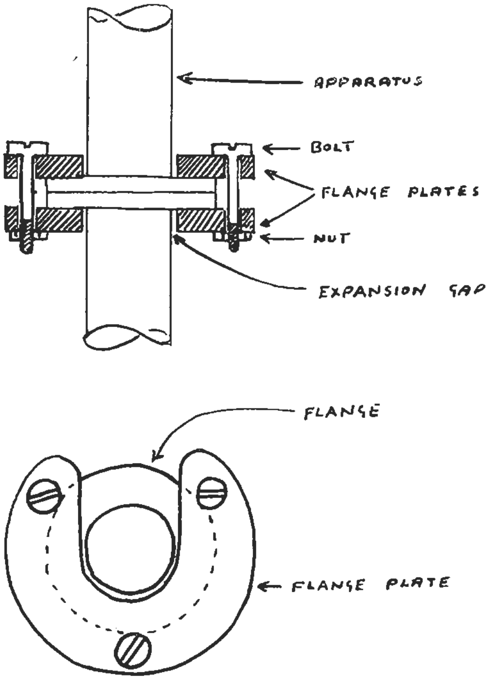
Photomultipliers are used for the detection of very low light levels and have great application in detecting high energy nuclear particles by their interaction with scintillating materials. They are used extensively in Photometry, Spectro-photometry and Spectro-chemical analysis. By the scintillation method they are employed in Hand and Body Monitors and in Gamma Cameras. Television Colour Systems and Film Scanning are other employers of these valves, together with Space Research. Unusual uses are those such as Seed Sorting, Diamond Selection, machines for automatic printing of Coloured Photographs and many other varied applications.

EXPANSION-COMPENSATING CLAMPS

Submitted by John Martin, Imperial Smelting Corporation Ltd.

An apparatus had to be constructed in Borosilicate glass which could be easily dismantled, yet operated at temperatures up to 500°C. Flanged joints were selected, being the least likely to sieze, but the commercially available spring-clip clamps were not suitable as the springs tended to soften at elevated temperatures and ordinary bolt-up flange clamps would loosen due to the different expansion coefficients of the glass and metal.

A flange clamp was designed of two dissimilar metals, so that the expansion of one counteracted the expansion of the other to give a resultant expansion approximately equal to that of the flange, so that on heating, the clamping pressure remained the same. In this instance copper clamping plates were used with stainless steel bolts, with a thin asbestos paper washer between the metal and glass to take up any slight inaccuracies in the flange. In operation the copper expands more than the stainless steel so that it can only expand inwards relative to the steel, thus it is possible, by varying the length of the steel bolt, and the total thickness of the copper flange plates, to make the apparent expansion between the inside faces of the two copper plates match the expansion of the flange, provided its expansion is less than that of the stainless steel.



SKETCH OF CLAMP ASSEMBLY

The relationship between the thickness of the flanges, the thickness of the flange plates, the operational length of the bolts, and the expansion coefficients of the materials was calculated, and can be expressed as

$$A = B\left(\frac{\alpha a - \alpha b}{\alpha a - \alpha c} - 1\right)$$

Where

A = Total thickness of flange clamping plates;

B = Total thickness of flange to be clamped;

αa = Coefficient of expansion of flange clamping plates;

αb = ,, ,, ,, flange

αc = ,, ,, ,, Bolts

EXAMPLE:

If a clamp is required for a pair of Pyrex flanges 0·1 cm. thick, using Stainless steel Bolts and copper plates:

αPyrex $= 33 \times 10^{-7}$;

αStainless Steel $= 111{\cdot}5 \times 10^{-7}$;

αCopper $= 167{\cdot}8 \times 10^{-7}$

$$A = 1{\cdot}0\left(\frac{167{\cdot}8 \times 10^{-7} - 33 \times 10^{-7}}{167{\cdot}8 \times 10^{-7} - 111{\cdot}5 \times 10^{-7}} - 1\right) = 1{\cdot}395 \text{ cms.}$$

(i.e.) The total thickness of the copper plates will be 1.395 cms.

Where thick gaskets are to be used, the extra amount of copper required to compensate for them can be calculated from the same expression (e.g.) If two asbestos gaskets are placed between the flange plate and the flange, using, say, 0.5 mm. asbestos paper, giving a total thickness of 0.1 cms. (αb can be taken to be 0 due to the compressibility of the asbestos):

$$A = 0.1\left(\frac{167{\cdot}8 \times 10^{-7}}{167{\cdot}8 \times 10^{-7} - 111{\cdot}5 \times 10^{-7}} - 1\right) = 0{\cdot}198 \text{ cms.}$$

Thus the total thickness of copper will be $1{\cdot}395 + 0{\cdot}198$ cms.

It should be noted that although the coefficient of expansion for stainless steel is taken as $111{\cdot}5 \times 10^{-7}$ in this example, this figure will vary for the different types of stainless steel that are available.

BOARD OF EXAMINERS (*See also page* 44A)

ANNUAL AWARDS 1970

At the Symposium to be held at the University of Surrey on the 10th, 11th and 12th of September, 1970, the A. D. Wood Cup, Jobling Cup and the Thermal Award will be presented to the student members for the submitted glass apparatus considered by the Board of Examiners to be the most outstanding examples of craftsmanship.

In addition to the Cups awarded for the best entries, Certificates of Merit will be awarded to all entrants whose work is considered to be of a high standard.

The judging will take place at a meeting of the Board of Examiners to be held in August. Please make sure your entry is in the hands of a member of the Board of Examiners by the end of July, or by a date arranged with your Section member of the Board.

The pieces of apparatus submitted must bear a card giving the entrant's full name and address, membership number and section, and length of time of glassblowing experience up to September 1970. Please fasten this card to the apparatus and not the packing box.

A. D. Wood Cup. To be held by the successful candidate for one year, a replica cup will be the winner's personal property. Entrants for this award must be Student Members of the B.S.S.G. with glassblowing experience not exceeding three years.

Jobling Cup. To be held by the successful candidate for one year, a replica cup will be the winner's personal property. Entrants for this award must be Student Members of the B.S.S.G. with glassblowing experience not exceeding five years.

Thermal Syndicate Award. To be held by the successful candidate for one year, a replica will be the winner's personal property. This Trophy will be awarded for the most outstanding piece of apparatus fabricated primarily in vitreous silica. Entrants for this award must be Student Members of the B.S.S.G. with less than five years experience as a scientific glassblower.

In addition to the Trophy, Messrs. Thermal Syndicate Ltd. have kindly offered to pay the expenses of a Student Member to spend up to one week at their Works. Such a stay could include time in their Apprentice School and Research Department and would obviously be of great value to a student whose previous experience of silica working was very little, yet whose future career was likely to involve such work.

Will Student Members interested in this opportunity please write to the Secretary of the Board of Examiners.

Secretary, Board of Examiners,
N. H. Collins,
8 Holden Terrace,
Liverpool, L22 6QL.

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ABSTRACTS

Compiled by S. D. Fussey

GLASS

(665) **Borosilicate Glass Process Plant.**
R. C. Brain, *Mat. Eng.*, 70, 7, 101, Dec. 1969.
Résumé of QVF pipeline and equipment with comparison of thermal conductivity, corrosion resistance, thermal expansion, mechanical strength etc., with other commonly used materials. J.M.

(666) **Why Not Glass?**
Jour. Eng. Mat., Comp. & Des., 12, 11, 1683, Nov. 1969.
Collection of papers by well known experts, covering many aspects of glass. Authors headings are:– "What is Glass", "Properties of Glass", "Machining Glass", "Working with Glass", "Applications for Glass – Chemical", "– – Thermal", "– – Optical", "– – Electrical", "– – Reinforcement" and "Current Developments". J.M.

(667) **Heat of Annealing in Simple Alkali Silicate Glasses.**
R. E. Tischer, *Jour. Amer. Ceram. Soc.*, 52, 9, 499, Sept. 1969.
Study of the enthalpy changes associated with annealing glass indicates that it eventually comes to a metastable equilibrium state and has a unique heat of solution dependent on its fictive temperature, the magnitude of which is related to the, molar volume of the glass. The significance of these heat effects is discussed. J.M.

(668) **Calculation of Residual Stress in Glass.**
O. S. Narayanswamy & R. Gardon, *Jour. Amer. Ceram. Soc.*, 52, 10, 554, Oct. 1969.
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(669) **Interaction of Radiation and Conduction in Glass.**
Granger K. Chui & R. Gardon, *Jour. Amer. Ceram. Soc.*, 52, 10, 548, Oct. 1969.
Interaction of radiation and conduction was treated for one-dimensional heat transfer, both transient and steady state. Some steady state results are discussed, showing that the interaction affects temperature distributions and heat fluxes in a variety of ways. Illustrations include a computer simulation of experiments to measure thermal conductivity of glass and an attempt to predict the vertical temperature profile in a glassmelting tank. J.M.

(670) **Effect of Uniaxial Stress on Glass Resistivity.**
R. J. Charles, *Jour. Amer. Ceram. Soc.*, 52, 6, 350, June 1969.
Discussion of experiments determining the resistivity of a glass and the effect of uniaxial stress on the results. J.M.

(671) **Coaxing Effect During the Dynamic Fatigue of Glass.**
A. L. Pranatis, *Jour. Amer. Ceram. Soc.*, 52, 6, 340, June 1969.
Discussion of the effect of understressing or cyclic stressing below the fatigue limit (of borosilicate glass) on the dynamic fatigue properties of the glass. J.M.

(672) **Kinetics of Leaching Glass by Ethylenediaminetetraacetic Acid.**
D. A. Olsen, R. E. Johnson, J. Kivel & F. C. Albers, *Jour. Amer. Ceram. Soc.*, 52, 6, 318, June 1969.
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(673) **Electro-Technical Glasses, Data Sheet No. 247.**
Data supplied by L. F. Oldfield, *Jour. Eng. Mat. Comps. & Des.*, 12, 11, 1709, Nov. 1969.
Physical and electrical data presented in tabulated form for soda-lime, lead, borosilicate, aluminosilicate glasses and silica. Refs. J.M.

GLASS APPARATUS

(674) **CPD Studies of Adsorbtion of Polar Vapours.**
T. Fort & R. Nash, *Jour. Coll. & Surf. Chem.*, 31, 3, 319, Nov. 1969.
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Allim Ullah, *Jour. Chem. Educ.*, 46, 12, 821, Dec. 1969.
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(676) **A Quantitative Diffusion Experiment for Students.**
M. de Paz, *Jour. Chem. Educ.*, 46, 11, 785, Nov. 1969.
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(677) **Determination of the Viscosity Coefficients of Gases.**
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(678) **A Simple Apparatus for Gas Reactions.**
A. F. Trotman-Dickenson, *Jour. Chem. Educ.*, 46, 6, 397, June 1969.
Glass Bourdon gauge monted in a 500 ml. flask, to study the reactions in an inert atmosphere rather than a vacuum. F.G.P.

(679) **A Constant Pressure Gas Absorber Reactor.**
M. B. Kennedy & J. R. Lacher, *Jour. Chem. Educ.*, 46, 8, 533, Aug. 1969.
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(680) **An Improved Gas-Circulating Pump.**
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Modified version of the Watson (1956) all glass circulating pump. Teflon is used for non-return valves and on piston head. Piston wear has been reduced, replacement made easy and improved pumping speed achieved. Drawings and circuit. D.A.H.

(681) **Viscosity of Perfluorobutene-2; A Relative Method for Measurement of Gas Viscosity.**
N. Madhaven & W. E. Jones, *Rev. Sci. Instr.*, 40, 10, 1293, Oct. 1969.
Simplified method of measuring the viscosity of an unknown gas by comparison of the flow times of gases with known and unknown viscosities through a capillary. Schematic of glass apparatus. S.D.F.

(682) **Grahams Laws. Simple Demonstration of Gases in Motion.**
R. B. Evans 3rd., L. D. Love & E. A. Mason, *Jour. Chem. Educ.*, 46, 6 & 7, June & July 1969.
The first article deals with molecular theory of matter with a section on normal or continuum diffusion. The second paper contains (1) Apparatus and description of Grahams diffusion experiment, (2) Apparatus arrangement for determination of frit permeability by pressure decay technique, (3) Apparatus for steady state permeability measurements. F.G.P.

GLASS TECHNIQUES

(683) **Glass-to-Metal Seal Alloy.**
Ceram. Age, 8, 12, 33, Dec. 1969.
Cyclops Corporation's Uniseal 42 exhibits a closely controlled thermal expansion, matching glasses such as Corning 1075 and 8830 for making glass-to-metal seals. Brochure from manufacturer presents mechanical and physical properties and a typical analysis of the alloy. J.M.

(684) **IEEE – IGA – Glass Industry Sub-Committee Conference – Glass to Metal Seal.**
Ceramic Age, 8, 12, 21, Dec. 1969.
Note on discussion by D. Oldham concerning R.F. induction heating of metal for sealing to glass. Particular mention is made of trepanning holes in glass by R.F. heated nickel cutting tool. Holes of repeatable dimensional accuracy can be made in flat glass in a few seconds. J.M.

(685) **Fabrication of Extremely Fine Glass Micropipette Electrodes.**
T. K. Chowdhury, *Jour. Sci. Instr.*, 2, series 2, 1087, Dec. 1969.
A semi-automatic pipette puller to produce a short taper with a tip of 500 Å or less. Glass is softened by a heated filament and air blown through small nozzles on to the softened portion prior to pulling. Drwgs. D.A.H

MISCELLANEOUS TECHNIQUES

(686) **An Apparatus for Handling Reactive Liquids.**
M. C. Waldman, *Jour. Chem. Educ.*, 46, 6, 369, June 1969.
Simple apparatus for handling air sensitive and highly reactive liquids during purification by V.P. chromatography. Sampling is under nitrogen through a silicone septum. F.G.P.

(687) **Nitrogen Controller.**
T. L. Nunes, *Jour. Chem. Educ.*, 46, 6, 401, June 1969.
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(688) **Apparatus for the Addition of Suspensions or Solids to a Reaction Mixture.**
A. de Groot & K. Hovius, *Jour. Chem. Educ.*, 46, 8, 499, Aug. 1969.
Special separating funnel using cavity type plug for dropping in samples under nitrogen. F.G.P.

(689) **Single Walled, Space saving Liquid Nitrogen Dewars.**
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An easily made, inexpensive, single walled "Dewar", using polyurethane and nylon. Seals made with Adhesive 80 cement. T.D.R.

(690) **An Inexpensive Motor Driven Burette.**
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Syncronous motor harnessed to a micrometer is used to operate a micro syringe. F.G.P.

(691) **Stability of Colloidal Silica.**
L. Allen & Egon Matijevic, *Jour. Coll. & Sur. Chem.*, 31, 3, 288, Nov. 1969.
Description of moving boundary cell using platinum and cadmium electrodes for measuring negative mobilities. F.G.P.

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Design of a simplified generator which "– – – is recommended for the laboratory preparation of ketene because of its easily accessable parts, simple assembly and greater efficiency and yield" (authors). J.M.

(693) **A Simple Composite Helium Dewar.**
V. M. Conway, P. David & M. Heath, *Jour. Sci. Instr.*, 2, series 2, 1110, Dec. 1969.
Using a copper radiation shield attached to a double-ended Pyrex to copper seal, a Dewar has been constructed so that the shield is in contact with liquid nitrogen and shields the liquid helium. The Dewar has been used with a small electromagnet gap. Drawing. D.A.H.

(694) **An Improved Laboratory Stirring Device.**
J. Bitz, *Rev. Sci. Instr.*, 40, 10, 1344, Oct. 1969.
An inexpensive, effective stirring device with a two-piece paddle, suitable for hot corrosive liquids in flasks from 200 to 1000 ml. Drawing and photograph. T.D.R.

(695) **Apparatus for the Purification and Crystal Growth of Organic Compounds.**
C. C. Gravatt & P. M. Gross, *Jour. Chem. Educ.*, 46, 10, 693, Oct. 1969.
Details of a zone refining apparatus and a crystal growth cell. F.G.P.

(696) **The Infrared Spectra of Gases at 300°K and of Frozen Films at 77°K.**
W. H. Guillory, *Jour. Chem. Educ.*, 46, 10, 681, Oct. 1969.
A modified Hornig low temperature cell using sodium chloride or potassium bromide windows. F.G.P.

(697) **Mikhail Somonosov and the Manufacture of Glass and Mosaics.**
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(698) **High Temperature Ceramic End Seal.**
Ceram., 20, 248, 66, Oct. 1969.
Details of alumina-base ceramic cement "Ceramacast". Will form a dense end-seal and adheres to metal and ceramics; is oil, solvent and acid resistant. J.M.

(699) **New Ideas in Materials Engineering – Liquid Crystal Window can be Clear or Clouded.**
Mat. Enging., 70, 7, 17, Dec. 1969.
Nemetic liquid crystal incorporated between two sheets of conductive glass will provide a clear window at room temperature, but application of a low voltage causes it to become translucent. J.M.

VACUUM

(700) **A Simple Vacuum Monitor.**
E. P. Harbulak & S. P. Valayil, *Jour. Chem. Educ.*, 46, 11, 739, Nov. 1969. Increase or decrease of pressure in a vacuum storage dessicator is indicated by an hypodermic syringe used as a gauge. F.G.P.

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A Pirani type gauge with a range of 10^{-3} to 10^{3} torr. Max. temperature of filament is 300°C. Full description of design, manufacture and performance of a very simple instrument. T.D.R.

(702) **A Large Bakeable High Vacuum Valve.**
W. T. Baxter & R. J. Dusman, *Rev. Sci. Instr.*, 40, 10, 1355, Oct. 1969.
Large stainless steel high vacuum valve, bakeable to 450°C, opened and closed by heating a pure tin seal. Drawing. T.D.R.

BOARD OF EXAMINERS

STAGE ONE COURSE-LATHE GLASS WORKING

The examination for the B.S.S.G. "Stage One" certificate comprises practical examination in manipulation and oral examination in elementary theory.

Syllabus

Theory

Properties of the glasses in general use – working temperatures, co-efficients of expansion, annealing, thermal resistance, chemical resistance, correlation of these factors.

Cutting glass tubing – use of cutting tool and steady, description of cut.

Burners – pre-mix type and surface mix type, adjustments.

Glassworking lathes – types and maintenance.

Gas supplies – safety precautions, non-return valves, Oxygen and air supplies.

Values of materials and equipment.

Manipulation – Material: borosilicate glass.

Setting up of tubes in both heads. Methods of alignment. Straight joins by blowing and centrifuging, using tubing of up to 75 mm diameter. Parting by melting and by thermal shock. Repeatable exercise of parting and joining.

Setting up prepared assemblies within tubing or other prepared work, utilizing packing material such as, asbestos, copper wire. gauze or strip, also other specilized techniques.

Forming bulbs by blowing and by centrifuging. using heavy wall tubing up to 50 mm diameter, Forming re-entrant and conical bulbs. Making multiple-bulb fractionating column.

Forming domed and flattened ends on tubing up to 100 mm diameter.

Various shaping exercises. Using tools both fixed and free-hand.

Forming flanges on tubing up to 100 mm diameter.

Forming tapers by external tooling and internal reaming.

Coil winding of coils up to 150 mm diameter.

THE SMOOTHNESS OF GLASS SURFACES

*By Prof. S. Tolansky, F.R.S. Royal Holloway College, University of London**

The technique now called multiple-beam interferometry in a procedure of high sensitivity for revealing the micro-topographical structures of surfaces. It has been extensively applied to the study of the surfaces of crystals, metals, plastics, biological objects and of course also glasses.

See for reference any of the following books: (1) S. Tolansky, "Surface Microtopography," Longmans, 1960; (2) S. Tolansky "Microstructures of surfaces," Arnold, 1968; (3) S. Tolansky, "Interference Microscopy for the Biologist," Thomas, 1968. In these references techniques, methods are gone into in some detail, much more than can be discussed here.

In essence this technique produces an *optical* height contour map of a surface which shows, with high fidelity, up-down micro-structure. Consider as an analogy the familiar contour lines in a typical ordnance survey map of an area of countryside. A contour line on such a map is a line joining all those regions which are at the same height above the sea-level. Suppose we have a map drawn with 50ft. contours, we can visualize this as arising through the intersection of the countryside hills and dales by a series of horizontal planes each 50ft. apart. Now in like manner it is possible to produce *optical* contour lines (optical interference fringes) from a surface. This is achieved by matching an optical flat surface against the surface under study, and then illuminating the combination, at perpendicular incidence, with a parallel beam of light of one wavelength (monochromatic light). If the optical flat is tilted slightly relative to the surface under study, to form a slight air wedge; then if the two surfaces are (1) specular and (2) close together, optical interference takes place between the light beams reflected from the two surfaces. The upshot is that the surface is seen covered with "contour lines" (fringes) exactly analogous to the contour lines on the countryside ordnance map; but with the very great difference that here, optically, instead of 50ft. contours, these optical contour lines each represent regions which show changes in level separation between the two surfaces of a mere half of a wavelength of light. For green light this quantity is about one hundred thousandth of an inch. So the fringes represent contour lines which are a measure of the slight slope of the studied tilted surface relative to the optical flat.

When two glass surfaces (or similar ones) are matched we obtain what are called "*two-beam*" fringes in that the interference arises from the two reflected beams (one from each surface). In such fringes the alternate light and dark regions are of the same width. Now in our special development, which we call "*multiple-beam*" interference, a great increase in sensitivity is created in that by a special optical device the fringes are made into narrow and sharp lines. So narrow are they that their widths are only about one hundredth part of the separation between two fringes. We shall soon see that this produces an altogether higher order of sensitivity in revealing surface microtopographical fine structure.

The multiple-beam effect is obtained by depositing on the two glass surfaces a critically correct thin film of silver, using vacuum evaporation deposition. This silver film must be of very high quality, with reflectivity at least 95% and of a thickness some 700 Å (i.e. something like one four hundred thousandth of an inch and this thickness must be correct to within one five millionth of an inch). When two such silvered surfaces are correctly illuminated, light beams bounce back and forth between them and the result of this (if certain optical conditions be satisfied) is to produce extremely sharp narrow fine fringes through what is called multiple-beam interferometry.

Now we have repeatedly demonstrated by several independent methods that evaporated silver has a formidably close power of contouring a surface. Indeed, repeated separate independent tests by us establish that a correctly deposited silver film can contour microstructure with such high fidelity, that indeed it contours detail *down to within molecular dimensions*. Let us imagine then that we have two extremely flat smooth pieces of glass, silver them, place them together to enclose a slight air-wedge and suitably illuminate them. The fringes we get are straight lines, equally spaced and parallel to the line of contact of the air wedge formed by the two pieces of glass, which have been set so as to touch at one edge. There are two things to note, namely (a) the fringes are narrow sharp lines, occupying in their width only one hundredth of the spacing between adjacent fringes (b) the separation between fringes can be altered by modifying the wedge tilt. It is not difficult to place fringes to be, say, one inch apart on the surface, on which they thus appear as fine narrow hairline lines.

Let us see what this implies. Consider two such straight fringes, one inch apart. We know that in moving from one fringe to its nearest neighbour the height on the wedge has changed by one hundred thousandth of an inch. Clearly then the true magnification in contour height (note this *only* refers to magnification in the *up-down* direction) is here x 100,000. Suppose now there is some small defect on the surface (a minute hill or a minute hollow) then a fringe on crossing over this feature will show a small local curved region, curving one way for a hillock, the other for a valley. Since the fringe width is only one hundredth of a fringe separation, a kink equal to displacement by one fringe width is created by a feature of height (depth) of one ten millionth of an inch. Indeed we have further established that under the best of conditions a kink displacement of merely one fifth of a fringe width is actually detectable, i.e. one five hundredth of a fringe separation is observable. This quantity is a mere fifty millionth of an inch (i.e. some 5 Å), a quantity of only molecular dimensions.

If then we have one perfectly smooth and flat surface we can match this to secure the micro-topography of some other surface. The question which immediately comes to mind is this, can we secure, indeed for reference a smooth flat surface? Now if we are going to use a microscope at say x 100 or more then the criterion we must seek is in fact *smoothness* rather than flatness. For the flatness criterion is relatively easy to satisfy over such small regions. If a piece of glass of say 1 square cm. is flat to within, say a tenth of a light wave, then a selected region of one square millimetre – a hundredth of this – (still appearing as sq. cm. in our microscope of course) can be considered as flat to within a thousandth of a wave (5 Å) provided that the surface is smooth. Clearly what matters then is *smoothness* rather than flatness.

We discovered the answer to this problem as far back as in 1945 when we found that cheap fire-polished glass (not mechanically polished glass) has a phenomenal degree of smoothness. The proof of this was simple. For when two such pieces of glass were matched together the fringes formed were beautiful narrow straight lines quite free from structure. We have in fact found three different kinds of structure-free glasses and will illustrate these in turn. These are (1) cheap fire-polished thin sheet glass (2) drawn glass tubing (3) Pilkington float glass. We shall soon demonstrate by means of multiple-beam fringes how smooth such surfaces can be. It remains to consider the cause. The reason is really simple. Glass, when fire polished is in effect a super-cooled liquid. The molten glass surface has very high viscosity and takes on the natural smooth specular perfection of a liquid surface. When it solidifies it retains this natural perfection, it retains the smoothness of a highly viscous fluid and so fire polished glass has an extraordinary smooth perfection of surface.

When commercial glass tubing is drawn the condition of fire polish exists. A tube when matched against a flat gives a set of fringes consisting of straight parallel lines, parallel to the axis of the tube. The fringe positions obey the rule of Newton's rings, i.e. the system is in effect a "one-dimensional" Newton's ring system. The "diameters" of the fringes are thus proportional to the square roots of the natural sequence of numbers. Plate 1 shows the multiple-beam fringe system given by a randomly picked out piece of glass tubing matched against a piece of cheap fire polished glass. Notable are (a) the narrowness of the fringes and (b) the absolute complete absence of any structure. The surfaces are indeed remarkably smooth and good reference surfaces. To show what an irregular piece of glass looks like, compare now Plate 2 and we see how structure free are both the drawn glass and the reference surface of cheap fire polished glass.

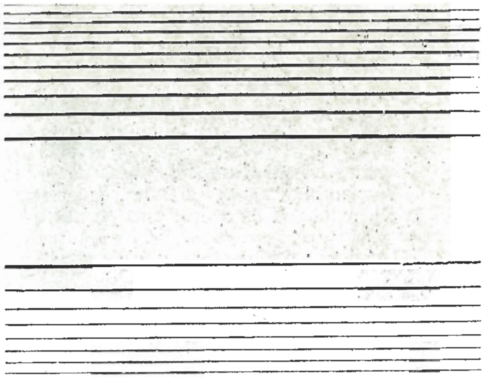

Plate 1

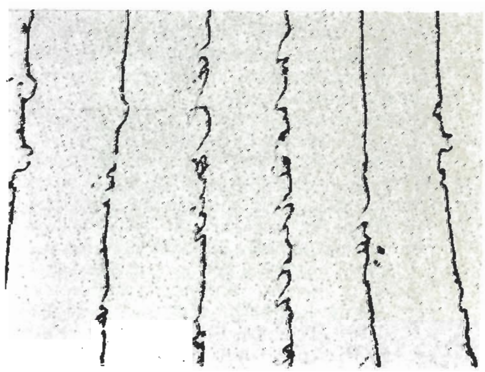

Plate 2

Within recent years Pilkington of St. Helens have perfected the production of "float glass" and this bids fair to replace world production of plate glass for all industrial and building use. The former plate glass, produced either by casting, drawing or softening from the cylinder was invariably mechanically polished. Not only is this slow, creating a production bottleneck, but it is costly, time consuming and in the end the polish is somewhat imperfect, since it is carried out by big machines.

Now float glass is produced in the following way. A thin soft sheet of hot (almost molten) glass is extruded from a furnace. It then enters a large tank containing a pool (many tons) of tin, heated well above the softening point of the glass. The glass sheet is brought forward by rollers and in effect its soft surface moulds itself to the perfection of the molten tin liquid (vibrations are carefully excluded). At the same time hot gas flames play upon the upper surface of the sheet of glass. The upshot is that the sheet as it emerges is not only very flat, it is also fire polished on both sides, although indeed by different mechanisms. The sheet moves on through a long annealing region and is ultimately cut in sheets and stacked. The process is continuous, fast and smooth without bottlenecks and the finished product has a better and smoother surface than the best mechanically polished plate glass.

We realized as soon as Pilkington's announced their process that such float glass should have a superb interferometric smoothness. This is indeed the case. Plate 3 shows fringes from two pieces of float glass matched against each other. The picture speaks for itself. Remember that from fringe to fringe this represents a contour height change of one hundred thousandth of an inch. The minor wriggles in the fringes give a good idea of the superb character of the surface.

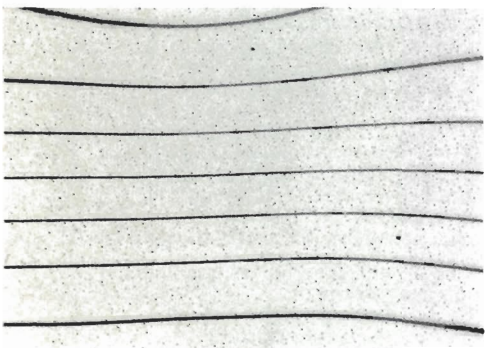

Plate 3

We do find that at times a gas bubble has been trapped between the tin and glass and this leads to the defect shown in Plate 4.

Plate 4

Finally having secured such good reference surfaces, we show in Plate 5 the remarkable kind of fringe pattern given by the surface of a crystal (in this case a diamond) when matched against a smooth piece of structure-free fire polished glass.

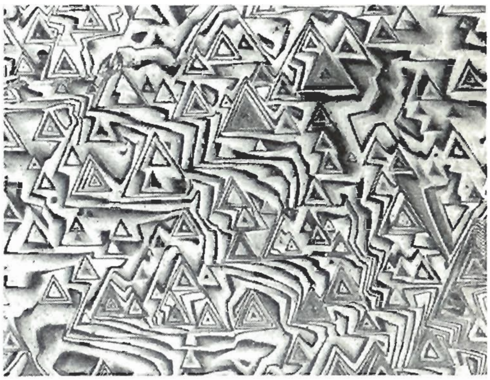

Plate 5

We can, we see, have complete confidence in our reference surface of glass and indeed do know that the complex microtopography shown in Plate 5, must indeed belong exclusively to the crystal and is in no way falsified in the slightest by any effects from the glass reference surface. Indeed a cheap piece of fire polished glass can be absolutely reliable as a reference surface for the study of complex microtopographies, even down to very fine limits.

**Professor Tolansky established an international reputation through his development of multiple-beam interferometry for studying fine detail of surfaces of a wide variety of materials from diamond to the recently acquired samples of glassy spherulites brought back from the moon by Apollo teams.*

Professor Tolansky was made a Fellow of the Royal Society in 1952 and occupies the Chair of Physics at Royal Holloway College. We thank him for this paper written for the Journal.

The Production of Fine points on Rods of Tungsten and Other Refractory Metals

by J. S. MacDonald

INTRODUCTION

The manufacture of fine points on tungsten rod is a requirement in many fields of research. Two methods commonly used are grinding and electrical erosion. For many requirements grinding is unsatisfactory as the point is left with many small striations, and frequent redressing of grinding wheels is necessary owing to the hard nature of the materials.

The second method (1) is perfectly satisfactory with regard to finish, however the time taken to produce a fine point is excessive and the procedure of adjusting acid concentrations and voltage levels is tedious. This memorandum describes a simple method of producing fine points on rods of tungsten and other refractory metals by controlled oxidation in a blow torch flame followed by electropolishing in a standard solution.

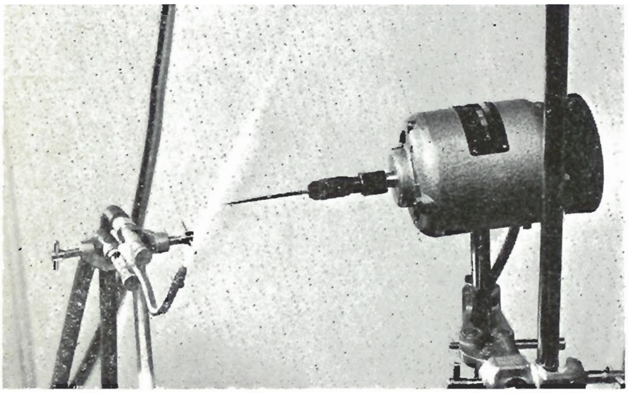

Fig. 1

METHOD

A uniform point is obtained by rotating a tungsten rod about an axis at an angle of 45° to a fierce gas and oxygen flame as shown in Fig. 1. Speeds of rotation in the range 60 to 500 r.p.m. are satisfactory and are conveniently available from the type of small electric motor used for laboratory stirrers. This method of sharpening tungsten rods is extremely fast. The average time taken to produce a fine point on a 1mm tungsten rod is approximately 60 seconds. The shape of the point produced by this method can be varied by adjustment of flame size and angle. Quality of the surface finish in the region of the points is equivalent to a 13 C.L.A. finish (2). A typical example of a finished point is shown in the accompanying photograph Fig. 2.

After the point is made it will be covered with a layer of oxide which can be rapidly cleaned off by any of the standard tungsten cleaning methods. The method that I find most satisfactory is as follows:–

A 500 ml. beaker is filled with Langmuirs solution and 15–25 Volts A.C. is applied between the rod to be cleaned and a piece of carbon rod immersed in the solution. Current is switched on for approximately 20–30 seconds after which time the point is both cleaned and polished.

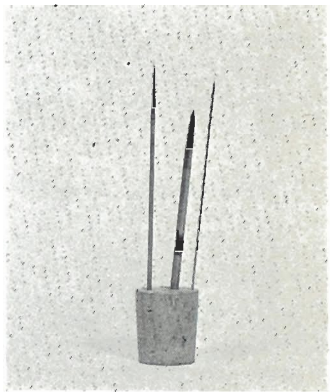

Fig. 2

Langmuirs solution for cleaning and polishing tungsten consists of:

Sodium Nitrite	159 g
Potassium Nitrite	159 g
Sodium Carbonate	23 g
Sodium Hydroxide	23 g
Distilled Water	2 l

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(2) C.L.A. Finish is the accepted measure of surface finish to B.S. 1134.

DEWAR PUMPING

In the case of Dewar vessels which are to be used at liquid helium temperature it is customary to evacuate only partially leaving a few millimetres of air which the liquid helium removes by cryopumping. It seems that this same principle can be used for Dewar vessels constructed to hold liquid air or similar refrigerants.

In an emergency replacement of a liquid air container the usual vacuum bake was omitted and the Dewar was attached after silvering, via a cold trap, to a mechanical pump which is the normal method of drying. Before drying was complete it was sealed off and was found to be perfectly satisfactory in use, since when other Dewars have been processed in the same way to confirm the result.

A one litre spherical with a simple sheet asbestos cover held liquid air for three days which is comparable with a fully processed one.

It is probable that when the refrigerant is poured in, the inside surface is cooled and freezes out the water vapour at the same time 'gettering' any residual air, resulting in a good vacuum which persists as long as the Dewar is cold.

Hence when Dewars are to be used under these conditions vacuum baking is unnecessary but we would still consider baking essential for vacuum jackets, fractionating columns, etc., which are to work above 0°C.

J. H. BURROW 12th December 1969

SECTION REPORTS

Thames Valley Section

4th December 1969, at C.E.G.B. Laboratories, Marchwood.

This meeting was a real workshop session. Many members got down to fully describing and demonstrating not just pet gadgets to do the odd job in an odd way, but clever, well thought out devices and methods of making or preparing glass components to a high standard in minimum time.

Every member present at this meeting must have left Marchwood at least a little wiser for having seen such splendid demonstrations of glassblowing ingenuity.

1st January 1970, at Reading University.

Modern Adhesives, Why and How, by V. L. Malempre, BSc., A.R.C.S. of C.I.B.A., Cambridge.

Having broken the ice with an appropriate touch of humour, our speaker went on to describe a whole range of adhesives, their properties, uses, test procedures and the meaning of test results. He described the three groups into which any adhesive can be fitted, and by means of slides and samples, demonstrated that by correct selection and use, adhesives can be advantageously employed with many conventional materials to give enhanced appearance and mechanical properties.

A quick look into the future showed that some of the basic components of the older adhesives may well come to the fore when used with new application techniques.

Thank you Mr. Valempre, we enjoyed your lecture.

5th February 1970, at Reading University.

Dating the Past, by Dr. Switzer of Cambridge University.

A brief résumé of the formation of the planets together with some of the ice happenings of the past two or three million years, was how Dr. Switzer introduced his superbly fascinating talk. An impressively simple explanation of radio-active carbon dating, plus slides showing the apparatus in use at Cambridge University, had all members very much alive with interest. Handling samples – through polythene wrappers – of relics of the past, including a female leg bone some 4000 years old, was an unusual experience to say the least.

Glass was not completely left out. We learned that it may be dated by microscopic counting of "weathering" layers irrespective of it's having been buried in earth or sea.

Finally, if any member has sea shells with positive proof of being before 1815, Dr. Switzer would like to have them to aid future dating programmes.

Due to the interest expressed after this lecture, Thames Valley hope that our speaker may be prevailed upon to take us further into "the past".

S. D. FUSSEY

Western Section

Some 15 members attended the Annual General Meeting which was considered a reasonable proportion of the Section membership. The Chairman Mr. Fred Porter reported the progress which had been made since the programme of monthly meetings was resumed in the previous September. There was now better support and 29 members and friends attended the Annual Dinner at Ashton Court Country Club.

Some debate took place on whether section meetings should be technical and related to glass-working or on other interesting subjects such as stained glass and art. It was concluded that variety was needed.

Mr. Fowler the Section Secretary also gave his report which confirmed that of the Chairman. Mr. D. A. Jones the Section Treasurer gave an account of the finances which showed a satisfactory balance.

The meeting then voiced the general feeling that Fred Porter, Malcolm Fowler and Dennis Jones had done an excellent job in reforming the Section after the lapse early in 1969. All three agreed to continue in office for another year and it was also decided to dispense with a Section Committee in 1970 and make all business meetings open to members.

Mr. Garrard, Section B. of E. examiner gave an account of the meetings attended during 1969 and reported that the syllabus for Stage 1 Lathe Glassworking was now complete and copies could be obtained from the B. of E. Secretary. One entry for Fellowship had been received and was being considered.

In response to an appeal for a new Section representative on Council, Mr. John Martin agreed to attend the meeting and report back.

Various points relating to Council meetings were then discussed together with possibilities for future section meetings and the Annual Works visit.

The Section tenders its thanks to Prof. Heller of the Pharmacy Dept., University of Bristol, for allowing the Section to use the Conference Room in the Medical School for its meetings.

February Meeting

This was held as usual in the Bristol University Medical School and after some discussion on John Martin's report of the February 7th Council Meeting members proceeded to Malcolm Fowler's workshop for a talk on graded glass seals. He explained the reasons why graded glass seals are used mentioning special applications such as photo-multiplier tubes, and also conditions which have to be observed to make them successfully. An expansion difference of 7×10^{-7} should not be exceeded in each step, overlap should be avoided, and they should not be thick. Annealing is almost impossible and handling hot seals with cold asbestos gloves is dangerous.

Mr. Fowler included demonstrations of making 50 mm diameter Pyrex to Kodial seals on a glass lathe and smaller Pyrex to lead glass in a bench burner. This burner was particularly interesting being a miniature turret burner giving a wide range of flames.

These demonstrations led to some interesting remarks and discussion of the fine points of graded glass seals and the good attendance at the meeting confirms the popularity of technical subjects.

R. J. BATCHEN

East Anglian Section

The Section A.G.M. was held on 16th Januray and was attended by 27 members. During the Chairman's remarks concern was expressed at the dwindling attendances at meetings and he said that this tendency must be remedied for the Section to continue successfully.

Reports on the Clacton-on-Sea Symposium were given which included an explanation of the financial loss which was mainly due to an unexpected 10% service charge by the Hotel.

A vote of thanks was given to Mr. L. G. Morrison for his work as Secretary during the last year. Section officers, Committee, Council and other representatives were then elected for 1970.

Two representatives of the Section, Mr. L. G. Morrison and Mr. E. G. Evans will be available to advise the Southern Section on the 1970 Symposium at the University of Surrey.

Following the meeting a discussion was launched by Mr. L. G. Wellstead on North Sea Gas and its problems and a variety of converted burners were on show. The overall opinion was that these were not as versatile as current town gas burners and techniques will have to change when North Sea Gas is used. It is probable that a further meeting with Gas Board representatives will be arranged.

About forty members attended an interesting and instructive meeting held at Harston on 27th February on Silica Working. The meeting was made possible by the kind and generous cooperation of Hans and Horst Baumbach who gave an interesting talk, and showed an extremely good and well made film which had been produced in their own workshops.

The evening began with a talk on the problems which were experienced by glassblowers when working Silica many years ago, including the early difficulties of tube manufacture and in getting the correct diameters of tubing which were required. Hans and Horst had brought along some samples of old silica tubing for comparison with present day material. The glassblower of today may still fault his silica tubing, but compared with what was available in the early days there has been a tremendous improvement and it has become a pleasant material to work with. It was stated that silica tubing is now manufactured up to 800 mm diameter.

A selection of Glassblowing Tools and equipment made by Baumbachs' was also on show for members to inspect and discuss.

After the talk members were shown the film on silica working which included the preparation of the tubing with particular attention to cleaning, methods of working, and the tools required. The film included the manufacture of joints, flasks and bending spirals, as well as constricting and methods of closing the ends of tubes.

Hans and Horst Baumbach were given a hearty round of applause for their excellent talk and superb film and we would like to thank them through this Journal for giving the benefit of their experience which was appreciated by all those present.

R. A. PRYKE

Southern Section

Extracts from News Bulletins 21, 22 & 23.

December Meeting

Mr. J. H. Burrow of H. H. Wills Physics Laboratory gave a talk entitled "Aspects of Glassblowing". As he explained, with a title as open as that, he could talk about practically anything related to glassblowing – and he did. Beginning with the composition of glass in its powder form and how the basic ingredients would affect the type of glass made, on to strain and annealing, then to the actual working. Mr. Burrow prefers to check his ovens by instilling strain in a piece of glass and then taking the temperature up to the point where it disappears rather than using a thermometer or pyrometer and relying on manufacturers annealing figures.

He is also an ardent advocate of the lathe and hand torch working as against bench working: even to the extent that he does not see any reason for training apprentices in the traditional manner to use the bench blow lamp to develop those particular skills necessary for working glass. He also told us that he still prefers the ring type burner, with set diameter and height control, to other forms of adjustable banks of jets, and for many applications a carborundum cutting wheel instead of a diamond impregnated one. A useful hint he passed on was the re-setting of the cutting edge of a carborundum disc with a piece of tungsten instead of the more usual greenstone.

Mr. Burrow's bantering good humour pervaded his talk and his 'tongue in the cheek' remarks often elicited the audience participation he wished to evoke. That the members enjoyed his talk was shown by their hearty appreciation.

January Meeting

After reading the minutes of the last A.G.M. the meeting concerned itself with suggestions for lectures both for the 1970 Symposium and next season's series of Section meetings.

The desire for more practical demonstrations was evinced by many, particularly in respect of visitors and wives at the Symposium. The reading of technical papers is of course essential but it seems that a majority would like to see more practical work being carried out. Mr. Ron Blackston pointed out that not every glassblower has the artistic ability to make glass animals and he would advocate one or two members being given a chance to show their skill. He also offered his wife's services to organise interests for wives who attended. This offer was gratefully accepted.

There was also interest in Natural Gas and Mr. L. Noon suggested that his firm, B.P., could be approached to provide not only a lecturer but also a visit to their laboratories.

Another suggestion was that a Section meeting be left open for a few members to talk about their own sphere of glassblowing, describing techniques and answering questions.

Yet another suggestion was that through the Arts Council it might be possible for members to hire a glass melting furnace and create artistic objects straight from the furnace.

These were some of the ideas put forward at the meeting but others are needed and the Committee will consider whether they can be implemented.

February Meeting

On the 20th some fifty-eight people met in the Bedford Room of the Horseshoe Hotel, Tottenham Court Road, for the Section's Annual Social occasion. This took the form of a buffet meal spread on eleven tables each with six seats. The tables were tastefully decorated with flowers and the lighting was very effective. The meal was followed by dancing. Many members obviously enjoyed the occasion though it seems some would prefer the usual "Stag Dinner".

Questions and Answers

Q. Is there a good marking pencil that makes a clear mark which disappears when melting point is reached?

A. Warwick Branch gives one answer to that – "Lyra Orlow" Cellugraph 6360. It is made in Germany and can be ordered through stationers".

Personally, I use a "Venus" All Surface, which can be obtained in various colours and, unlike a "Chinagraph", is clean and does not bubble when heated. Then there are coloured dye markers like Woolworth's Gem and the felt tipped Flash Dry, but these leave a stain.

I would like to thank Mr. L. Noon for two samples he sent me. One again is German, made by Faber. It is the Van Dyke "Multi" 666: fine marking it is not very easy to see. The other is something I have never come across before: it is a piece of Zirconium rod about $\frac{1}{2}$ inch long, $\frac{1}{8}$ inch thick, tapered to a point, and the suggested holder an Eclipse No. 123 pin chuck. The mark it makes looks like a fine lead smear; it does not scratch the glass in the manner of a diamond pencil and the mark remains after heating.

One last pencil, while we are on this subject, and it is rather an unusual one. It is the Canada "blaisdell" China Marker Black 173. Unusual in that it is not made of wood but paper wound around the marking core. When the point is worn one merely pulls on a small tag end to unwind and expose a new tip within an even taper.

Q. What types of glass are usually used in glass to metal seals? P.K.

A. This is a large field to cover and the obvious thing is to read "Glass to Metal Seals" by J. H. Partridge which was re-printed in 1967: but, very briefly, Paul, almost any glass. If you mean glass-metal seals which are vacuum tight, then a matched alloy is used:–

Soda – 48% Ni.Fe. Alloy.

Lead – 42% Ni. 5% Cr. 53% Fe. (No. 4 Alloy, Wiggins Nilo 475). Telco 3. Koppercoated Ni.Fe.

Kodial, Corning 7052, M.E.I., borosilicate glasses with a co-efficient of expansion approximately $48 \times 10-7$: –29% Ni. 17% Co. 54% Fe. (Nilo K, Kovar etc.)

Q. Why is it a bad thing to have Potassium in some glasses? A.N.

A. Potassium is slightly radioactive so, if used in a device such as a geiger counter or photo-multiplier envelope it would add its own radiation count.

Q. Where is it possible to see a Glass Technology Exhibition?

A. At the Science Museum, Kensington. An excellent exhibition of Glass in all its forms, its history, its composition, Cut glass, etched and polished glass. Glass with strain and glass with toughened surfaces. If you can possibly spare the time to pay it a visit the exhibition is on the first floor gallery overlooking the main hall, and is well worth seeing.

Q. I have often wondered how effective different diffusion pumps are in relation to each other. I have over sixty vacuum pump systems to maintain so have some interest, but owing to a conservative attitude on the part of the users, lack of opportunity or time because of more pressing needs, on both sides, I have never experimented with any other diffusion pump than our own single stage type. On occasion we have used a Ball or G.E.C. two stage pattern but I have never assessed the speed or capacity or ease of making of one against another. Perhaps someone reading this Bulletin has done so; if not in practical usage perhaps someone has done a little mental work on the theoretical side? If so, how about passing your information on to me for inclusion in the next Bulletin? I am sure there must be many who have an interest in the various types of pumps or even cut-offs. What type do you use? Solenoid, magnet, mercury? Let me hear from you and perhaps we can form a picture of advantages or drawbacks which can be passed on to others.

If any young apprentice has a book token or a few shillings left over after his Christmas spending spree, he might very well be interested in "Creative Glassblowing" by Hammesfahr and Stong, published by W. H. Freeman & Company. Well written and illustrated by excellent line drawings it describes how to set up a small workshop, make tools and equipment, and although one needs more than a book to learn glassblowing, it does provide a lot of information. It does not cover lathe working and, unfortunately, the list of suppliers is American. Nevertheless, I know of no better book giving practical information on bench blowing.

If you are interested in antique glass, I see Odhams have "The Collector's Dictionary of Glass" which surveys the entire field of glass-making from Roman times to the present day and features all the famous glassmakers, European and American, past and present. It costs 55/–.

R. J. W. Harvey

CHURCHILL AWARDS

Members of the Society will be interested to know that one of these awards has been gained by Mr. Bill C. Tys who is a scientific glassblower of the Research School of Chemistry at The Australian National University, Canberra, Australia. Over a period of three and a half months he will visit the U.S.A., Britain, Holland and Germany, in order to study the latest developments in glass technology. He will attend the A.S.G.S. Symposium and if his time in England coincides with the B.S.S.G. Symposium we may have the pleasure of meeting him. He would be pleased to receive suggestions for inexpensive accommodation for himself and his wife while in England (two to three weeks in September).

His early training was received at the Philips Laboratories, Eindhoven, Holland, after which he worked at Shell Research Laboratories in Amsterdam, obtaining the Master Diploma in Glassblowing at Leiden in 1949. In 1952 he joined the Australian National University.

NEWS ITEMS

S.I. Units and the Glass Industry

An exhaustive study of S.I. Units in relation to the Glass Industry has resulted in a full report issued by the Glass Manufacturers Federation.

Metrication is explained in detail with the advantages and some inconveniences of S.I. Units. A section is devoted to each unit of measurement with recommendations on orders of magnitude to be used.

Appendix I gives a summary of units recommended for use in the Glass Industry. Appendix II gives conversion factors and Appendix III gives a full list of multiples and sub multiples.

Members wishing to study the report will find a copy in the Society Library or alternatively it can be purchased from the Glass Manufacturers Federation, 19 Portland Place, London W1N 4BH.

Promotions

We congratulate both Mr. E. G. Evans who has recently been promoted from Technical Advisor to Technical Director of Day Impex Ltd., Earls Colne, Colchester and, Mr. R. Briggs, promoted from Works Manager to Works Director.

The American Scientific Glassblowers Society

A preliminary programme has been received for the Fifteenth Annual Symposium and Exhibition which will be held on June 23, 24 and 25, at the International Hotel, Los Angeles, California.

There will be an Address of Welcome by the Mayor of Los Angeles, a Board of Directors and other business meetings, Technical Papers, Workshop Sessions and various social functions.

Information Required

Can any firm supply asbestos corks or bungs from $\frac{1}{4}''$ to $4''$ diameter. If so, please contact Mr. R. Brown, BCURA, Randalls Road, Leatherhead.