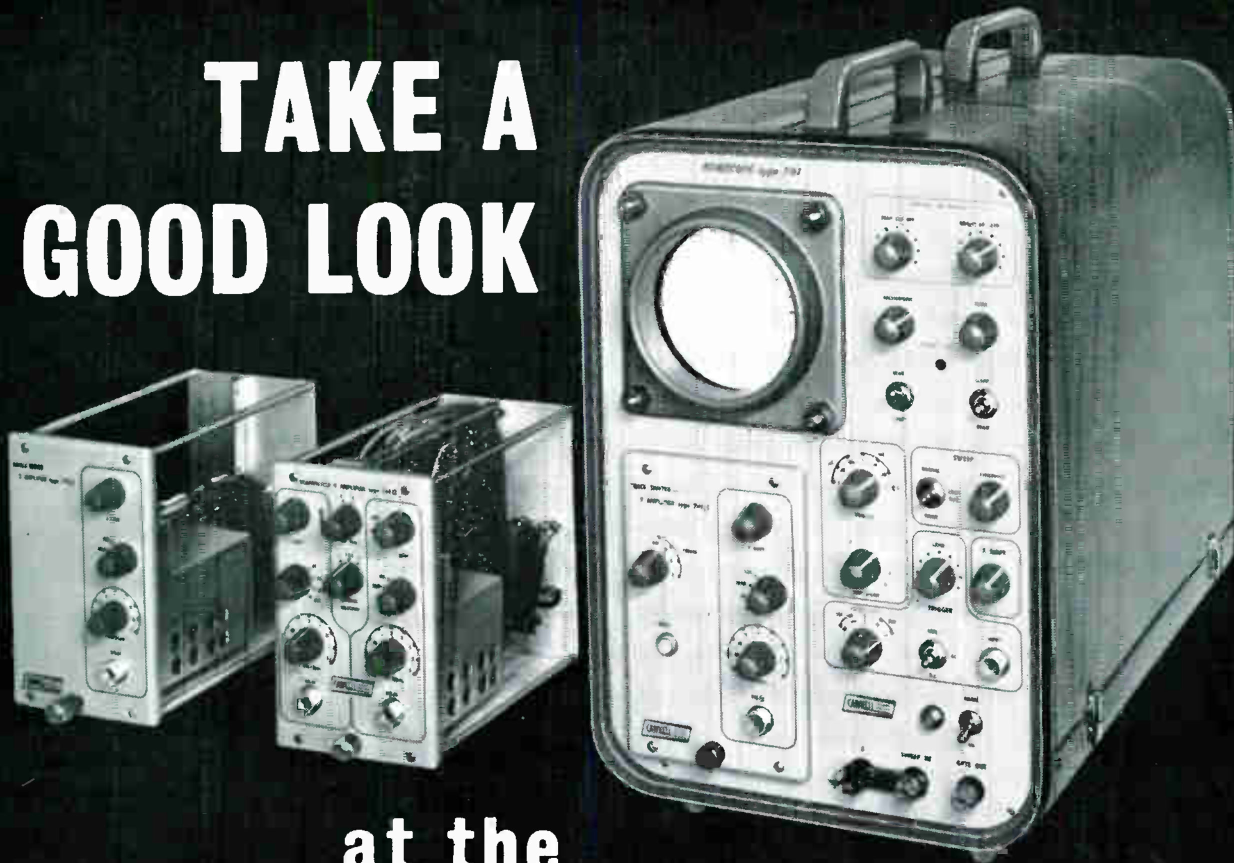
INDUSTRIAL ELECTRONICS

MARCH 1965 5s 0d

TAKE A GOOD LOOK



at the REMSCOPE 741...

Three interchangeable amplifiers available:—

Y-amplifier Type 741 3—for normal single-beam display. U.K. list price £45.

2-channel Beamswitch amplifier Type 741 2—enables two signals to be stored simultaneously, facilitating correlation of related but separated events. U.K. list price £120.

Trace shifter amplifier Type 741 1—enables successive phenomena to be recorded and displayed vertically. U.K. list price £75.

Remscope Type 741 with 741/3 amplifier. U.K. list price £525.

its simple and uncluttered layout allows fast transient phenomena to be recorded with ease for study at leisure.

Take a good look at the REMSCOPE and you'll readily understand why it is the ideal storage oscilloscope for taking a good look at transient phenomena. It will store a trace for up to a week and display it continuously for up to 10 minutes or intermittently, as required, for a total time of 10 minutes.

For certain research work the Remscope is essential:—

- Accurate measurements can be taken, and data amassed from short-lived events.
- It eliminates the delays involved in photographing and filming an oscilloscope screen.
- It reduces costs by dispensing with recordings on charts.

Review the progress of your research work, and weigh up the advantages a Remscope can bring you. If in doubt on any point, get in touch with Dawe and ask for a demonstration.

DAWE

Full technical data from:—

DAWE INSTRUMENTS LTD., WESTERN AVENUE, ACTON, LONDON, W.3 Tel: ACOrn 6751

A member of the Simms group of companies

INDUSTRIAL ELECTRONICS

Automation Instrumentation Control

Volume 3 **Number 3** **March 1965**

Contents

continued overleaf

Published on the first Thursday after the 5th of each month by
Iliffe Electrical Publications Ltd., Dorset House, Stamford Street, London, S.E.1
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Telephone: *Waterloo* 3333. *Telegrams/Telex:* Electronics Iliffepres 25137 London

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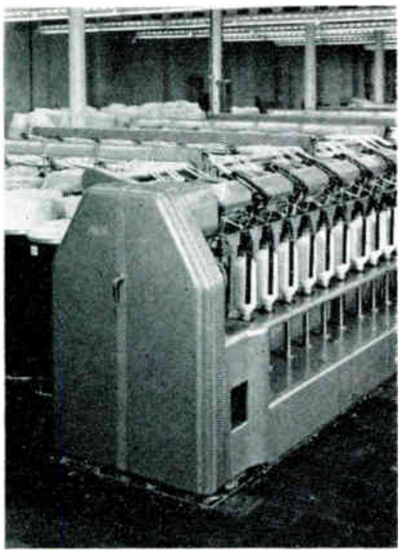
A

INDUSTRIAL ELECTRONICS

Automation Instrumentation Control

Contents *continued*



OUR COVER

This month's picture taken in a well-known Lancashire mill illustrates that electronics is being used more and more in the textile industry. Shown here is a modern Platt 'Speed Frame' which uses photoelectrics to detect breakages in the material. More about this aid is given in an article which starts on page 114.

Features

TO SAVE YOUR TIME

We will assist you to obtain further information on any products or processes described or advertised in this issue. Just use the enquiry cards included in this journal.

Next Month

The Olympics-standard swimming bath at the Crystal Palace Recreation Centre is provided with one of the world's most advanced race-timing and display systems. This system is illustrated and described by one of its designers in next month's issue. 'Electronics in Textile Machines 2: Winding Speed Control' is among the other feature articles.

For further information circle 203 on Service Card

BRITAIN'S WIDEST RANGE OF RESISTORS TO DEF 5115 SPECIFICATION ...from WELWYN

DEF 5115 CLASSIFICATION	DEF 5115 STYLE	WELWYN TYPE AND STYLE
	CARBON FILM RESISTORS	
2% Stability Fixed General Purpose Insulated	RFG-3	C80 Series
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0.1% Stability Precision	RFP-1	RB Series
	OXIDE FILM RESISTORS	
3% Stability Fixed General Purpose Insulated	RFG-2	F252 Series
1% Stability Fixed General Purpose Insulated	RFG-5	F255 Series
2% Stability High Temperature	RFH-1	F64 Series
	METAL FILM RESISTORS	
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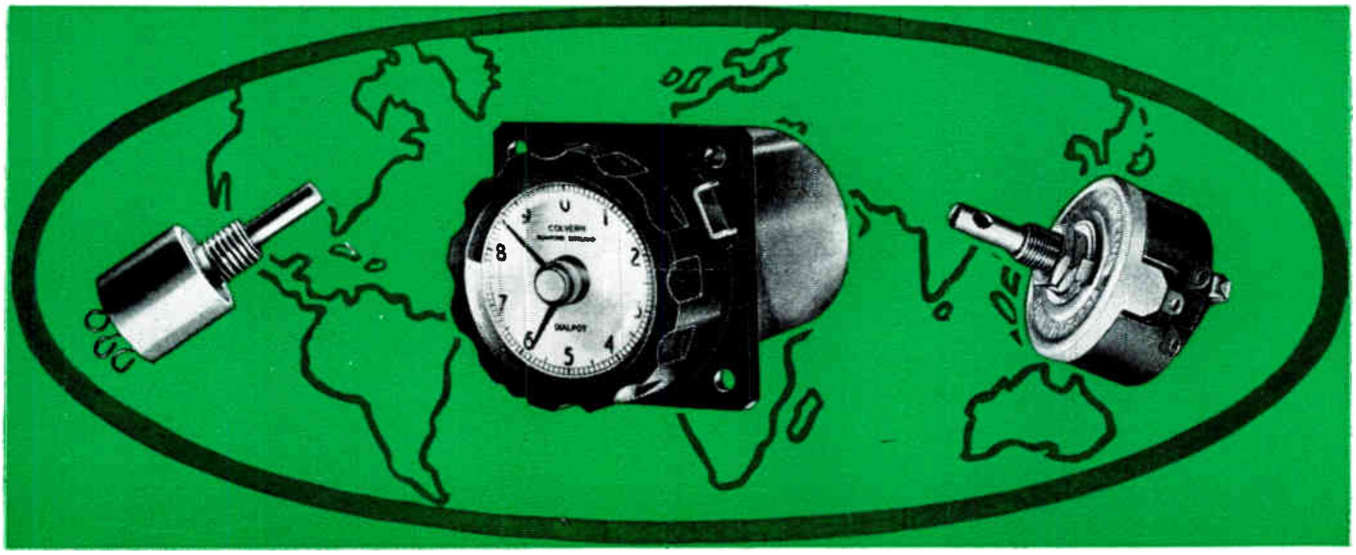

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for wire wound POTENTIOMETERS

- ★ STANDARD TYPES 1–25 WATT.
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With over 50 basic types in production this comprehensive range covers most of the requirements of a wirewound potentiometer, but if you have a special problem contact our advisory engineering service. Literature also available.

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WHY PAY MORE FOR LESS ?

THE 1026.003 MULTIMETER GIVES YOU THREE FUNCTIONS IN ONE METER

The 1026.003 Multimeter is the latest in a long and distinguished line of PACE solid state, high speed conversion instruments. It is the only meter which combines digital read-out of AC/DC voltages and Ohms resistance in one unified meter.

The 1026.003 features BCD (8, 4, 2, 1) and decimal outlets on all ranges · in-line projection indicators · floating input · continuous/single shot operation · automatic polarity and parameter indication · 20% over-range on all ranges and self-checking calibration facility.

The 1026.003 incorporates numerous quality features derived from long experience in the manufacture of high precision scientific computers. Field proven components, chopper stabilised transistorised operational amplifiers, temperature stabilised comparator diode gates and Zener reference will keep you and your 1026.003 Multimeter up-to-date for many years to come.

SIX MONTH CALIBRATION ACCURACY

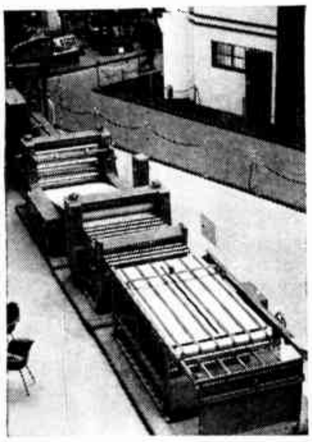
EAL

ELECTRONIC ASSOCIATES LIMITED *Burgess Hill, Sussex. Burgess Hill 5101.*

For further information circle 210 on Service Card

The International Plastics Exhibition in Europe for 1965
LONDON OLYMPIA 16-26 JUNE

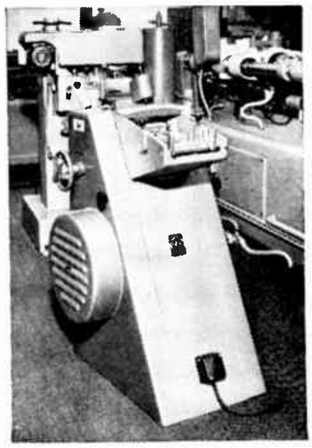
interplas
interplas



Typical of latest machinery—Prodex sheet plant incorporating a $4\frac{1}{2}$" extruder and double shell cooling rolls embodying a built-in heat exchanger.

Many of the most brilliant achievements in plastics design in the International Design Display.

Information on all aspects of plastics and plastics trade—materials, markets, suppliers, customers, potential new applications.



The latest equipment for plastics moulding, extrusion, vacuum forming, welding and printing—much of it in full operation.

an essential event for all concerned with plastics

This huge display—biggest ever held in Great Britain and unique in Europe in 1965—will present the latest achievements in plastics manufacture, design and technology. More than 500 firms from Great Britain, Germany, United States, France, Japan and other leading countries. Plant and machinery in action . . . materials . . . processing equipment . . . finished and semi-finished plastics products . . . industrial and consumer goods ranging from boats to paper clips—more than 10,000 exhibits. An incomparable opportunity to gather new ideas for product improvement, cost reduction.

SEE THE UNLIMITED POTENTIAL OF PLASTICS TODAY

MAIL THIS NOW

To: The Exhibition Manager, INTERPLAS 65, Dorset House, Stamford Street, London SE1

Please send full information and a free season ticket

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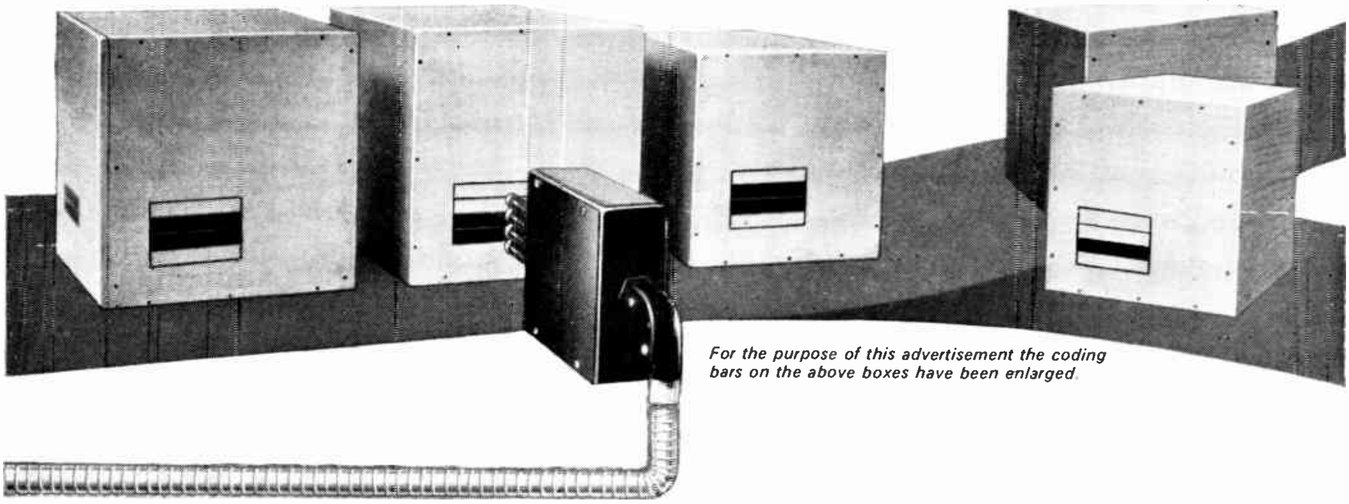

For the purpose of this advertisement the coding bars on the above boxes have been enlarged.

COUNTING AND SORTING BY CODE BARS WITH THE LC110 DECODING UNIT

The coding is in the form of three parallel bars, mounted one above the other, with the background used as a reference. The three bars give a choice of up to six different codes. In operation a code is placed on to the side of each carton to be routed and is illuminated by a spot light.

A bank of four photo-cells detects the light reflected by the codes. One photo-cell is the reference and the other three recognise the codes.

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COMPANY ....

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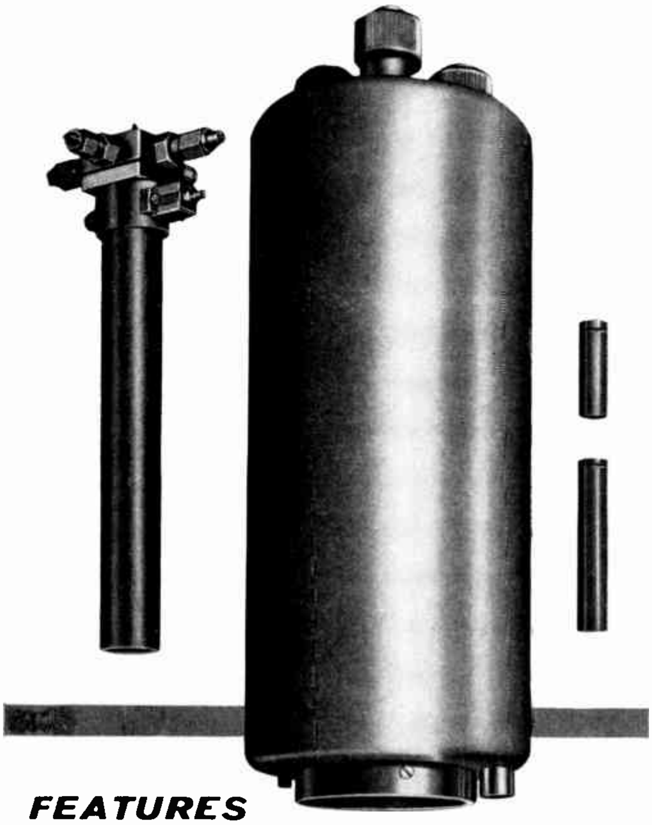
RAYTHEON

INFRA-RED DETECTORS



FEATURES

PHOTOCONDUCTIVE—Germanium detector activated by gold, mercury, cadmium or copper.

LOW TEMPERATURE–operating temperatures in range up to 78 Kelvin.

SPECTRAL RANGE—covers from visible to microwave frequencies.

HIGH SENSITIVITY · RUGGED

SHORT TIME CONSTANTS

APPLICATION AREAS

High temperature shock wave measurements

* Non-destructive testing * Chemical analysis
* Near-space investigations
* Terrain mapping * Process-stream analysis

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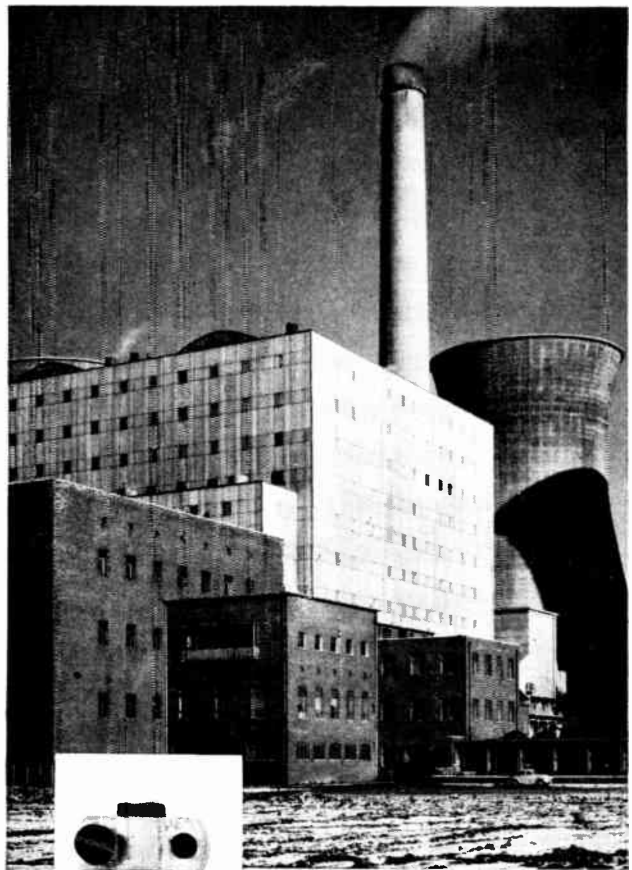

PRESSURE DATA?

Are you aware that the unique qualities of Consolidated Electrodynamics type 4-326 pressure transducer make it ideally suited to the requirements of modern power station data logging systems? These qualities include excellent long-term stability, ability to function in adverse environments, linear thermal co-efficients, rugged design and fast, easy installation facilities. Furthermore, it is now available with sealed electrical connectors and cable assemblies.

Write for Bulletin No. 4326L3

Consolidated Electrodynamics

a division of **BELL & HOWELL LTD.**

14 Commercial Rd., Woking, Surrey. Tel: Woking 5633

CATHODE RAY TUBE TYPE MX51

The MX51 is a 5 inch, high sensitivity, high brightness oscilloscope tube, using post deflection acceleration, for applications where fast response time is essential.

Characteristics

Phosphor Green sulphide, short persistence (equivalent to P.31)
Useful screen area 100 mm X by 60 mm Y
Electrical
(All voltages are referred to cathode)
Heater voltage V 6·3 Typical
Heater current A 0·55 Typical
A_1 voltage kV 1·5 Typical
PDA voltage kV 12·0 Typical
POA ratio to A_3 10:1 Max.
Deflection sensitivity
X plates 10·5 V/cm
Y plates 3·1 V/cm

PHOTOMULTIPLIERS TYPE 9558B AND 9558Q

The 9558 photomultiplier has an end window trialkali cathode giving high response at wavelengths up to 0.8 microns. The high quantum efficiency at wavelengths between 0.6 and 0.8 microns, compared with other types of cathode, makes the tube of great interest to spectroscopists and astronomers and workers in the laser field. The dark current from the trialkali cathode is very low and is around 500 electrons per second per cm^2 (at room temperature).

Characteristics

Dimensions Cathode diameter 44 mm min.
Seated height 140 ± 3 mm.
Bulb diameter 51·5 mm max.
Photocathode Trialkali—Caesium Sodium Potassium Antimony.
Window 9558B—Pyrex (0·3—0·85μ)
9558Q—Fused Silica (0·16—0·85μ).
Dynodes 11 Venetian Blind, SbCs coated.
Photosensitivity 140 μA/lm typical
100 μA/lm minimum.
Voltage for 200 A/lm* 2000V typical.
Dark current at 200 A/lm† 10^{-8} A max.
2×10^{-9} A typical.

**Measured with 2870°K Tungsten lamp; 150V C-D1, uniform dynode chain thereafter. 200 A/lm corresponds to a gain of circa $1{\cdot}5 \times 10^6$ in a median tube.*
†At 20°C, measured after one hour operation in dark.

ULTRA-VIOLET VIDICON TUBE TYPE 9677 UV

This new ultra-violet sensitive television camera tube can be used to observe cracks and other defects in the surfaces of red hot ingots. It has equally significant applications in medical diagnosis and biological research.

EMI Vidicon Type 9677 UV has a specially developed target layer to give high sensitivity in the ultra-violet region of the spectrum to at least 2500 AU. The high ultra-violet sensitivity of the tube allows a television camera to be fitted directly to a UV microscope, so providing a continuously visible image of the material being studied. High sensitivity also enables the UV radiation to be reduced to a sufficiently low level for living cells to be studied.

Type 9677 employs the latest EMI electrode structure which increases the ease of operation by allowing it to be overbeamed without loss of resolution, so enabling it to cope with a wide range of light levels.

O-BAND KLYSTRON TYPE R9653

This Reflex Oscillator is a recent addition to the range of EMI millimetre tubes. Applications include electron spin resonance, materials research, and microwave testing and development work, including scaled aerial experiments.

The tube has a mechanical tuning range of about 4 Gc/s in the 4 mm band and variants are being developed to cover the frequency range 65 Gc/s to 85 Gc/s.

A resonator voltage of between 2.0 kV and 2.5 kV at 25 mA produces a power output in excess of 10 mW and electronic tuning is of the order of 100 M/cs between the half-power points. Output is taken from waveguide size WG 26 (RG 99/U) and the standard flange is the American type UG 378/U, although other types can be fitted by special request.

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HAYES · MIDDLESEX · ENGLAND

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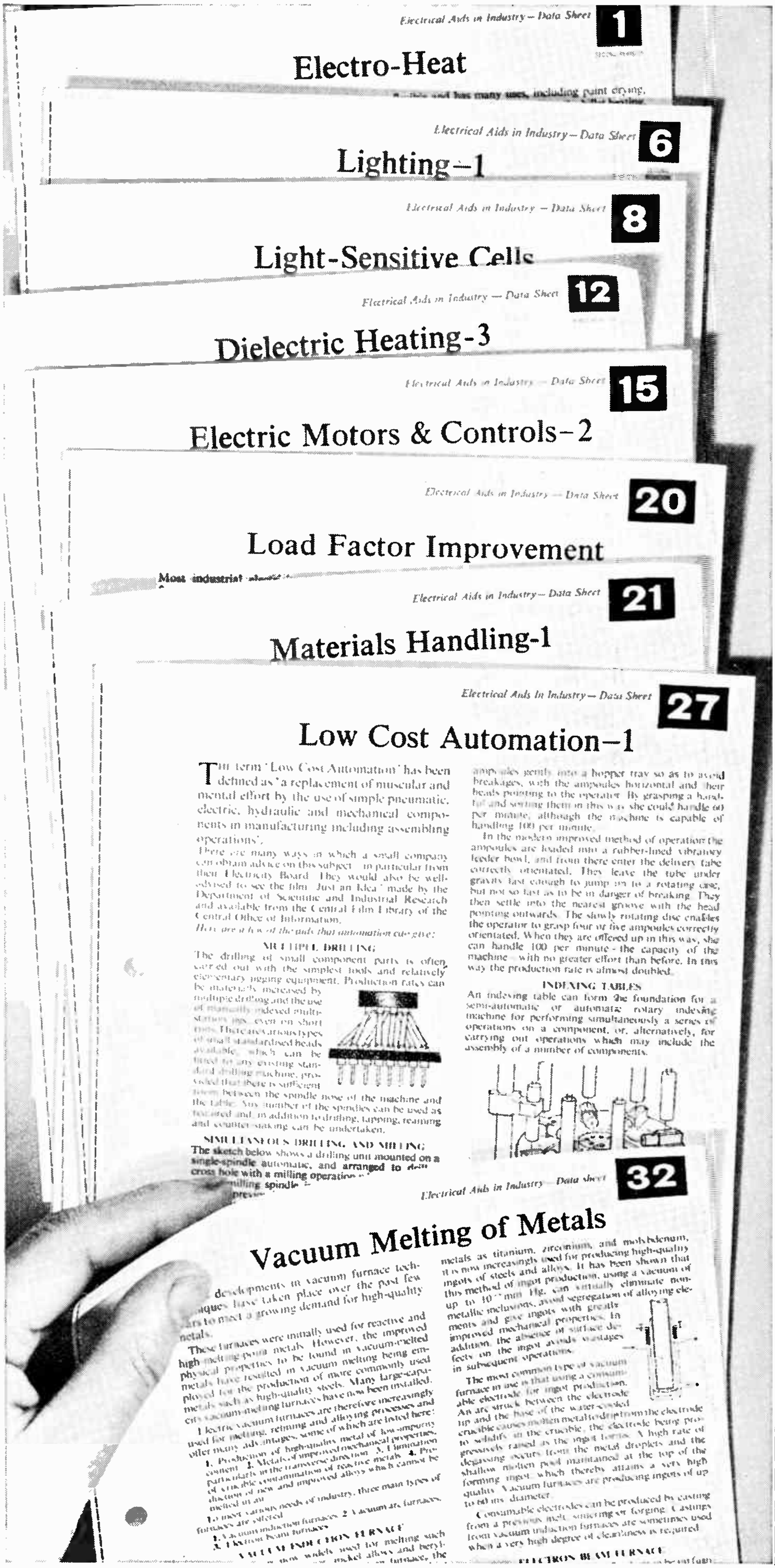
EMI

EMI ELECTRONICS LTD
VALVE DIVISION, HAYES, MIDDLESEX
TELEPHONE: HAYES 3888 · EXT. 2165



FREE! Data sheets

The quickest and most reliable way to keep informed on new electrical ideas for industry. Single copies are free from your Electricity Board. Or direct from the Electrical Development Association. (Complete set in folder, 3/6.) Tick subjects that interest you, and post coupon to EDA, Trafalgar Buildings, 1 Charing Cross, London, S.W.1.

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Please add my name to the mailing list for future Data Sheets (U.K. only).

Covers the very wide Frequency Range 0·2c/s to 1·22Mc/s

TRANSISTOR DECADE OSCILLATOR TYPE TG 66A

Frequency is selected by means of four in-line additive decade controls and a five position multiplier switch. The last of the additive controls is continuously variable so that any frequency may be selected with a discrimination better than ±0·03% or $\frac{1}{10}$th of the specified frequency accuracy, whichever is the greater. The output source voltage of the oscillator is monitored by a meter with an expanded scale, and a continuous control is fitted so that the output may be set with a discrimination better than ±0·05dB.

SPECIFICATION

ACCURACY

±0·02c/s below 6c/s.
±0·3% from 6c/s to 100kc/s.
±1% from 100kc/s to 300kc/s.
±3% above 300kc/s,
all measured at 25°C.

STABILITY

±6% mains voltage change produces less than ±0·005% frequency change up to 100kc/s. Change of frequency with temperature is less than ±0·025% per °C above 100c/s.

DISTORTION

Less than 0·15% from 15c/s to 15kc/s
Less than 0·5% at 1·5c/s and 150kc/s

OUTPUT

Continuously variable from −94dBm. to +10dBm. into 600 ohms. Source voltage variable from 30μV to 5V. Output impedance 600 ohms at all settings. Meter fitted with dBm and V scales.

TEMPERATURE RANGE

−10°C to +45°C.

POWER SUPPLY

"Mains"—100/125V. 200/250V; 50/60c/s; 6VA.
"Batteries"—4 Self-contained type PP9, life 300 hours.

SIZE

6½" high × 10¼" wide × 7" deep.

WEIGHT

12 pounds.

LEVELL
PORTABLE INSTRUMENTS

Price complete with batteries

£150

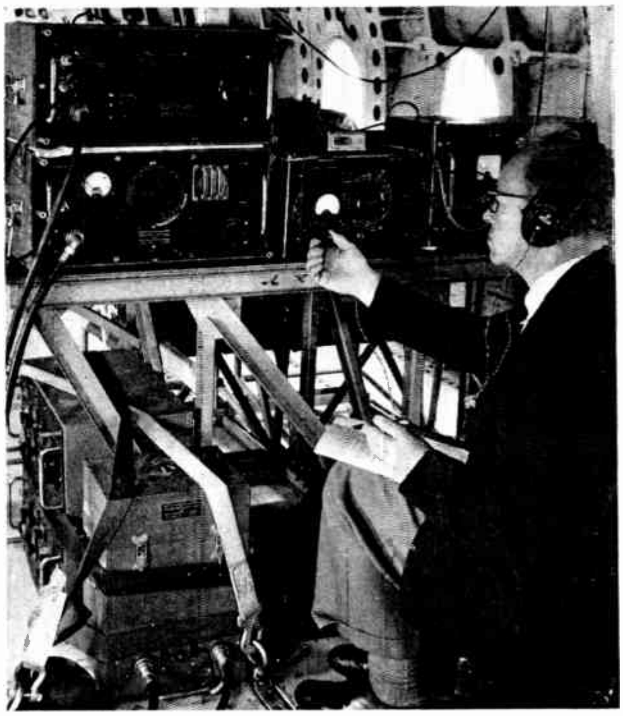
Leather case £5 extra.

Fully detailed leaflets available on our complete range of portable instruments.

LEVELL ELECTRONICS LTD.

Park Road, High Barnet, Herts.
Telephone: BARnet 5028.

For further information circle 219 on Service Card



Interference suppression service expanded

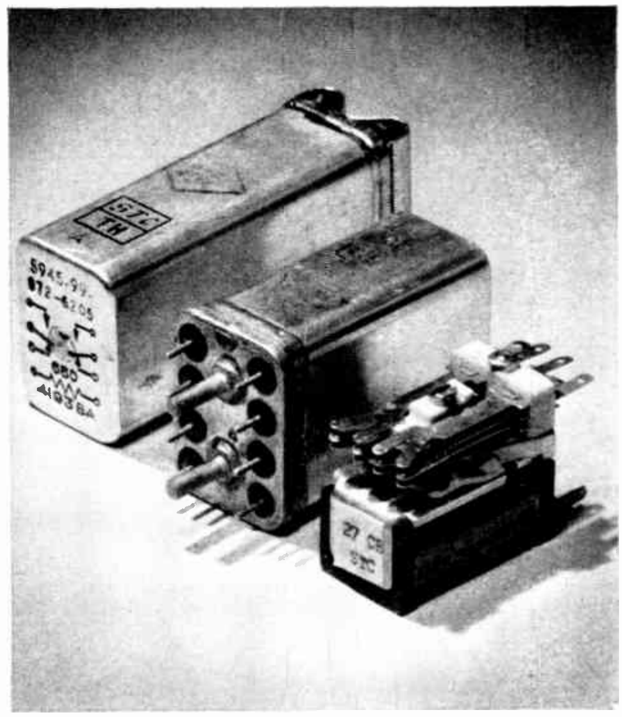
STC has expanded its radio interference suppression service to provide new and greater facilities for its established aircraft and marine business and, additionally, to offer increased help to manufacturers and users in general industry.

STC experience in radio interference suppression includes surveys and recommendations for virtually every British military and civil aircraft built within the last twenty years, work for the Admiralty and the Merchant Marine, and other Service applications such as fighting vehicle radio and electrical equipment. The Department is a Ministry Approved establishment and is equipped and staffed to offer a comprehensive survey and supply service to all relevant NATO and MIL specifications.

STC manufactures separate ranges of interference suppression capacitors for aircraft, marine and general industry. In this way, the equipment manufacturer and the user can obtain interference suppressors in the right cost range for the particular application.

For details of the STC Interference Suppression Service and the ranges of interference suppressors, write, 'phone or Telex STC Capacitor Division, Brixham Road, Paignton, Devon or London Sales Office, Footscray, Sidcup, Kent. Telephone FOOtscray 3333. Telex 21836.

For further information circle 220 on Service Card



Midget relays

STC midget relays, developed originally for use in civil and military aircraft, are now available at competitive cost for general industrial use. They have a great space-saving advantage over equivalent types as well as their DEF specification reliability factor. When hermetic sealing is unnecessary, uncanned versions can be supplied.

These relays are made in light, medium and heavy duty types. The light duty version is a 2-changeover relay with contacts handling up to 2A. The medium duty device is also a 2-changeover switch rated for 0·5-3A. The heavy duty midget relay has a one make contact that will switch 10A.

Type 27 Relay

This is a particularly economic midget relay specially designed as a low-cost industrial version of the original range. It is a plug-in relay, has a plastic cover and will switch up to 2A with a 2-changeover action.

For Data Sheets and prices, write, 'phone or Telex STC Electro-Mechanical Division, West Road, Harlow, Essex. Telephone Harlow 21341. Telex 81184.

New 100 kW ceramic r.f. power triode

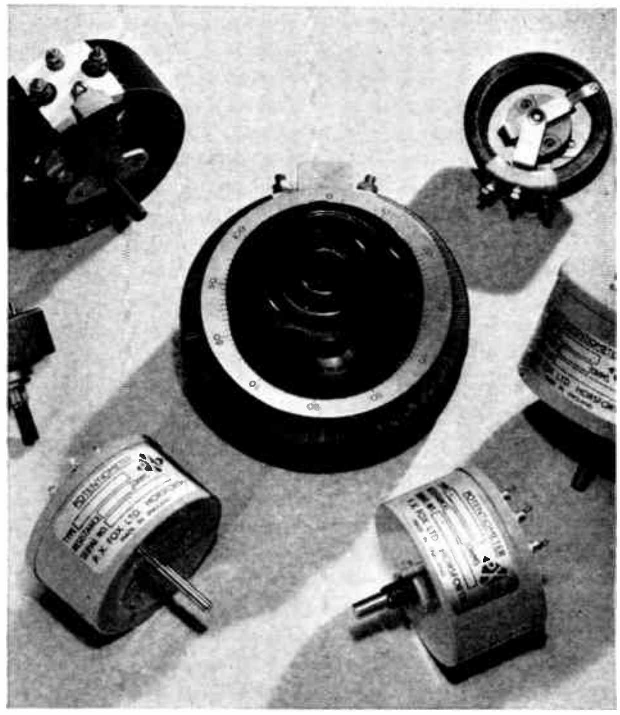
The STC 3QC/294J high efficiency water-cooled power triode has been designed for use in radio transmitter service and in industrial heating applications. Special features, such as a ceramic-metal envelope and coaxial connectors, ensure robustness, low electrical loss and ability to operate at frequencies up to at least 30 Mc/s at full ratings for the usual applications required.

The 3QC/294J fits the same water jacket (type 235-LRU-12A) as the type 3Q/294E and may be used as a unilateral replacement for that valve. The illustration shows the 3QC/294J fitted with corona rings which are supplied as extra items.

Characteristics and Ratings

μ	20		Class C Operation (Unmodulated)
g_m	60	mA/V	
V_a(d.c.)	13·5	kV	
P_a	40	kW	
Output	104	kW	
f_{max}	30	Mc/s	

Write, 'phone or Telex for Data Sheets to STC Valve Division, Brixham Road, Paignton, Devon or London Sales Office, Footscray, Sidcup, Kent. Telephone FOOtscray 3333. Telex 21836.



Potentiometers

The complete product ranges of potentiometers made by P. X. Fox Limited and General Controls are now marketed by STC Potentiometer Division. The two potentiometer manufacturers are now part of the STC organization. Between them, the two firms manufacture the biggest range of precision potentiometers used in the UK, as well as manufacturing for an extensive export market.

Shown above are examples from two typical ranges manufactured in large quantities. The canned components are low-cost, heavy duty potentiometers with precision outputs. They represent a trouble-free design with years of built-in operating experience. Principal data for the three types are:

TYPE	RATING	TORQUE	LINEARITY
B	5W	36g/cm	0·1%
C	5W	144g/cm	0·35%
E	10W	108g/cm	0·25%

The un-enclosed potentiometers shown are toroidal, heavy duty, ceramic types. The simplicity of the design and the precision winding provides maximum mechanical strength and reliability in all operating conditions. A range of eight standard ratings is stocked from 10W to 1000W. The 10, 25, 50 and 100W types can be supplied enclosed in ventilated containers for bench mounting.

Write, 'phone or Telex for Potentiometer Catalogue or specific Data Sheets to STC Potentiometer Division, West Road, Harlow, Essex. Telephone Harlow 21341. Telex 81184.

high-grade components by **STC** COMPONENTS GROUP

For further information circle 223 on Service Card

for a high quality self-fluxing enamelled wire *Lewcosol* is the unanimous choice

Manufactured under strictly controlled conditions on newly developed plant, these wires will find immediate application where size, solderability, and a consistently high quality are essential requirements.

Write for pamphlet LB19

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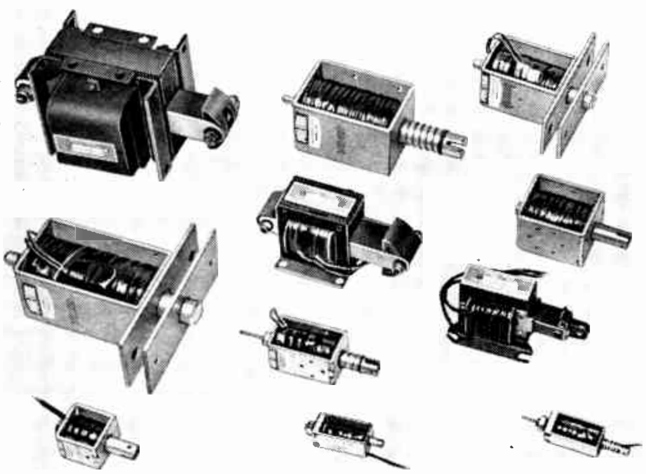

Phil-trol

For the Widest Range of Solenoids

Phil-trol Solenoids range from the small type 45, suitable for ⅝″ spacing (i.e. for typewriters), to the AC type 83, 47 lbs over 1¾″ on impulse duty and also up to 650 lbs-ins for the DC type 96, with a complete range of AC and DC types between, push type, pull type, spring return and DC fitted with fully damped silicon rectifier circuits for AC supplies.

● *For particulars ask for pamphlet 108a.*

PHILLIPS CONTROL (G.B.) LTD

DEPT. K7 · FARNBOROUGH ROAD · FARNBOROUGH · HANTS.

Telephone: Farnborough 1120 *Grams and Cables: Philtrol, Farnborough, Hants.*

For further information circle 225 on Service Card

GORING KERR PHOTO-ELECTRICS IGNORE SUNLIGHT

A NEW CONCEPT

- Compact Head Units
- Virtually Indefinite Life
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- Ignores All Extraneous Light
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- Rugged Cast Aluminium Enclosure
- Withstands High Degree of Lens Coating

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Model GKP Photo-Electric Unit is Completely Independent Of Direct or Reflected Light From the Sun or From Any Other Source, Including Incandescent or Fluorescent Lamps. False Operation From Any External Cause is Completely Impossible

GORING KERR LTD.

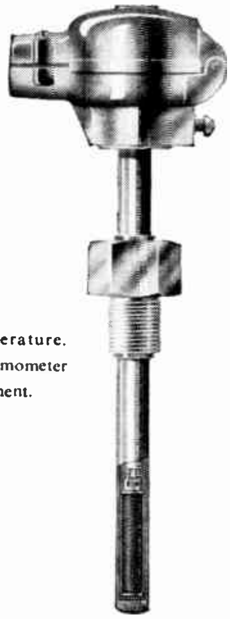
HANOVER WAY, WINDSOR, BERKS.

TELEPHONE: 63211

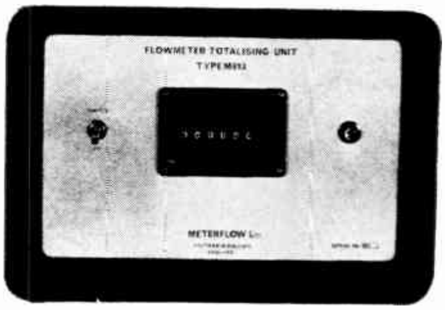
Another new addition to the FOSTER RANGE

B.Th.U. INTEGRATOR

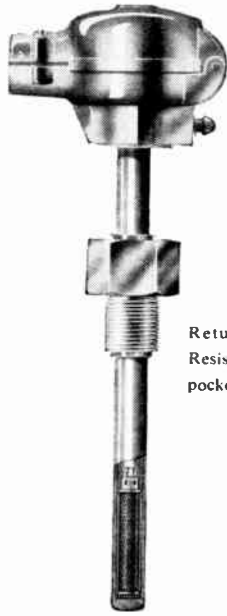
Patent Applied for



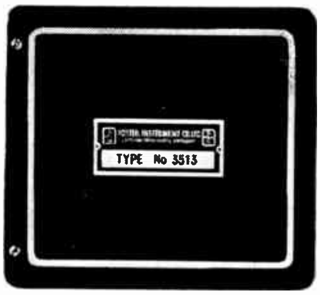
Outlet temperature. Resistance thermometer pocket and element.



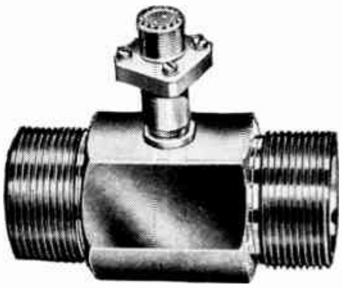
Totalising Unit Type M813 by courtesy of Meter Flow Ltd., Feltham, Middlesex.



Return temperature. Resistance thermometer pocket and element.



Type 3513 Differential Temperature and Flow-Rate Integrating Unit.



Flow-Meter (photograph by courtesy of Meter Flow Ltd., Feltham, Middlesex).

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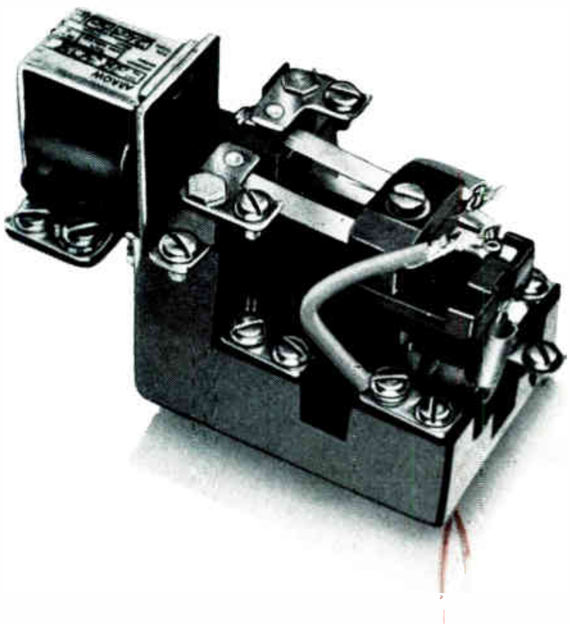

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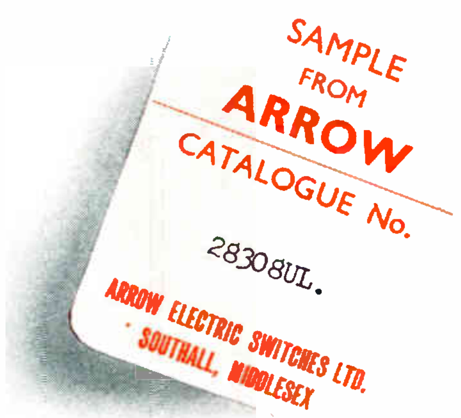

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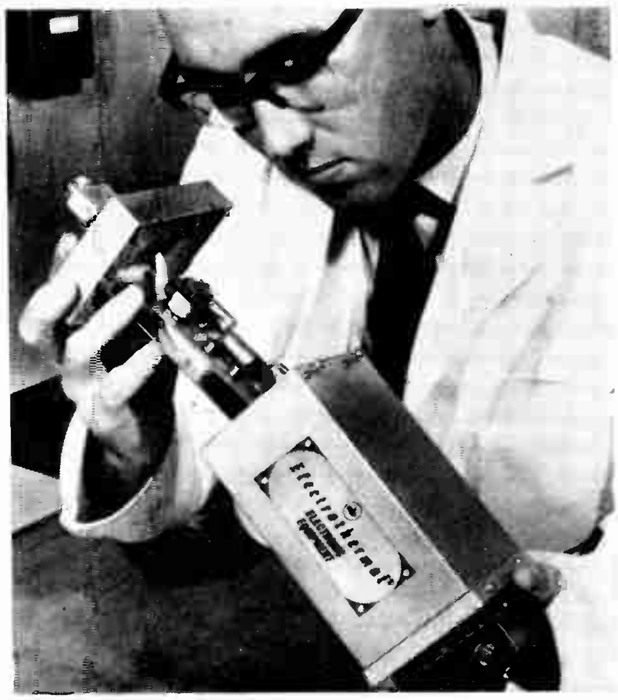

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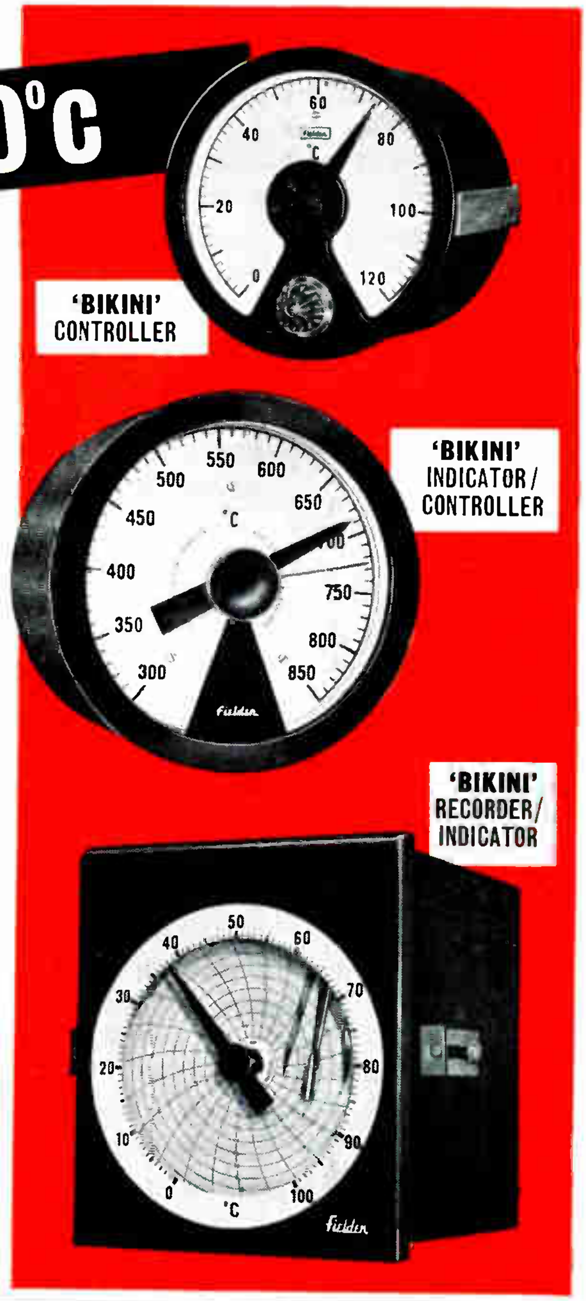

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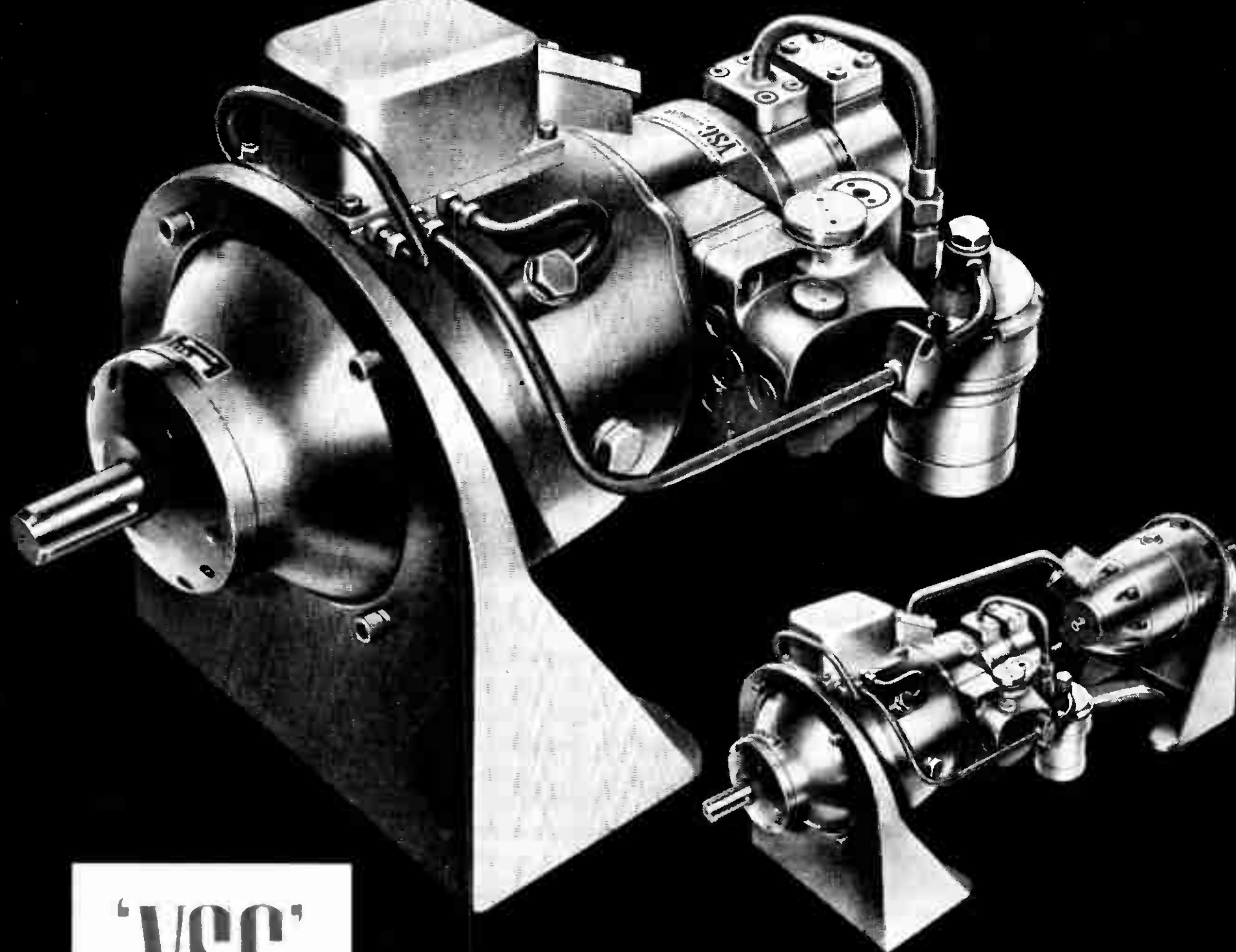

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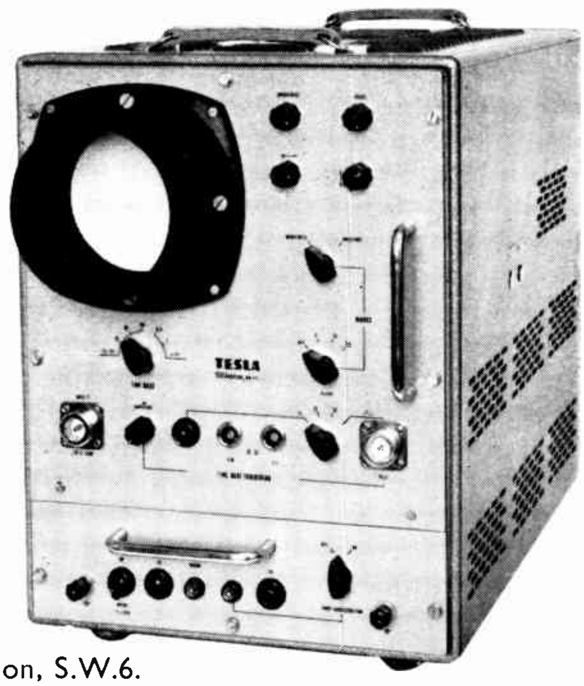

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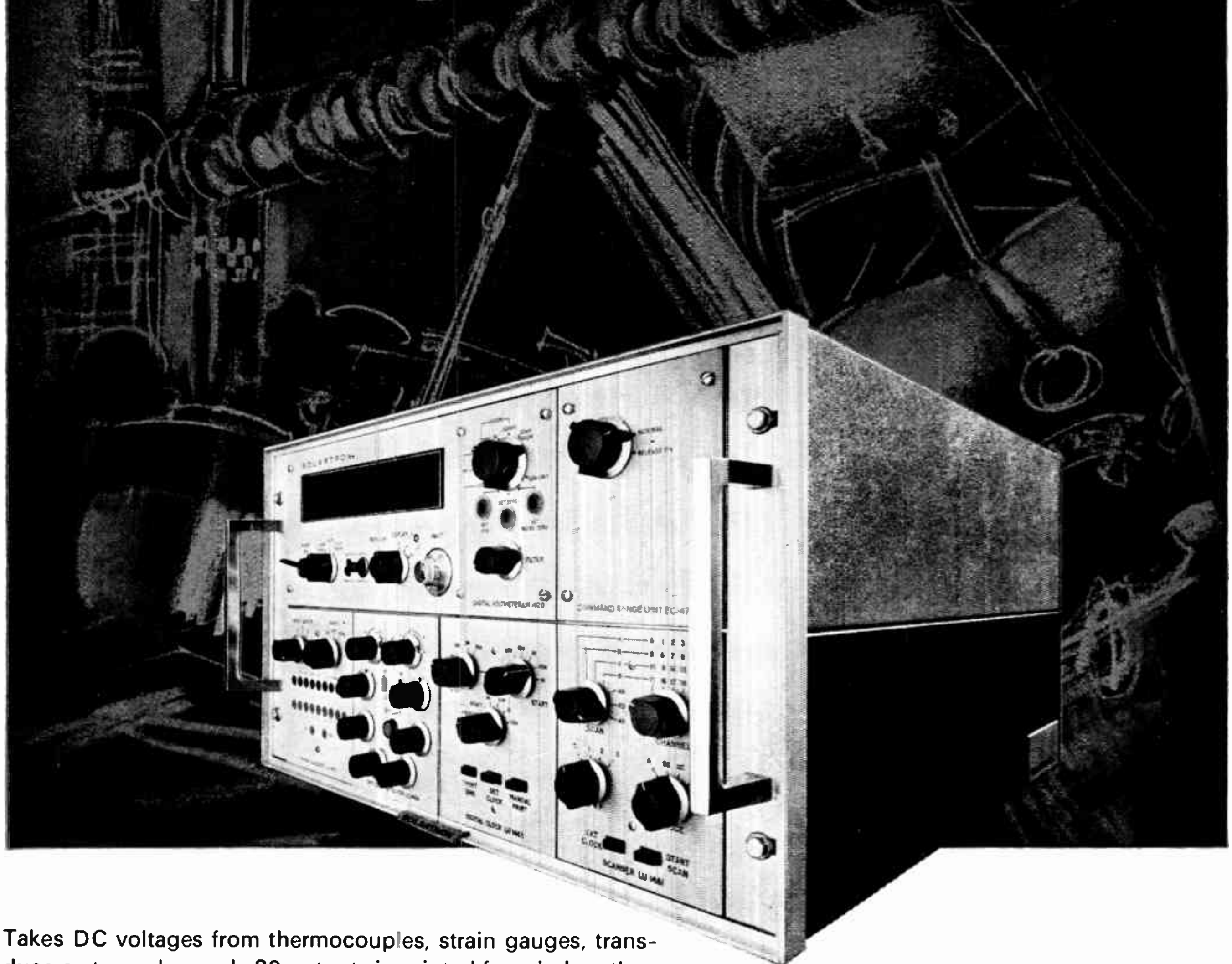

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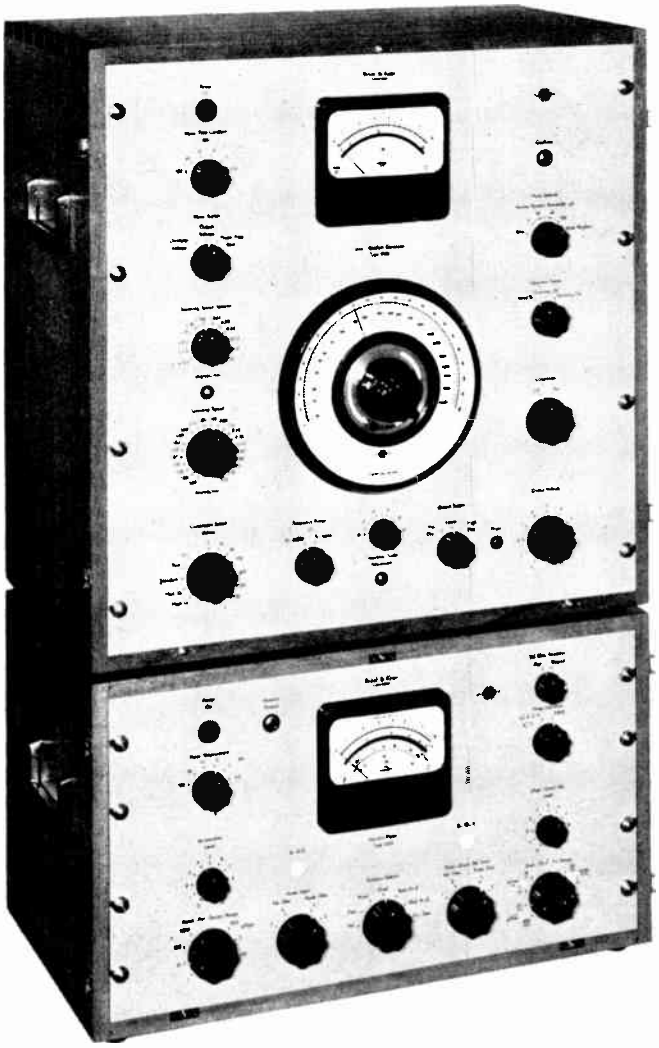

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INDUSTRIAL ELECTRONICS

NERC

We commented in the September 1964 issue on the formation of NERC (National Electronics Research Council). As we said then it is not a research association but has been formed to ensure that the best use is made of the existing research effort and facilities. We now learn that NERC is producing a quarterly review of progress in electronics research. It is called *NERC Review* and we have just received Vol. 1, No. 1, dated January 1965.

We said in September that NERC was setting up a working party to investigate the retrieval of information. This working party has now reached the conclusion that the most pressing need is for 'current-awareness information'. By this is meant that each research worker should be notified of those items which he would pick out if he personally scanned all journals and lists. The working party has recommended that NERC should investigate the usefulness of a system which does this and a request for financial assistance was made to DSIR last October.

The system is called 'Selective Dissemination of Information' (SDI) and has been in operation in the U.S.A. for some time. Basically, all documents are scanned and indexed in a central bureau and the index is placed in a machine file. Users indicate their interests using the same vocabulary and their lists are placed in a second machine file. The two lists are matched in a computer which produces for each user an individual list of references to the literature. Feedback from the user is included, since if he finds that the references which he receives are not what he wants, his list is modified appropriately.

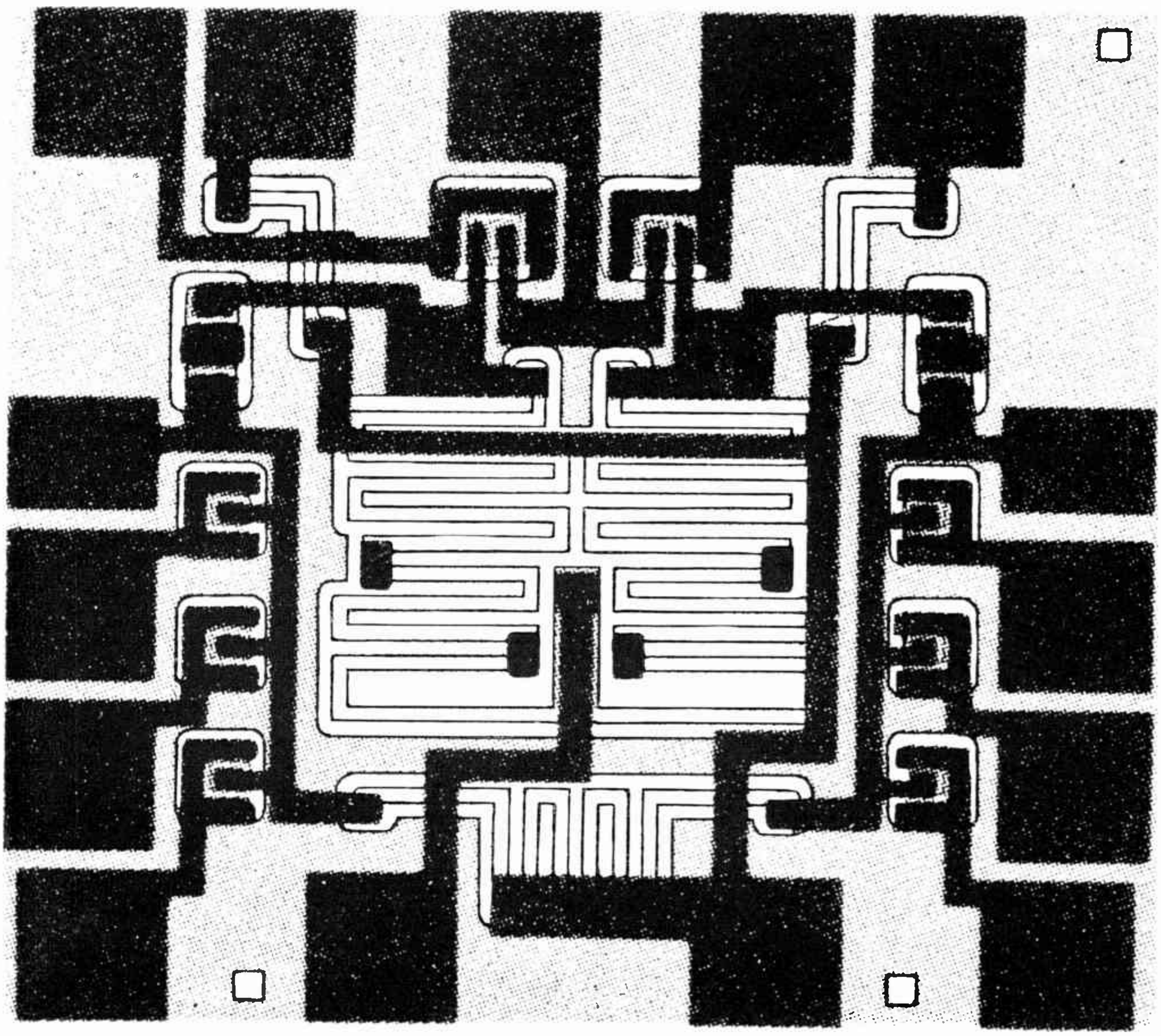
It is a scheme of this nature which NERC is proposing to try out over a period of three years. It is envisaged that the first year will be mainly occupied by setting up the system and getting it into working order. There will then be six months' experimental use of the system after which it will go operational for a year. The final six months will be used for assessing the performance and preparing a report. NERC requires some 800 volunteers from those engaged in pure and applied electronics research to take part in the scheme. Those interested should write to the Technical Officer, NERC, 8–9 Bedford Square, London, W.C.1, which is also the address of *NERC Review*, containing much fuller details of the scheme than we have been able to give here.

The volunteers will be drawn from industry, universities and technical colleges, and government establishments and will form a user group who will be required to co-operate for about two years. This co-operation is likely to be most active and require most work from the group during the six-month experimental period.

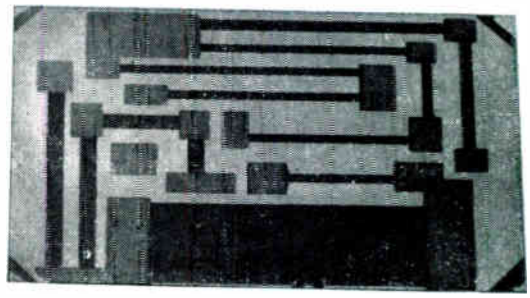
This scheme is undoubtedly an interesting one and it is hoped that it will prove successful, for information retrieval is unquestionably one of today's major problems.

modern trends in microelectronics

By S. S. FORTE, Ph.D., M. W. RIGNALL and
D. G. STEWART*



Thin-film circuit for a focus-current regulator



The various forms which microelectronics can take are discussed in this article and the two most important processes are described in some detail.

MICROELECTRONIC technology has now been with us for a sufficiently long time, and its potential benefits are sufficiently appreciated to enable an appraisal to be made of the state of the art as it exists today as well as some thoughts on likely future trends.

In order to avoid confusion regarding the varied microelectronic terminology which has found current favour, some definitions have been included, these being the interpretation of the nomenclature as used throughout this paper.

Thin-Film Circuit. This is a circuit in which all the passive components and conductors are formed on inert substrates by evaporating, sputtering, plating or other similar processes, and in which the active devices must be added as discrete components.

Semiconductor Integrated Circuit. This is a circuit in which all the passive and active elements required to perform a specified electronic function are formed in or on a semiconductor substrate by diffusion and/or epitaxial growth processes.

Multiple-Chip Circuit. This is a variant of the semiconductor integrated circuit which instead of being realized in monolithic form is formed in or on several semiconductor substrates or chips which are subsequently interconnected within a single component package.

Hybrid Circuit. This is a circuit in which thin film passive devices have been added to semiconductor integrated circuits as overlays.

Thin-Film Circuit Techniques

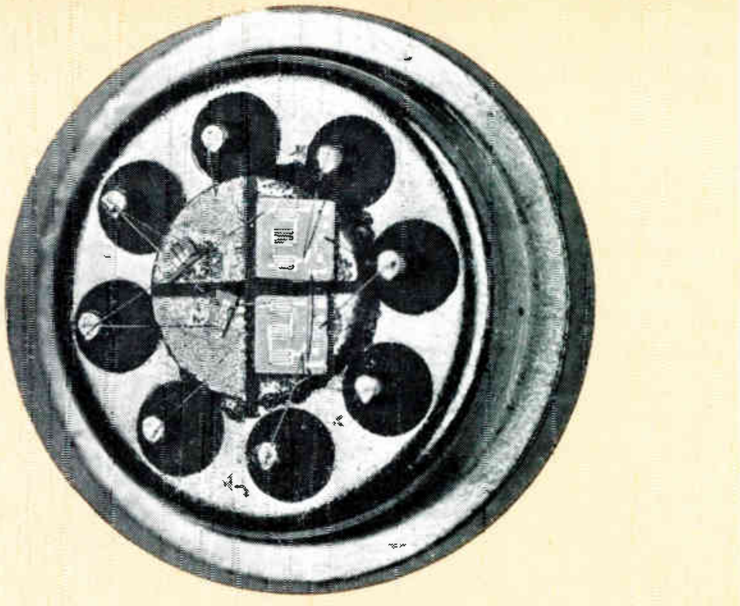
The technique of depositing films by high-vacuum methods, as used commercially for some twenty years in such fields for the production of low-reflectivity coatings on optical components, has in recent years been successfully applied to electronics. In this class of microelectronic circuit, all passive components and conductors are in the form of very thin films deposited on an inert substrate.

There are two very similar processes currently being used for the production of thin-film circuits.

The first process entails the use of a metal mask. This is in the form of a thin sheet upon which the desired pattern has been formed by photoetching, electroforming, electron-beam cutting or other appropriate techniques. This mask is inserted between the vapour source and the substrate surface on to which the deposition is to take place. This is done inside a vacuum chamber after a very thorough cleaning of the substrate has been effected. When the required vacuum has been achieved, the source material to be deposited is heated by one of several techniques to its boiling point. The boiled-off material will be deposited on all surfaces which are visible to the source and unobstructed by the mask so that films are deposited in a pattern dictated by the apertures in the mask. Successive layers can be deposited by shifting the substrate from one mask to another, preferably without removal from the vacuum chamber between operations.

The second technique or 'in-contact masking' technique is somewhat different. The substrate is placed in the vacuum chamber and a layer of resistor material followed by a layer of conductor material are deposited on the entire substrate surface. The surface is then coated with a suitable photosensitive resist. A photographic image of the pattern to be produced is projected on to the surface resulting after processing in a photoresist mask. Selective etching of the conductor material followed by selective etching of the resistor material results in the desired geometry. The main disadvantage of this technique is the large amount of handling which the substrate must be subjected to in the course of the various processes. The first technique with the entire operation carried out under the one vacuum pump-down would seem preferable on most counts.

* The Marconi Company Ltd., Chelmsford, Essex, England.



(Right) Example of a multiple-chip semiconductor-integrated circuit, a double high-speed NOR element. The four chips are mounted on a metallized ceramic of 0·135-in. diameter, the larger chip containing two resistors and a non-linear element consisting effectively of three diodes in series, while the smaller chip contains the fast transistors and the catch diode

(Far right) Example of a monolithic semiconductor-integrated circuit. This chip 0·050 × 0·050 in. comprises four transistors and eight resistors and was designed as a multipurpose linear building block

In either of the two techniques a number of substrates are processed simultaneously in order to obtain production runs at reasonable costs.

Once the substrate has been completed with the resistors, capacitors and interconnections, external active devices must be added to produce a functional electronic circuit.

The Semiconductor Technology

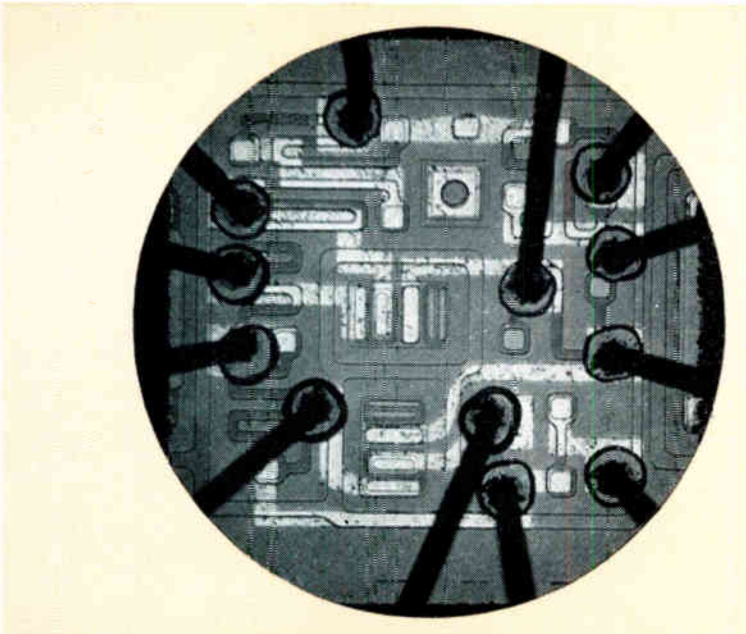
The planar process, now in universal use for the fabrication of transistors, has made possible the fabrication of entire circuits in semiconductors. This utilizes the technique of oxide masking to confine the diffusion of selected doping materials to parts of the surface from which the oxide has been removed. Another process which has proved indispensable in the fabrication of integrated circuits is that of epitaxial growth.

A layer of high-resistivity material is epitaxially grown on a low-resistivity substrate wafer. This layer becomes a single crystal extension of the substrate and forms a p-n junction at the interface. Epitaxy is normally used in transistor technology to provide low-resistance collectors. In the context of integrated circuits, the use of epitaxy obviates the need for deep diffusion to provide isolation within the monolithic circuit. Sub-epitaxial diffusion can be additionally used to provide truly epitaxial transistors with the advantages that these bring. Since isolation diffusion does not have to be carried out through the entire substrate but only through the thin epitaxial layer (of the order of 20μ thick), the substrate wafer may be made sufficiently thick to provide mechanical rigidity without affecting the electrical properties.

Several wafers, with epitaxial layers, are then placed in a furnace containing an oxidizing atmosphere resulting in the formation of a stable surface layer of silicon dioxide, a hard glass-like material which affords the passivation and protection of the substrate throughout the subsequent handling.

The masking technique which is used for all the subsequent diffusion and metallization steps will now be briefly described. The oxidized wafers are coated with a photoresist, which is a material sensitive to ultraviolet light. A high resolution mask is then aligned on to the wafer and the substrate is exposed to ultraviolet light. The exposed portions of the photoresist (not covered by the mask pattern) are soluble and are washed off. The remaining photoresist hardens to provide an etch-resistant film. An acid etch is used to dissolve the unprotected oxide coating thus engraving 'windows' through this coating according to the pattern dictated by the mask. Different mask patterns are required for the different diffusion steps, each one requiring the opening of a new set of windows, and the major problem becomes one of registration accuracy. The more common process utilized in the industry is the 'step-and-repeat' process during which the master mask is photographically reduced to as little as 1/400 of its original dimensions (thereby ensuring good dimensional accuracy) and is then repetitively reproduced on to a photographic plate. A set of these masks is then used to fabricate simultaneously up to several hundred integrated circuits. Error in registration can obviously be introduced by this method since random errors can occur in the various step and repeat processes. New masking techniques which are coming into usage will be briefly described in a later section.

The first diffusion cycle in the fabrication of an integrated circuit is used to provide isolation of the circuit components from each other. The normal process utilizes a p-type substrate with an epitaxially grown n-type layer which is then coated with a layer of silicon dioxide. The isolation is achieved by creating islands of n-type material isolated by p-type material. The wafers, with the isolation pattern etched in the oxide coating, are placed in a special high-temperature furnace. A carrier gas containing the evaporated diffusant (in this case boron) flows over the surface of the wafers and the dopant diffuses into the silicon surface at those areas exposed by the photoengraving process. By controlling diffusion time, dopant concentration and furnace temperature, the depth of penetration of the impurity can be closely controlled. The areas where the original silicon dioxide was etched away are then recoated with another layer formed by surface oxidation, or in other words, the 'windows' are now closed. In these isolated islands can be fabricated the various components which will constitute the completed circuit. This isolated n-type region, resulting from the first diffusion cycle, will



constitute the collector of the transistors used in the integrated circuit.

A second process of photoengraving followed by diffusion is used to produce the p-type area to be used as the transistor base or alternatively as a resistor. The current path in the case of a resistor is limited by the p-n junction, and when the voltage on the p-type layer is less positive than that on the n-type layer the current flows only in the p-layer. The value of the resistance is determined by the geometry, the thickness and the doping of the diffusion layer.

A third diffusion cycle is used to produce the n-type region for the transistor emitter.

The diffusion cycles are similar in every case except that different mask patterns are used, and different dopants are utilized to produce the correct type of impurity in the selected areas.

Capacitors can also be produced in integrated circuits, although because they are rather wasteful of wafer area they tend to be designed out. Two methods can be used to produce capacitors. The first method utilizes the capacitance of a reverse-biased p-n junction as produced in the diffusion processes described above. This has the disadvantage of being voltage-variable. The alternative method utilizes the silicon dioxide layer as the dielectric and the bulk silicon itself as one of the capacitor electrodes. The second electrode is formed by the vapour deposition of a suitable metal over the oxide layer, again using a photolithographic mask to define the capacitor geometry.

Having produced the various circuit elements in the silicon wafer, the next problem is to connect these in the desired circuit configuration. Once again photoengraving is used to open up windows through which contact can be made with the appropriate joints on the various circuit elements, and a mask is used through which the wafer is subjected to a metallization process which produces the ohmic contacts on to the various components as well as the interconnection pattern between components and the circuit terminal contact pads.

At this stage, each wafer contains a large number of integrated circuits. It is then diced up into the individual circuits which are individually mounted into a suitable package. Connections are made to the package by fine wires (usually gold) which are thermo-compression bonded on to the circuit contact pads and on to the package pins.

A final wash followed by a high-temperature vacuum bake-out prior to hermetic sealing in an inert atmosphere completes the fabrication process.

Although this brief outline described the fabrication of a totally integrated circuit, it is obvious that the same steps apply to the fabrication of wafers carrying only one type of device, transistor, resistor, capacitor. It is also obvious that, by subsequent dicing and sorting, these various chips can be mounted into a package and subsequently interconnected by the same thermo-compression bonding technique to provide a multiple-chip integrated circuit.

Trends in Technology

Both techniques suffer from severe limitations and it is with a view to eliminating as many of these as possible that new developments are being brought about.

Thin-film circuits can be made to reasonable manufacturing tolerances and they are usually produced in such a way that some form of trimming can be employed to reduce these tolerances even further. The temperature stability of thin-film passive components is considerably better than that of their semiconductor equivalents, and since they do not suffer from the parasitics associated with the semiconductor circuits, thin-film circuits are inherently capable of appreciably higher operating frequencies. Thin-film circuits, therefore, would have considerable potential were it not for the need to find suitable discrete active elements compatible with the circuit configuration, the difficulties of attaching these active components to the thin-film network and the difficulty and high cost of obtaining a good hermetically-sealed package for such a circuit.

Because of the introduction of an additional multiplicity of interconnections, and particularly because the objective of unified compatible manufacturing processes under a single control is not attainable, these circuits do not appear to offer the same expectation of improved reliability as their semiconductor counterparts.

Thin-film circuits will truly come into their own when a deposited thin-film active device can be produced reliably. This would eliminate the discrete active components and give a true thin-film *integrated* circuit, in which *all* the components, both passive and active, are deposited on the same substrate in one given sequence of operations. Much work is being pursued in this field in several laboratories, but progress is very slow and for a long time to come we do not expect to see the inclusion of these devices into practical circuits.

Until such a time, the more likely use of the thin-film techniques will be found in the marriage of thin-film passive components to semiconductor integrated active components to form what we have defined as a hybrid circuit. This approach will give the best of both worlds. It enables total control of manufacturing processes to be retained under the one roof and yet yields the better performance associated with thin-film passive devices, better tolerances, better temperature stability, no parasitics and hence higher operating frequencies. Circuits utilizing these techniques are beginning to be offered commercially, particularly for linear applications where stability and tolerancing tend to be more critical than in the logic field.

Capacitors are produced using the thermally-grown silicon dioxide as a dielectric. The bulk silicon on which the oxide film is grown forms the lower electrode, while the top electrode consists of an evaporated layer of aluminium. Maximum capacitances being offered are in the region of 100–300 pF, the limit being dictated in the main by physical restrictions of area.

Resistors have been produced in Nichrome in the same

(Right) Five-stage 5-Mc/s amplifier with 60 dB gain and 300 kc/s bandwidth

(Far right) Thermocompression bonding of the connecting wires on to a semiconductor-integrated circuit

manner as in the normal thin-film circuits, albeit with a very reduced scale and consequent tighter dimensional tolerances. Tantalum has also been used to produce resistors, this being in many ways a preferable material. The principal advantages are (1) that it offers better compatibility with the silicon technology; (2) it is capable of controlled oxidization which can be used as a means of trimming the resistance value to very tight tolerances. Line widths smaller than 0·0005 in. have been achieved with these techniques.

One of the problem areas in the use of integrated circuits has always been the residual coupling between components in isolated areas of the substrate because of the parasitic p-n junction capacitances.

One solution which is being actively pursued is the use of multiple-chip techniques where critical components are truly isolated by being made in separate chips of semiconductor. This technique provides better flexibility of design, enables last minute changes to be made prior to encapsulation by the provision of redundant components and enables individual components to be fabricated on materials selected for optimum characterization for the type of component concerned. Because of the better isolation it is obviously better adapted than monolithic circuits to high-frequency requirements. It can also offer a distinct economic advantage over monolithic circuits where the high cost of preparing the complete set of photolithographic masks together with the relatively low yields obtained only justify the use of monolithics on economic grounds if really large quantities of identical circuits are used. The situation is somewhat eased with the multiple-chip circuit which gives to some extent the advantages of large-scale production for the individual chips even if the final circuits are only required in small numbers, as is very often the case with linear applications.

The various chips would be mounted on a ceramic insert inside the integrated-circuit package and interconnections made between them and to the package pins by thermocompression bonded gold wires.

The increased number of bonds would result in an inevitable degradation in ultimate reliability so that other techniques are also being considered. An example of this is where connections between the chips and to the package pins are effected by means of conductors evaporated on to the ceramic, the semiconductor chips being turned face down and connected directly on to the appropriate metallized areas on the ceramic by high-temperature soldering, diffusion or similar techniques.

One of the areas of difficulty has always been the bonding of wires, since there is the ever present danger of 'purple plague', a silicon-gold-aluminium compound which forms at the aluminium/gold interface under certain conditions. This is a brittle compound which in addition to the introduction of a high-resistance joint could ultimately result in the total failure of the joint.

An all-aluminium system has been proposed and is in fact being used as an alternative in certain cases, but the use of aluminium wires introduces a new set of problems. Another method is to use an all-gold system. This entails the replacement of the aluminium overlay pattern by a thin gold film overlay. In order to avoid problems of gold migration into the silicon, a chrome-gold deposition would be normally used, so that the thermocompression bond becomes a gold/gold interface.

Attempts to solve the problem of parasitic coupling between components in semiconductor-integrated circuits without having recourse to the physical separation of these components as in the multiple-chip configuration described above, have led to several new techniques of isolation in monolithic circuits. As described earlier, component isolation in integrated circuits is generally attained by a deep diffusion resulting in a back-biased p-n junction formed at the collector-substrate boundary. Because of the relatively large area of this junction, the junction capacitance is relatively high. This capacitance, as has already been mentioned, is the main limiting factor in the maximum operating frequency or maximum switching speed. In one of the most promising processes proposed to date, the components in the monolithic circuits are isolated from each other by silicon dioxide and polycrystalline silicon. This is claimed to offer a reduction in parasitic collector-substrate capacitance by a factor of 10 or more, an increase in collector to substrate breakdown voltage (and hence

component isolation) in excess of 100 V, absence of other parasitic effects in the device, and finally simplified buried layer diffusion.

Another area where improvements in technology are being made is in the photolithographic and masking techniques. As has been described earlier, the commonly used step-and-repeat photographic process can introduce random errors in registration. The introduction of the 'fly's eye' lens would appear to offer a solution to this problem. As its name implies this comprises an array of lenses so disposed that a master photographic pattern will produce a multiple reduced image in one operation, so that no stepping and repeating is necessary. The use of the same physical lens for the production of a complete set of masks ensures absolute registration between masks. Moreover, use of this technique results in a considerable saving in the time taken for mask production, thus easing one of the bottlenecks in the production of integrated circuits.

A further improvement consists of the replacement of the normal photographic masks by thin-film metal masks. The normal photographic mask is readily scratched and suffers from a very limited life. In the course of handling during production processes, masks are easily damaged so that it is necessary to produce several sets of masks as well as a master copy. This is an extremely costly and time-consuming process, with the additional registration problems due to multiple photographic processing.

The thin-film metal masks which have been recently introduced have a practically indefinite life. Chromium has been successfully used, and so have other metals such as tantalum. These masks can be scrubbed clean and can be used again and again where normal photoresist masks would have been scrapped. There is in addition an improvement in contrast and definition consequent upon the chemical etch of the chrome to produce the mask, resulting in improved definition of the final integrated circuit.

A combination of the above two techniques will show dividends in a considerable reduction in cost and time associated with the photolithographic processes, which form such a large portion of the integrated circuit production, thereby making these more attractive economically.

Future Prospects

There is no doubt that microelectronic circuits, having already established their potential advantages over conventional circuits, will find widespread use in the future. Because of the many problems to be solved before their complete acceptance into electronic systems, the application of microelectronic circuits will increase steadily rather than occur in discrete steps. A readjustment period for the electronics industry is essential, during which time circuit designers can learn to accept the new disciplines imposed by the new techniques, and the many advantages offered by the use of microelectronics can be exploited to the full.

The greatest use of integrated circuits will undoubtedly lie in the field of logic circuits, where repetitive circuitry occurs and where large numbers of identical units will be required, so that the use of monolithic semiconductor integrated circuits can lead to the greatest advantage on grounds of reliability and economy. This pattern has quite clearly already been established within the industry as can be seen from the overwhelming proportion of logic circuits of one type or another being offered commercially.

Linear circuits, as a generalization, tend to be much more individualistic in their component requirements than logic circuits and are therefore in demand in much smaller quantities. In such a case, that is, one in which the complete equipment consists of a number of individual elements rather than a predominant repetition of identical circuits, multiple-chip and hybrid circuits will undoubtedly continue to be used. However, a certain degree of rationalization and standardization in this field is inevitable and this will carry in its wake increased usage of monolithic circuits.

Looking further ahead, as confidence in the reliability of microelectronic circuits is built up one can visualize more and more complex circuits within the one hermetic encapsulation. These might well combine all the techniques described in this paper. For example, complete subsystems are being considered in a single multilead flat package containing an assembly of thin-film circuits comprising resistors and capacitors deposited on one or more glass substrates, and silicon-integrated circuits either mounted on ceramic substrates and subsequently connected to the other circuits by thermocompression bonded gold wires, or alternatively directly 'flip-mounted' on to the thin-film circuits. The trend towards increased circuit complexity within the one circuit package will reduce the interconnection complexity between packages and thus increase overall system reliability as well as improve packing densities.

The introduction of microelectronic circuits will probably proceed as a gradual spread from the space and missile requirements which are still providing the major impetus for the advancement of these techniques, via the Services requirements to the general run of industrial electronic systems, when the broadening of the market should bring with it commensurate decreases in prices.

Acknowledgment

The authors wish to express their thanks to the Director of Engineering & Research, The Marconi Company Ltd., for permission to publish this article.

WHAT'S ON AND WHERE?

This new forthcoming-events feature is to be found facing the inside back cover

ELECTRONICS IN TEXTILE

1. Sliver Break Detector

This article describes a simple electronic system for detecting breaks in slivers; that is, in the weak 'ropes' of cotton fibres which occur in an early stage of thread manufacture.

THE textile spinning industry is concerned with converting raw fibres such as cotton, wool and synthetics into thread form and in general the basic principles involved in the processing machinery have not changed much in the last half century. However, recent research and development has given some remarkable increases in the production speeds of the various machines. The cotton drawing frame, for example, had a production rate of approximately 150 ft/min in 1958 whereas the latest models are currently running in mills at 1,200 ft/min. These advances in textile technology and machine design have led to the need for a new approach to process control and fault detection in this industry and the place of electronic engineering in textile processing is rapidly increasing in significance.

The electronics engineer is faced with a number of difficulties in the application of his knowledge to textile machines. The environmental problems of vibration, dust and fibrous deposits found in textile mills are well known and their effect on electronic equipment must be taken into account, particularly when photo-electric devices are used. Under these conditions convection cooling is undesirable because of component contamination by airborne impurities and the extreme inflammability of open fibrous material requires the equipment to be free from the slightest fire risk, such as switch arcing. As well as the environmental conditions the electronics engineer is also faced with the problem that many of our textile machines are exported to the under-developed countries where the operatives may be barely able to read or write. Thus, our aim is to have a simple, reliable and self-compensating circuit with the minimum number of control knobs, preferably a simple on-off switch. The circuit must be 'fail-safe' and will in most cases be serviced or replaced by the mill maintenance electrician with very limited test facilities.

* T.M.M. (Research) Ltd.

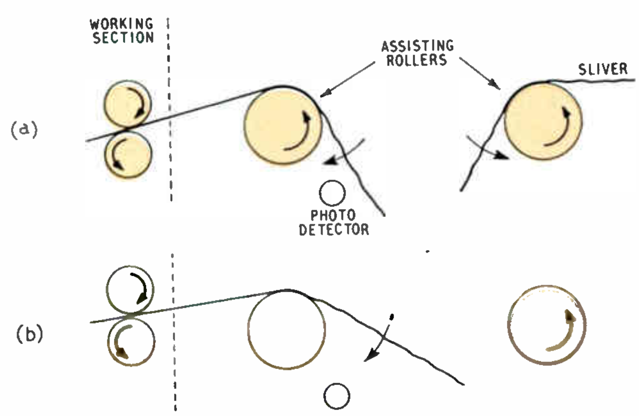


Fig. 1. A break in a sliver between the container and a working section (a) and the sliver tail from an empty container (b)

The following examples of the application of electronics to textile machines have been chosen to illustrate the difficulties of application and precise measurement met in applying electronics to our new textile machines, and are based on recent work at Textile Machinery Makers (Research) Ltd., Helmshore.

Photoelectric Sliver Break Detector

The process of converting raw cotton fibres into threads starts with separating and cleaning the fibres and then recombining them into a weak 'rope-like' form known as a sliver. This sliver is then drawn out by high-speed rollers to straighten the fibres and make them parallel. When the sliver has sufficiently drawn the finely attenuated output is tightly twisted together to form a thread.

Virtually the last stage of the drawing out of the sliver is accomplished on a machine which is known in the cotton industry as a 'speed frame', and is shown in the cover picture. The slivers are fed to this machine from tall, cylindrical containers at the back of the machine and are conveyed to the working or 'drawing' section over a series of assisting rollers. In the working section the individual slivers are drawn out and finally wound on to bobbins, a slight twist being simultaneously imparted to give the finely drawn fibres some strength.

The sliver emerging from the containers is weak and is liable to break as it is being withdrawn or as it passes over the assisting rollers towards the working section of the machine. These breaks and the sliver 'tail' as the container runs empty, must be detected and the machine stopped, otherwise a faulty package will be produced which, in turn, may damage neighbouring packages. It is also essential to stop the machine before the 'tail' or broken end has passed into the working section so that a simple splicing to the leading end of another sliver can be effected.

In the past the breaks or 'tails' have been detected by electro-mechanical devices acting on the slivers as they emerged from the containers. These detectors are of two

MACHINES

By R. GREENWOOD, B.Sc.*

types described as 'fingers' or 'electric rollers'. Finger detectors consist basically of a small strip of metal or plastic supported by the sliver and arranged to fall when a break occurs and, in falling, to operate a pair of switch contacts. Electric rollers consist of a pair of insulated rollers fed by a low-voltage signal and normally separated by the sliver passing between them, but when a sliver break occurs the rollers make contact and close a relay circuit.

At the new high production speeds the finger type detector can, in fact, cause breaks because the fingers gather stray fibres and the switch system can become contaminated with dust and fibre. Electric rollers suffer from two faults; the surface of the rollers can become contaminated with fibres and so prevent the contact being made when the sliver is absent, and a high circuit resistance can build up in the roller bearings and so prevent relay operation.

The electro-mechanical devices require re-setting by the operative and in seeking an alternative detector for the new speed frames we attempted to devise a system that would automatically reset itself after the detection of a fault. First thoughts were directed at a simple photo-electric detector for each sliver with the photo-detectors below the slivers and a light source above. This idea was eventually abandoned, mainly because each sliver does not follow a strictly defined path and the optical transmission characteristics of slivers can vary considerably.

It was noticed that the sliver breaks occur well before the last assisting roller shown in Fig. 1 so that in each case the tail falls down before this roller prior to being drawn into the working section. This condition raised the possibility of detecting the hanging sliver tail by a single photo-electric detector and light beam passing the full length of the speed frame below the last assisting roller. With this simple arrangement it was hoped that the sliver tails would block off the light beam but this proved unreliable because the sliver is only semi-opaque requiring a sensitive circuit prone to optical interference

Fig. 2. A view showing the photo-detector and lamp mounted below and just before the last assisting roller. One of the electric rollers previously used to control this machine can be seen in the centre foreground deliberately raised to make it inoperative during mill testing of the photo-detector

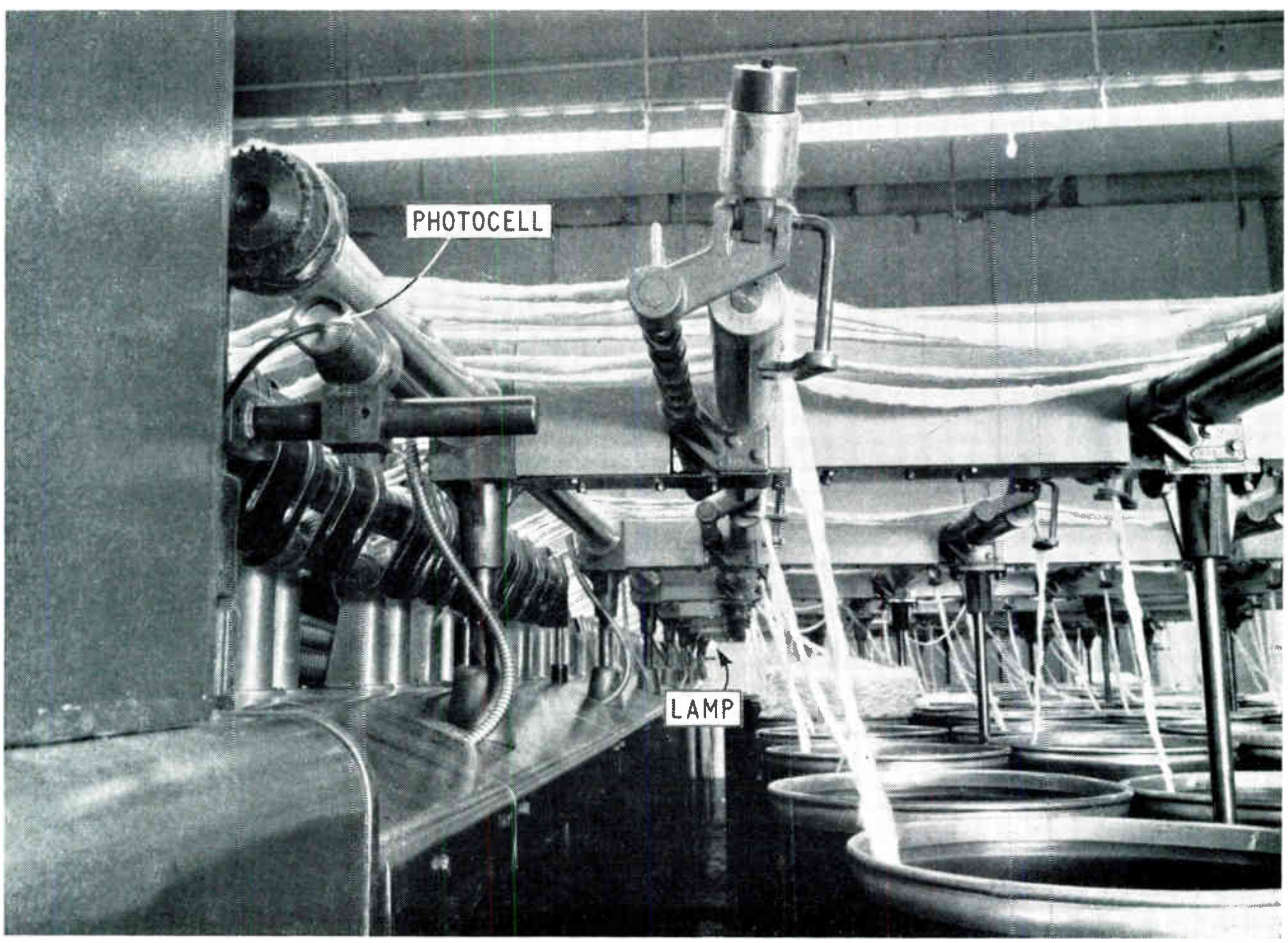
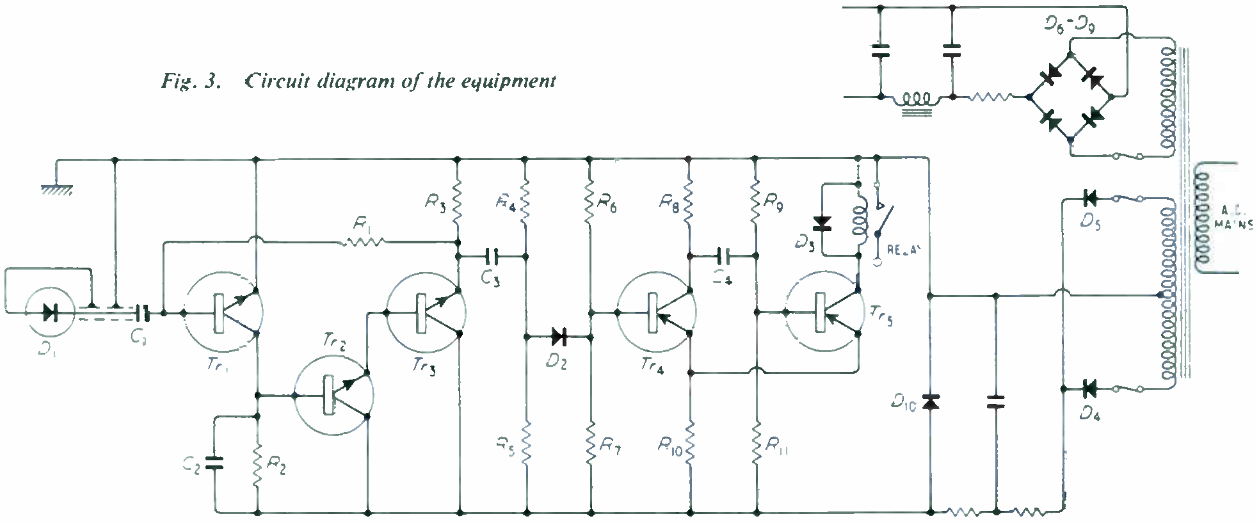


Fig. 3. Circuit diagram of the equipment



from other sources and also because the hanging tails can be displaced by even the slightest air current thus preventing detection.

The arrangement finally adopted, shown in Fig. 2, was to offset the light beam below and just before the last assisting roller so that the sliver tails pass through this beam as they fall before the roller. In passing through the beam the sliver tail causes a short pulse interruption of the photo-cell signal, not necessarily to zero volts, and the electronic circuit described below was designed to detect this pulse and to ignore other variations in light intensity, such as bulb ageing and, more significantly, variations due to dust and fibre build up on the lamp and photo-cell lenses. The circuit was also required to ignore the slow cutting off of the light beam, when on rare occasions a slack sliver may gradually sag and then recover and in doing so pass slowly through the light beam.

The photo-cell chosen is a Ferranti silicon photovoltaic type MS4B and to prevent stray light falling on the photo-cell it is mounted at the end of a 7-in. long, 1-in. diameter optical receiver tube blackened on the inside. The light-beam signal is condensed on to the photo-cell by a short focus lens slightly defocused to prevent edge effects from the filament image. The lamp system is simply a 6-V 6-W Cryselco automobile bulb mounted in a tube with a short focus lens. This type of bulb was chosen for its high intensity, which allows it to be slightly under-run for long life, and also for its rigid filament which minimizes variations in light intensity and distribution arising from mechanical vibration of the filament. The supply to the lamp is rectified and smoothed a.c. to prevent 100-c/s light intensity ripple.

The circuit diagram is shown in Fig. 3. The silicon photo-cell D_1 is connected so that the base of transistor Tr_1 is driven negative when the light source is blocked out. The photo-cell is a.c. coupled to the transistor network Tr_{1-3} via C_1. This network is a high-gain small-signal amplifier with 100% negative feedback via R_1 under static conditions to reduce temperature drifts. The output from Tr_3 is then a step change from a sliver falling through the beam. Despite the rigid filament chosen a certain amount of pick-up arose from filament vibration and this was made ineffective by inserting capacitor C_2.

Tr_4 and Tr_5 constitute a Schmitt trigger circuit with Tr_4 normally conducting. A positive pulse applied to the base of Tr_4 will cause the circuit to trigger and energize the relay for a period of two seconds set by C_4. The trigger circuit would normally operate on the application of 1 volt to Tr_4 base but the potential divider R_4, R_5 and diode D_2 effectively increase this signal value to 6 volts which allows up to 5 volts of noise to be tolerable on the output of Tr_3 and makes the germanium transistor trigger circuit Tr_4, Tr_5 insensitive to temperature changes. In mill testing we have found approximately 1 volt of noise under operating conditions and judge the circuit to be safe.

The output of Tr_3 is differentiated by C_3 and can be used to set the sensitivity of the system. This capacitor must be restricted in size or a very sensitive system would result that could operate as small tufts of airborne fibre pass through the beam.

The relay stops the machine by a pair of contacts in the electrical control stop circuit and as required in our original specification this relay circuit is self re-setting after approximately two seconds. Therefore no action is required by the operative other than to repair the fault and re-start the machine.

This single photo-detector is considerably cheaper than the multitude of electro-mechanical detectors used previously and has proved entirely reliable in a six month mill trial under cotton processing conditions at three-shift working. The cover photograph shows the speed frame used for the mill tests and in this view the numerous 'electric rollers' replaced by the single photo detector can be seen in their normal operating positions.

The system is the subject of a patent application and is now being designed for production; this will almost certainly involve minor changes to the circuit to make the production version capable of accepting wide tolerance transistors. A further development envisaged is to include an additional photo-detector in the package forming region of the machine to detect faults that occur as the package is formed.

TEMPERATURE MEASURING TEST SET

In order to check temperature control systems without having to operate the process over a wide range of temperatures, which may be difficult or dangerous, a device is required which simulates the effect of temperature. The essentials of a test set developed for this are described in this article.

By D. L. HOBSON*
and B. COHEN*

IN this modern age the temperature extremes encountered in engineering are far wider than has ever been known before. In order to achieve optimum working conditions and avoid reaching dangerously high temperature levels, it is now necessary to determine and control with great precision the operation of the modern marine and gas turbine engines, nuclear reactors of power stations, and bearing temperatures of large rotating devices. This may be further extended to the medical field and most branches of industry.

The temperature-controlling device generally employed is a form of servo-mechanism which is continuously adjusting the delicate balance of the device, thus automatically maintaining the required working conditions. To ensure the satisfactory operation of these servo-mechanisms, they must be periodically tested and adjusted. It is not always expedient to carry out these tests and adjustments in conjunction with the device controlled, as this must be operated under normal conditions, which can prove costly and sometimes dangerous. The requirement therefore exists for equipment which will be capable of simulating these working conditions, and provide a method of precise measurement.

* Ultra Electronics Limited.

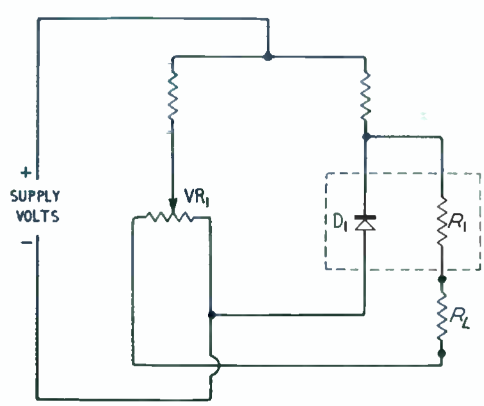


Fig. 1. Bridge circuit to provide a constant current through the load resistor despite supply voltage and temperature changes

This equipment, classified as temperature test equipment, needs to have an order of accuracy some five times better than the desired control temperatures and a reliability factor several times better than the system it is testing. Taking a gas-turbine engine as a typical example, an average range of temperatures may lie between 400 °C and 1,000 °C with a control mechanism to operate within ±5 °C of any temperature in this band. The temperature test set, therefore, must have an accuracy of better than 1 °C, whether used primarily as an indicating device or to provide a simulated signal. It becomes immediately evident that the conventional methods of measurement, such as a moving-coil pyrometer and a mercury-in-glass thermometer, will no longer fulfil the requirements. Discrimination, over such a wide band of measurement, is not possible with these types of instrument, and further, in the case of the pyrometer, power is drawn from the temperature transducers. This is not always desirable since loading errors can be introduced for which allowance must be made.

The problems of loading and discrimination are dealt with first. Assuming the temperature transducer to be an alloy type thermocouple, for example a Chromel-Alumel type producing 40 μV/°C for a temperature difference existing between its hot and cold junctions, then measurements could be undertaken using a d.c. millivolt potentiometer. This draws no power from the system, and accuracy and discrimination to a few microvolts are easily obtainable. However, even this method has several disadvantages. The major one is a problem associated with the thermocouple cold junction, the temperature of which must either be maintained at a stable predetermined level, for example 0 °C by immersion in a solution of ice in distilled water, or be accurately measured. The d.c. millivolt potentiometer also requires repeated calibration against a standard cell, an operation that can be unnecessarily time consuming and, if not meticulously carried out, can result in measurement errors. The ambient temperature working range of these instruments is strictly limited, and in general they are calibrated in volts whereas the operator is working in terms of temperature.

The d.c. millivolt potentiometer, therefore, is more suit-

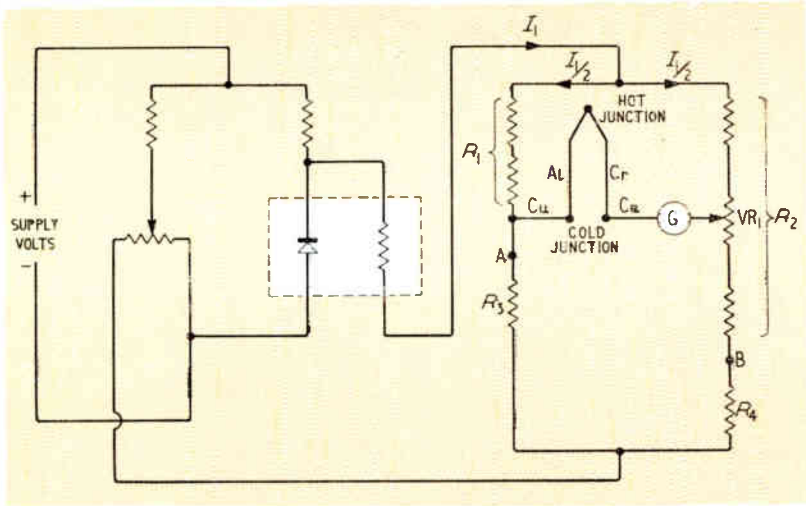


Fig. 2. The stabilized power supply of Fig. 1 is shown here with the temperature measuring elements

able for laboratory use by personnel of engineering calibre. However, it is not to be completely dismissed, since its basic theory of operation is the foundation of several temperature test sets which have been designed by the writers. One of these instruments is described in detail. This has been made in large quantities for testing the servomechanisms associated with the control of gas-turbine engines installed in aircraft.

The first design consideration must be the method of deriving a highly stable reference voltage against which the unknown thermocouple output can be compared. Normally a standard cell would be employed, but as previously stated these have limitations which render them unsuitable. The method chosen was a Zener diode. In appearance these diodes look much the same as any other, but their electrical properties are special. When a reverse potential is applied to a Zener diode and then gradually increased, a point of critical breakdown is reached and the diode avalanches. At this point of avalanche breakdown, the back resistance, which was previously high, drops to a low value and the diode current rises rapidly to a value determined by the external circuit resistance. If the voltage is increased further the diode current increases, but the voltage across it remains virtually constant. This can then be used as the reference voltage, independent of supply-voltage changes which can be as great as 25% of nominal.

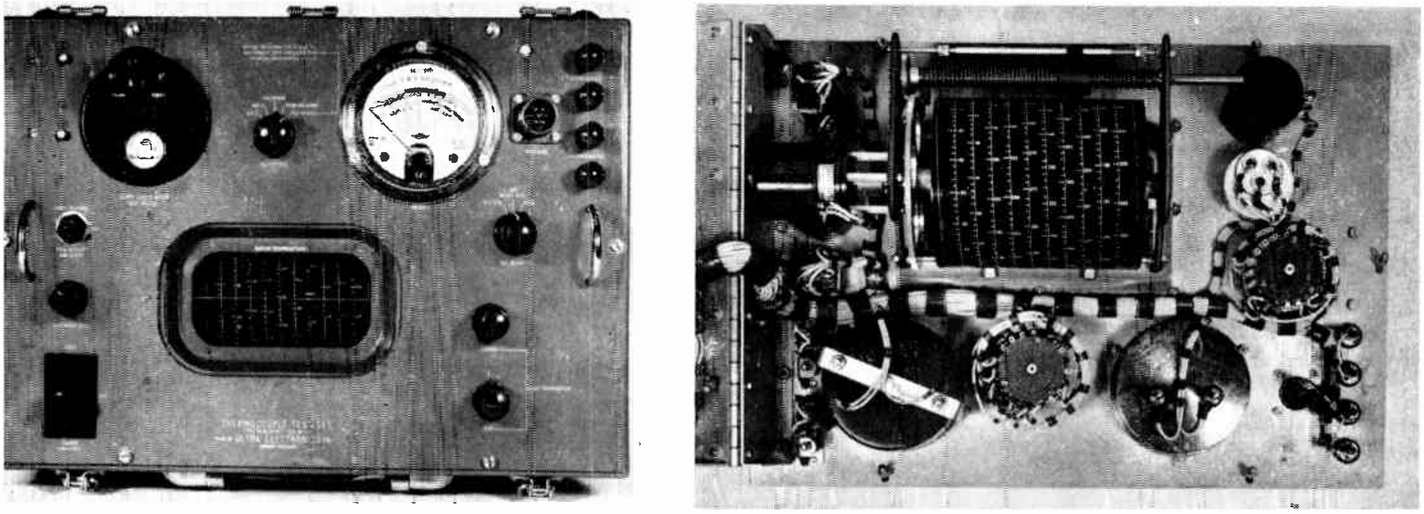
In order to achieve the desired stability from these devices, two factors must be accounted for; the temperature coefficient of voltage and the dynamic or Zener impedance. This is the reverse resistance of the diode in the avalanche condition. The circuit diagram, Fig. 1, illustrates a system whereby a fixed current can be supplied to the fixed load R_L, which is virtually independent of supply voltage and ambient temperature over a very wide range. The potentiometer VR_1 is adjusted to balance the bridge and the impedance term can then be neglected.

The special resistance R_1 is placed in physical contact with the diode, and both preferably attached to a heat sink, thereby introducing thermal delays. R_1 produces small changes in resistance relative to changes of temperature of the diode in such a manner that any voltage change in the diode caused by changes in the ambient temperature are automatically compensated and the current through R_L maintained at a constant level. If R_L is now replaced by a decade resistance and slidewire potentiometer, provision would be made for selecting a range of reference voltage levels against which unknown voltages can be matched, using a galvanometer as a means of balance.

A decade resistance and slidewire potentiometer unit is satisfactory for providing a linear output calibration, but not for calibration in temperature, for unfortunately the output law of a thermocouple is not usually a linear function. Consideration must also be given to a means of automatic allowance for the temperature of the thermocouple cold junction.

With regard to the calibration presentation, the writers made use of a helically-wound precision slidewire potentiometer. The spindle of the potentiometer was directly coupled to the shaft of a drum made from aluminium, so that it was free to rotate and turn the potentiometer wiper. The drum, 4 in. in diameter and about 6 in. long, had an 11-turn helix engraved on it with a pitch of ½ in. One turn of the potentiometer was represented by one turn of the helix, and for the full rotation of 3,600° an effective scale length of approximately 120 in. was obtained. The helix was then divided into 600 divisions representing the output law of a thermocouple and engraved from 400 °C to 1,000 °C. Each division represented 1 °C and was about ⅕ in. wide, so that sub-division by eye to 0·5 °C was easily obtainable. The addition of a suitable gear chain, a spindle and finger knob enabled the drum to be rotated.

In considering the complete circuit reference is made to Fig. 2. It will be seen that the load resistance R_L of Fig. 1 has been replaced by the bridge network consisting of R_1, R_2, R_3 and R_4. R_2 is a special component whose resistance varies with temperature and the bridge is so arranged that at 0 °C $R_1 = R_2$ and $R_3 = R_4$; the potential at point A is then equal to the potential at point B. The thermocouple



(Left) Front panel of a temperature test set for measuring thermocouple output for gas turbine engines. (Right) Revolving drum assembly, showing helix and calibrations in a temperature test set

leads are extended to a point inside the test set, using the same material as the thermocouple. This enables the thermocouple cold junction, the point where the special wire of the thermocouple reverts to copper, to be located inside the test box and its temperature continuously sampled. The change-over point consists of two copper blocks on to which is wound resistance R_3 so that although thermally connected they are electrically insulated. The resistance R_3 will then vary by an amount proportional to a change of temperature occurring at the cold junction. Providing R_1 and R_2 are large in comparison with the small resistance change in R_3, then the main stabilized current I_1 will divide equally through each limb of the bridge. By calibration of the potentiometer VR_1 in the manner previously described, a variable output can be obtained so that the slider is positive with respect to point A. The start point is determined by the lower resistance of R_2, which can then be combined with R_4 to form one resistance. Unknown outputs from the thermocouple are measured by adjusting VR_1 until null indication is obtained on the galvanometer and read off from the scale. The actual output between VR_1 slider and point A is continuously adjusted automatically by the changes of ambient temperature seen by R_3, which is also the thermocouple cold junction temperature. By design R_3 produces changes of output determined by the law of the thermocouple, and this subtracts from the main calibration output, thereby producing the desired effect of hot junction—cold junction= thermocouple output.

Circuit variations can be made to suit individual requirements but basically the device can be made accurate to ±1 °C working over ambient temperatures of −20 °C to +60 °C, and is independent of load resistance to the extent whereby the sensitivity of the bridge becomes so low as not to give satisfactory discrimination of a null condition on the galvanometer.

To simulate the conditions of the thermocouple under working conditions, a current must be passed through it to produce a volts drop equivalent to its normal output. This can be done with a battery and a simple potentiometer network to adjust the current, injection being made at some convenient point along the thermocouple leads. See Fig. 3. It should be appreciated that a thermocouple can be regarded as a simple cell having internal resistance, and if any device connected to it draws load current, there will be a resultant voltage drop, thus depressing the output voltage at the cold junction. Allowance for this should therefore be made either in the injection circuit or the measuring circuit.

The injected signal can be used to boost a normal output derived from the thermocouple. This allows the system under test to be run at levels considerably below normal but at the same time to operate the control mechanisms. This is particularly useful in cases where servo-mechanisms control fuel flow systems, as these can be operated to prove they function satisfactorily, while the system is run within an economical and safe margin. For bench testing purposes the thermocouple can be replaced by a fixed resistance of equal value, and connected to the device under test and to the test set with thermocouple leads.

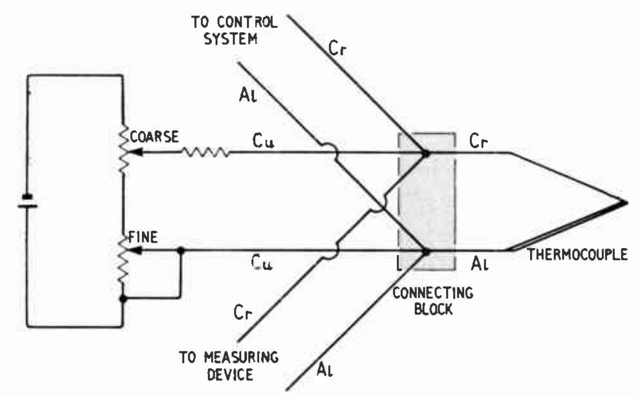


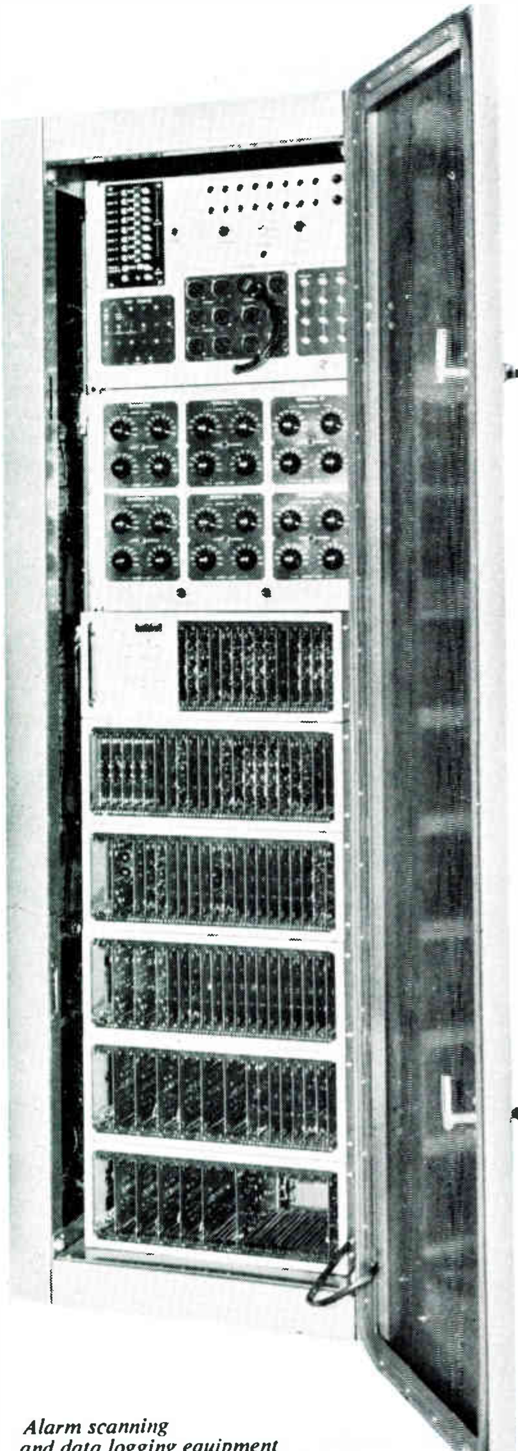
Fig. 3. This diagram shows how a current can be injected into a thermocouple to simulate a high temperature

WHAT'S ON AND WHERE ?

This new forthcoming-events feature is to be found facing the inside back cover.

This article explains the applications of alarm scanning and data logging equipment. The nature of the apparatus is also described in general terms.

ALARM SCANNING


Alarm scanning and data logging equipment

EFFICIENT operation of today's engineering installations and manufacturing plants demands the continuous monitoring of many variable functions such as flow, pressure, temperature, level, etc. This is because, if a significant change is not observed in time, a dangerous condition can arise or a whole production run may be spoiled. Automatic alarm scanning equipment can be depended upon to perform this 'watchman' action with more reliability than when this tedious duty is dependent upon the human element. Hence automatic alarm scanning equipment, which is readily capable of working 24 hours a day continuously, can result in greater plant efficiency and also in economies in running. This is because the plant can be left to the care of the alarm scanning equipment until such time as a fault occurs, when automatic audible alarms can be sent near or far for maintenance staff. Alarm scanning equipments are arranged to scan the variables continuously, comparing each one in turn with predetermined upper and lower limits and causing an alarm to sound if a function has moved outside these limits. The use of solid-state devices for the continuously-operating scanning circuits permits a large number of points to be scanned quickly with negligible maintenance requirements.

In many cases it is valuable to provide a printed record, or data log, of the variables, this printed record being up-dated say, every hour, but with an additional print out, including a record of time, when an alarm state has arisen or when demanded by the operator. When an alarm state occurs on one function this may well be due to a combination of changes of other functions which may themselves still be within limits, so that a complete print-out, when one function goes into alarm, will considerably assist in fault diagnosis. As a typical example of the value of the printed record consider the case of a motor bearing oil pressure falling to an alarm level. The question will arise as to whether the plant must be immediately shut down or perhaps be kept running until the end of the day shift. The record will show whether the failure has been coming on slowly so that it would be unlikely to reach dangerous proportions for several hours or whether it has developed quickly and must therefore be attended to at once. In more complex installations the data log can be made on punched tape for feeding to a computer to ascertain, for example, whether the plant is running under optimum conditions.

Another use for the printed data log is to enable growth of demand, such as on a pipeline system, to be watched over a long period of time and so to help with the further planning of the pipeline system to meet future demands. Yet another application is that, in certain instances, the printed data log can be used directly for accountancy purposes.

In some applications alarm scanning is the only facility required so that the output-writer and its associated drive circuits can be omitted. It is, however, convenient to

* Westinghouse Brake & Signal Co. Ltd.

AND DATA LOGGING

By J. P. COLEY, B.Sc.(Eng.), A.C.G.I., M.I.E.E.*

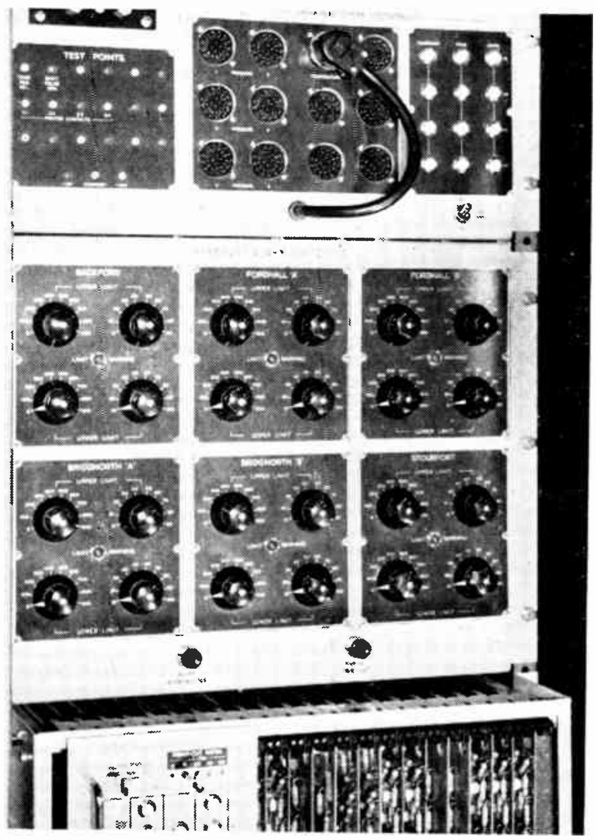
provide a digital visual indicator which can be used to show the actual value of any function, particularly to show the value of an out-of-limit one.

In the foregoing, reference has been made primarily to analogue (i.e., continuously varying) quantities, but changes-of-state, such as the movement of a valve, hopper or gate, or the stopping or starting of an automatically-controlled motor can also be logged with advantage but there would not normally be associated alarms. On the other hand, if motors stop when they should be running, reservoirs overflow or become unduly low, temperatures, pressures, etc., go outside the predetermined limits, then audible and visual alarms will operate and a complete print-out of all data will be initiated. Where the data log is printed out as the result of a change-of-state or due to an alarm, the actual function which has caused the print-out can be typed in red. The time at which the change occurred will also be recorded. Alternatively arrangements may be such that only the function which has changed is printed out. Yet another arrangement is sometimes adopted in which a separate strip printer is provided on which alarms are printed out in red followed by a 'return to normal' state in black. This arrangement has the merit of showing clearly the duration of each fault.

When alarm scanning of analogue quantities is provided the upper and lower limits may be set up in several ways. In some cases rotary multi-position switches are used for each temperature or pressure to be watched, on which the upper and lower limits can be set. Where there are a large number of functions, however, the appropriate upper and lower limits can be set up on a pegboard since the individual multi-position switch arrangement would occupy excessive space.

Some typical examples of the application of alarm scanning and data logging are as follows:—

1. *In ships' engine rooms* there may be between 100 and 200 points which require to be watched. These would include temperatures, pressures, r.p.m. readings, tank levels, fire detectors, fuel oil flows, etc., etc.
2. *In ships' refrigerated holds.* It is important that temperatures are correctly maintained within very close limits, if spoiling of the cargo is to be avoided. Furthermore, a complete log of measurements taken throughout the voyage will prove that the consignment has been properly handled.
3. *Process Plants.* A typical example might be a cooked food process plant where a large number of temperatures would need to be watched to see that they remain within limits. In addition such a plant might well have a considerable number of motor drives, the failure of one of which would cause disorganization of the plant and so would need to be brought to the supervisor's attention at once. The motors would be fitted with contacts closed when running which would cause an alarm to be raised in the event of a stoppage.
4. *Pipelines.* Oil, Gas and Water Authorities are all using alarm scanning and data logging. Throughout the length of a pipeline, information regarding flows, pressures, temperatures, valve positions, reservoir depths, holder heights, tank levels, pumps running or stopped, burst alarms, overflow alarms, etc., is brought back by telemetry systems to the control centre and then fed to alarm scanning and data logging equipment.
5. *Production Testing.* Where a number of units are on test each of which must have a number of measurements taken at regular intervals, data logging provides a simple and economic answer. For example, in the testing of engines, where fuel consumption, various temperatures and pressures, speed, brake horse power, etc., all need to be recorded over runs lasting several hours.
6. *Log of Defects on Rolled Strip Steel.* During the rolling of strip steel a typewritten log sheet can be produced showing the positions of all defects relative to the distance from the start of the roll. Some of the data would be fed in manually by an operator pressing a key when he sees a defect, and other data such as thickness of the strip would be obtained from transducers. The rolling machine would provide a



Close-up of the switches for setting the alarm levels

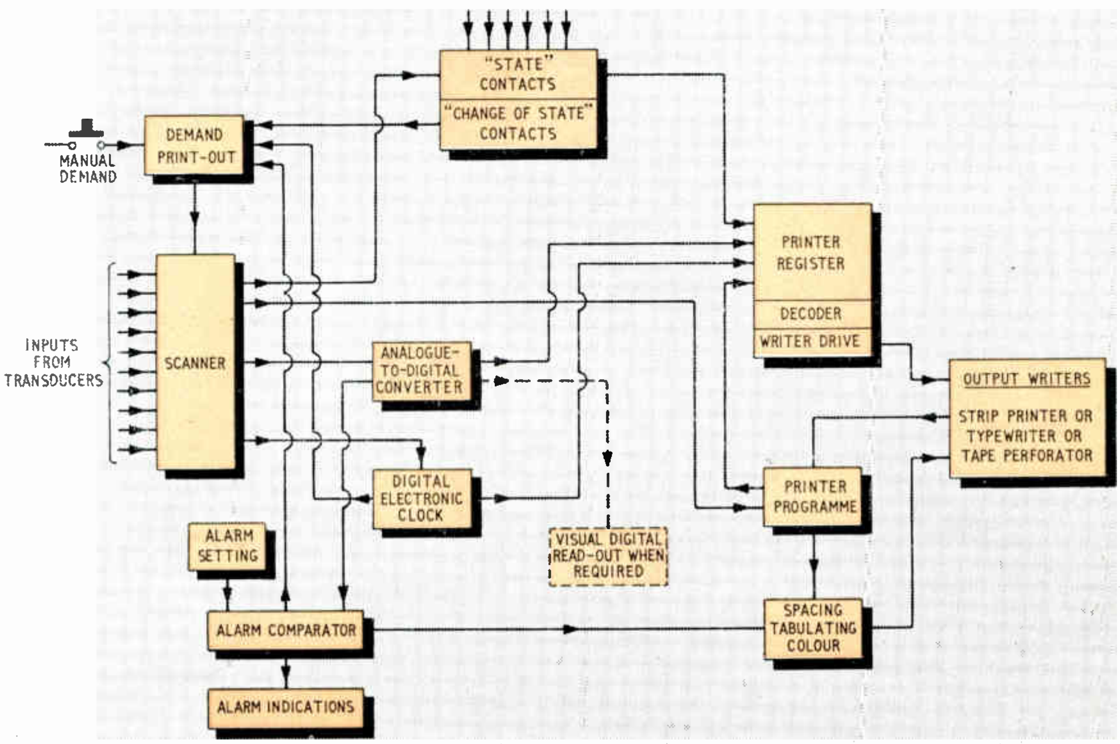


Fig. 1. Block diagram of typical alarm scanning and data logging apparatus

footage count and at the conclusion of rolling the data logging equipment would calculate the percentage of strip within various thickness tolerances.

This log is required so that, depending upon the nature of defects and thickness tolerance, the finished product can be channelled to the most appropriate commercial application.

7. *Monitoring of Heating and Ventilating Plant.* In some manufacturing processes correctly conditioned air is an essential requirement. This means that the cleanliness, humidity, temperature and pressure of the air fed to the plant must all be within predetermined limits, it being necessary to measure and monitor these functions at various points in the plant. In addition it would be necessary to monitor the heating or refrigerating plant and the pressurizing equipment.

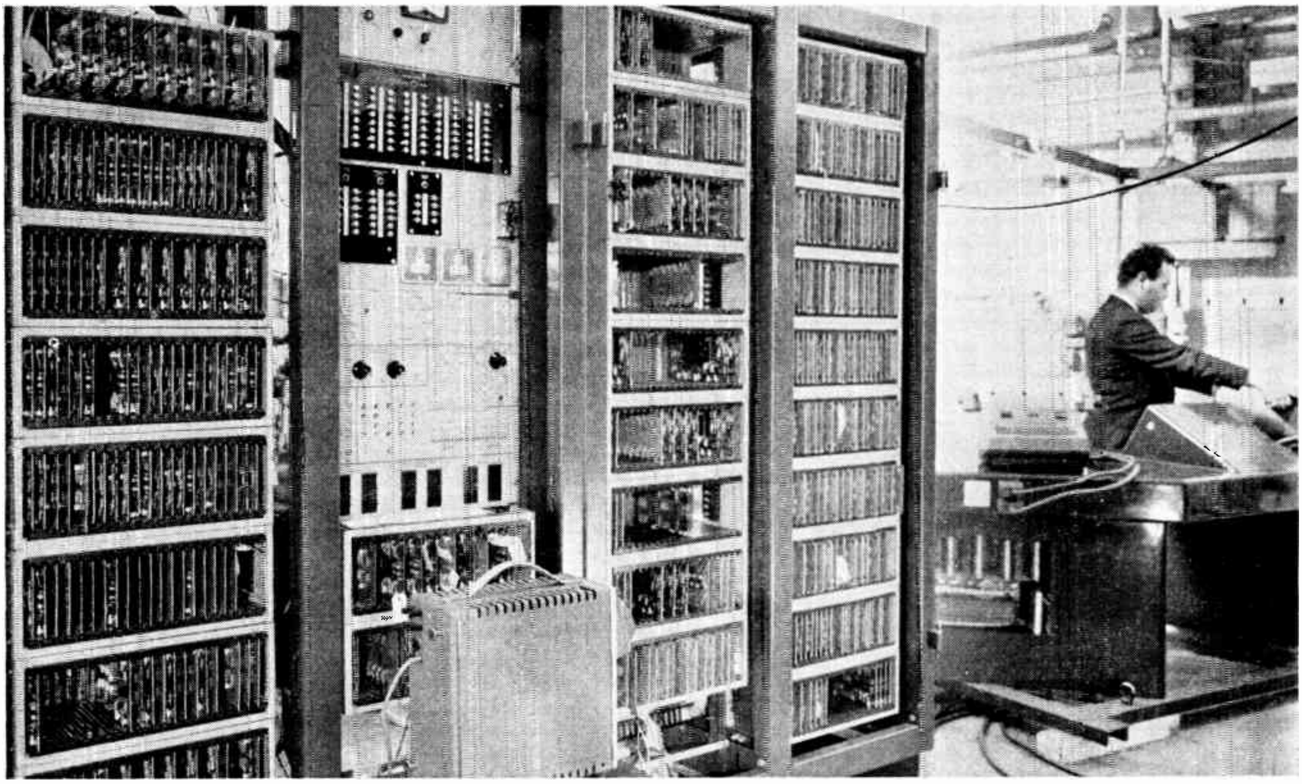
8. *Logging of Machine Tool Down-time.* The object in this is to record, on punched paper tape, every time one of a number of machines stopped, the time at which it stopped, a numerical code fed in by an operator to show the cause of stoppage and the time the machine restarted. When this information is fed to a computer a detail analysis of the down-time due to various causes can be provided. In this application the scanning circuits are replaced by storage arrangements to cater for a predetermined number of machines failing at the same time.

Schematic Arrangement of System

The first requisite for scanning analogue functions is to provide each of these with a transducer which will convert the temperature, pressure, etc., to a current or voltage which varies in a fixed relationship to the variable being measured (this may not be a directly proportional relationship and in such cases linearizing circuits have to be included in the scanning equipment).

The principal elements of an alarm scanning and data logging equipment are shown in Fig. 1. The heart of the system is, of course, the scanner itself which is an electronic step-by-step arrangement which causes a relay to energize and release again on each step. For the period that a relay is energized, it connects its associated transducer to the analogue-to-digital converter. This latter device converts the analogue quantity being measured to binary-coded-decimal form. That is to say, if the quantity is a 3-digit number then each of these digits is individually converted to a binary number and then stored. When this digitizing process is complete the binary-coded-decimal number is transferred to the printer register.

Dealing now with the ancillary circuits it is seen that the 'demand print-out' can be initiated either by manual operation, by a signal from the 'change-of-state' unit, by a signal from the digital clock, or by an out-of-limit alarm. After a print-out has been demanded by any one of these sources two things happen simultaneously when the scanner is on the first step of its scan, one being the print-out of time from the digital clock, the other being the digitization of the first function. By the time the equipment is ready to print out the first function, the time will have already been printed. To achieve this the digital clock reads out its four digits in binary-coded-decimal form into the printer register, and then the printer programme, another step-by-step electronic device, causes the binary-coded-



Data logging equipment for a water pipeline during factory testing

decimal digits, one at a time, to be decoded and fed to the writer drive. As each digit is printed a signal is sent back from the writer to drive the printer programme to its next step. The printer programme then causes the three digits of the first function to be printed. After this a feed from the final step of the printer programme causes the necessary spacing or tabulating action to take place.

If the alarm comparator shows a function outside limits a print-out is demanded and a signal is sent from the alarm comparator to the spacing, etc., control unit to change the colour to red for the particular function in alarm.

Construction of Equipment

The various systems are built up to suit specified needs, from a number of standard logic blocks which plug in to fixed sockets. Except for the transducer switching relays and part of the analogue-to-digital converter, only solid-state components are used. Where relays are used, they are lightly loaded and of a design which gives an exceptionally long life. Silicon transistors and diodes are used throughout, making these equipments of advanced design and capable of operating satisfactorily under the most arduous environmental conditions. A number of monitoring lamps are fitted, one or more of which will be illuminated in the event of a fault within the equipment itself, to give an indication of the group of cards within which the faulty one lies. A simple series of predetermined tests will then enable the maintainer to locate the actual faulty card, which can then be replaced by a spare to restore the equipment to normal operation.

Automatic-Unloading 'Robotug'

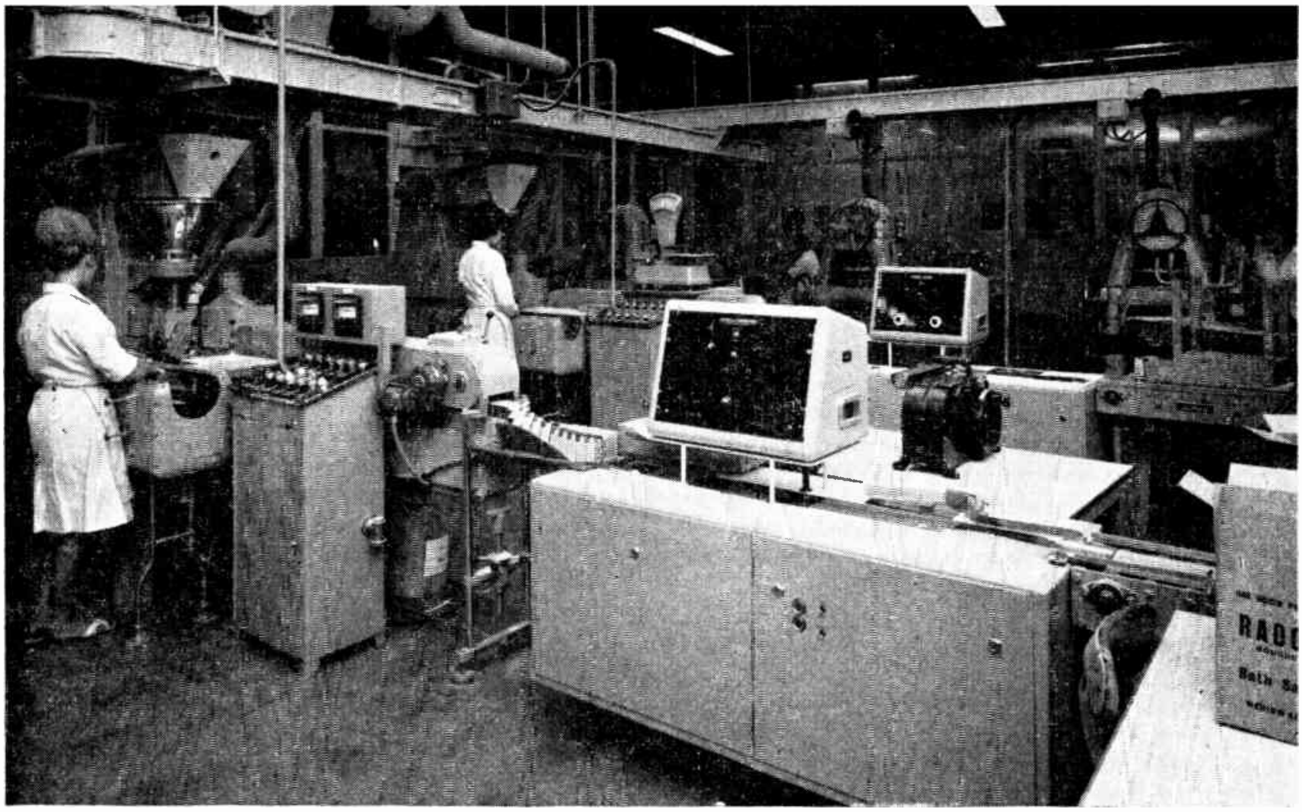
Metal baskets filled with screws still hot from the hardening furnaces at G.K.N. Screws and Fasteners Ltd.'s Heath Street Division factory, Birmingham, will be transported to the cleaning plant by the first Robotug driverless truck system to incorporate automatic unloading equipment. The system was manufactured and installed by E.M.I. Electronics Ltd. and Conveyancer Fork Trucks Ltd.

This Robotug can be programmed to stop automatically at any one of ten furnaces. Three full baskets of hot screws are then transferred from a storage conveyor to three short sections of conveyor permanently fixed to the top of the Robotug. Safety rails are raised and the tug started.

Upon reaching the cleaning plant, the Robotug automatically stops at a precise point, the safety rails drop, and a mechanical ram transfers the three full baskets to another conveyor for the next process. The Robotug then automatically re-starts and proceeds to another point where it collects three empty baskets. It transports these to a distributing point where they are automatically unloaded on to a conveyor for refilling with screws for feeding to the various furnaces.

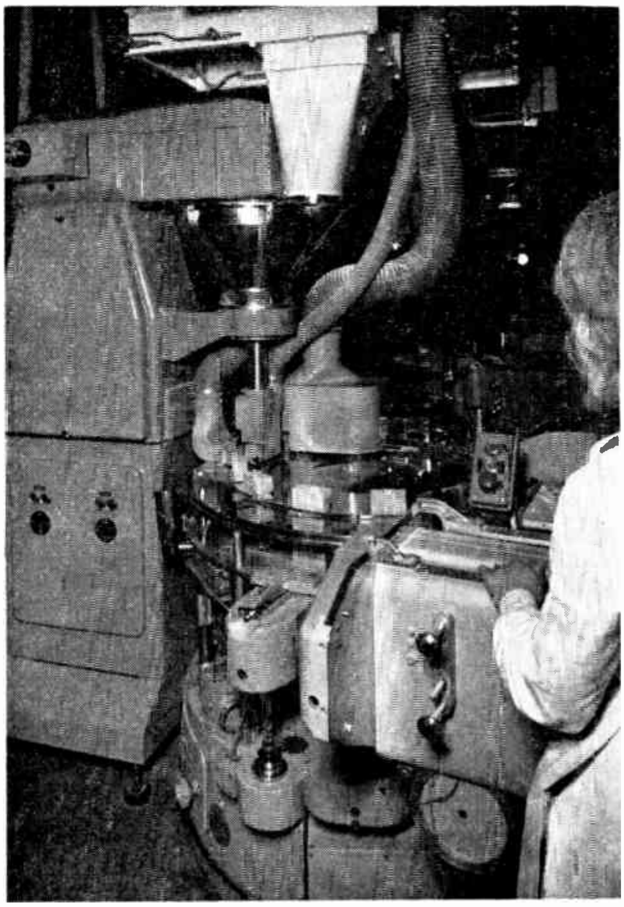
Robotugs, which follow an energized wire buried half-an-inch below the ground, can work round the clock.

For further information circle 47 on Service Card



Two automatic filling machines in use at the Slough factory of Nicholas Products Ltd. for Radox bath salts

HIGH-SPEED VOLUME FILLER WITH



A NEW type of automatic filling machine which combines the accuracy of net weighing with high-speed volume filling is now being produced by Southall & Smith of Birmingham. Known as the VF2 high-speed volume filler, it will handle powders and semi-free-flowing granular materials often within accuracies of $\pm\frac{1}{2}$ per cent.

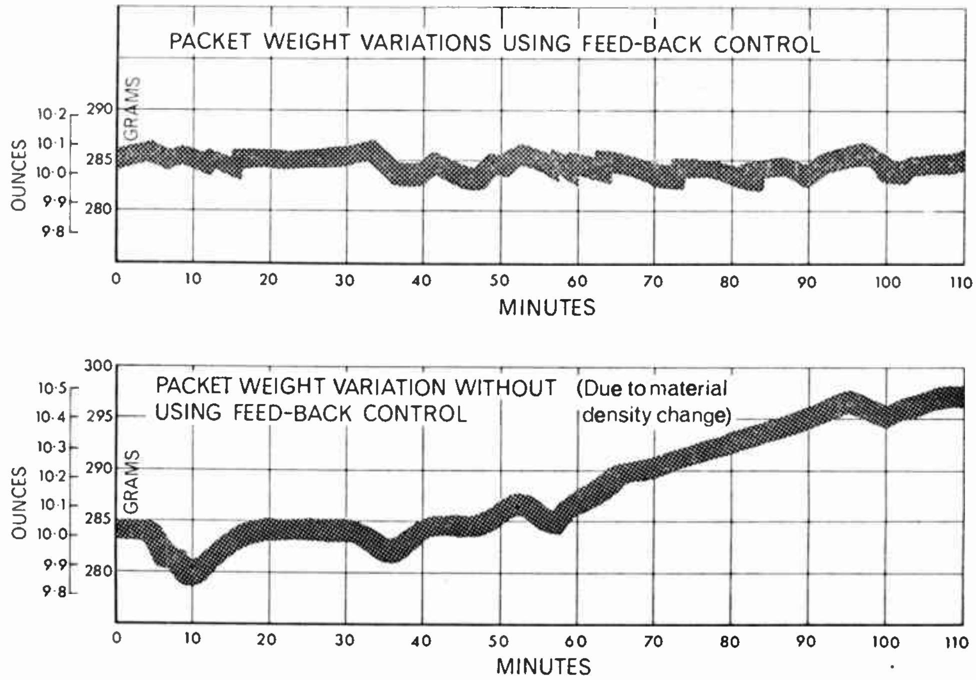
Two machines of this type are now in use at the Slough factory of Nicholas Products where 10 oz and 20 oz packets of bath salts are being filled. Additional precision has been built into the lines by the use of checkweighers and feedback units which maintain filling within closely-controlled limits despite density variation of the product.

Some idea of the machine's ability to deliver accurate quantities at high speeds over a long period can be had by mentioning that at Nicholas Products both machines have been operating at 60 fills per min for up to 14 hours per day for the past 12 months and under these conditions the machines operate to within $\pm 2\frac{1}{2}$ gm on 10-oz fills and $\pm 4{\cdot}5$ gm on 20-oz fills.

Infinitely Variable Controls

The whole essence of the design of the filler is the particularly accurate control of the angular travel of the auger, claimed to be within 5 degrees. This ability gives accurately controlled delivery of material. On standard designs, auger travel is between 1 and 9 revolutions. This angular travel can be infinitely adjusted to allow for density changes in the material and works in conjunction with the feedback unit. The speed of rotation of the auger is also infinitely variable thus enabling the whole of the filling time allowed by the packaging machine to be utilized.

The high-speed volume filler will handle powders and semi free-flowing granular materials, often within accuracies of $\pm\frac{1}{2}$ per cent



The feedback unit can adjust the amount of material dispensed by the filler based on any deviations in packet weights on the checkweigher. The top graph shows how packet weights are maintained within consistent limits with the feedback unit operating. The lower graph shows weight variations when the feedback unit is not used

FEEDBACK CONTROL

At Nicholas Products both machines deliver their quantities with the auger rotating at 600 r.p.m. between stopping and starting. While the packet in the packaging machine is stationary, the filler supplies one discharge in approximately 0·5 sec., for both 10 oz. and 20 oz. packets. (The diameter and pitch of each auger are different.) Only when a signal is received from the packer does the auger deliver its charge.

Design Features

The filling unit basically comprises an electric motor driving a Kopp variable speed gear box whose output shaft is connected to an electromagnetic clutch/brake unit. This unit is in turn connected to the actual auger in the filler hopper. The Kopp 'variator' allows the speed of rotation of the auger to be changed.

A dog clutch works in conjunction with the input shaft of the clutch unit and actuates a stirring device in the filler hopper.

Another and smaller 'variator' controls the angular travel of the auger. The output shaft of the clutch unit is connected to the input shaft of this second 'variator' which has on its output shaft a cam. A signal from the packer results in clutch engagement and auger travel until the cam rotation operates a microswitch controlling the magnetic brake thus stopping the auger. A bi-directional ratcheting device allows the travel to be increased or decreased with consequent results to the amount of material discharged.

Feedback System

The feedback system can adjust the amount of material dispensed by the filler. The feedback unit receives signals from the checkweigher and is able to sense whether the average weight of packets is changing. When a prescribed number of packets have exceeded the high or low 'correction' values, and a trend has been established, a signal will be sent by the feedback unit to a solenoid in the bi-directional ratcheting device on the filler itself. This device is attached to the small 'variator' which controls the angular travel of the auger and thus the volume of the material dispensed.

Having called for an adjustment, the feedback unit ignores all packets in the line between the filler and the checkweigher until the first one to receive the adjusted amount reaches the checkweigher. This mode of operation guarantees that corrections are made only according to true trends.

Although no practical checkweigher exists capable of dealing with 600 packets per min, the feedback unit is designed to accept signals at up to this rate.

For further information circle 48 on Service Card

Conference on Automating Engineering Manufacture

The Production Engineering Research Association (PERA) are to hold a conference on 'Automating Engineering Manufacture' from 23rd to 25th March 1965. This is to be held at PERA's headquarters at Melton Mowbray, Leicestershire ['phone Melton Mowbray 4133].

During the three days a balanced programme of 15 papers will be presented. The aim is to accelerate the exchange of practical information about automation techniques among production engineers, machine shop managers and plant engineers.

The whole field of the application of automation to the machine shop will be covered in one form or another: analysis of machine shop practice, problems of introducing automation, and the use of numerically controlled machines and other electronic labour-saving aids.

The part which electronics is playing in measuring the characteristics of soil is described in this article. The methods employed vary with the quantity to be measured and in some cases radioactive sources are adopted.

ELECTRONICS IN

DURING the past two decades electronic techniques have gradually found applications on an ever-increasing scale in almost every field of human endeavour. Perhaps one of the not so well known cases is the application of electronic techniques in civil engineering, but even here the examples are so numerous for it to be essential in a single article to consider only one branch of civil engineering. The branch chosen for the present article is soil mechanics, the subject concerned with the various mechanical properties of soils, e.g., the strength and deformation characteristics and their hydraulic conductivity. It is a fact that many of the applications of electronic techniques arise because of the use of such techniques in providing facilities for accurate timing of events and the measurement of short time periods, and this is also the case for many applications in soil mechanics.

Density and Moisture Content of Soils

Two of the important factors concerned with highway construction are the determination of density and moisture content of the compacted material layers. The conventional methods often prove too laborious and time consuming for the effective control of modern constructional methods and electronic techniques are now being employed to determine both these quantities.

In the case of density determinations a radioactive source is employed so that the material whose density is required is bombarded with gamma-radiation. In one variant of the system both the radioactive source and the radiation detector are mounted in the same apparatus, which is placed on the surface of the ground being investigated. Some of the gamma photons emitted downwards by the radioactive source suffer an interaction with an electron of the electronic structure of the atoms of which the ground is composed and are back-scattered on to the detector. This process is known as Compton scattering and the intensity of the signal returned is directly proportional to the atomic number (Z) of the atoms causing the scattering. On this basis, therefore, we should expect the signal received by the detector (i.e., the response of the instrument) to increase with increase of density of the ground being investigated. This, however, is only part of the story, because the gamma-rays in some cases, at least, actually pass through an appreciable thickness of soil before suffering an interaction, which causes the degraded photon to be back-scattered along a reciprocal path back to the detector.

The response of the instrument must therefore depend on the extent of the absorption during the round trip from source to detector through the soil. The higher the soil density, the greater the scattering and also the greater the absorption. Thus, the two effects tend to counterbalance one another to some extent, but it is usually possible to arrange conditions so that one effect is predominant. This is the absorption effect, so that characteristic of the instrument is such that the signal falls off approximately linearly with density.

The simpler, but less useful form of apparatus, is the 'direct radiation' type, in which gamma-radiation from a source contained in a probe placed in a vertical hole in the ground is transmitted through the soil to a detector placed

ELECTRONICS
INSTRUMENTATION
CONTROL

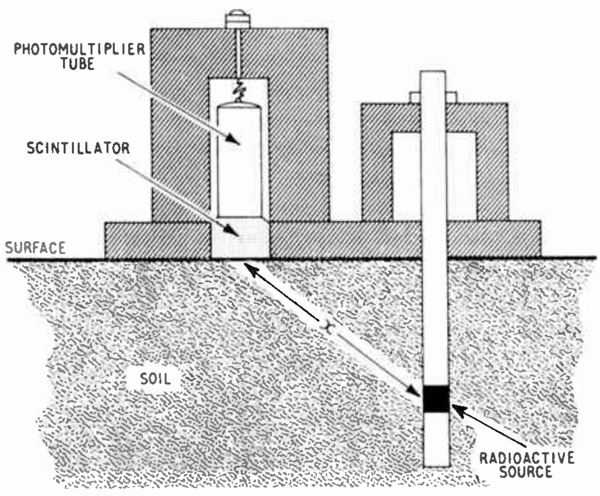
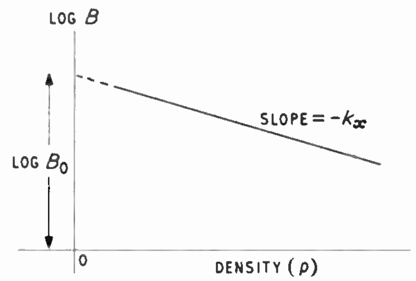


Fig. 1 (Left).—Schematic of direct radiation gauge

Fig. 2.—Calibration curve for direct radiation gauge



SOIL MECHANICS

By DENIS TAYLOR, M.Sc., Ph.D., M.I.E.E., F.Inst.P.*

on the surface of the ground. The actual arrangement is shown in Fig. 1. In the passage from the source the gamma photon beam is attenuated, the attenuation following an exponential law, viz.

$$B = B_0 e^{-\mu x} \qquad (1)$$

where B is the number of photons crossing unit area in unit time, μ is the linear absorption coefficient and x is the distance travelled; i.e., the distance between the detector and the source.

It is found for the common elements in soils from carbon Z = 6 up to Z-numbers of about 26 (i.e., iron and elements below iron in the periodic table) that μ is directly proportional to the density ρ, which means that $\mu = k\rho$ where k is a constant equal to 0·075 when the gamma-ray energy is in the range 0·6–0·7 MeV.

From equation (1) we may write

$$\log (B/B_0) = \log B - \log B_0 = -\mu x$$

$$\therefore \log B = -\mu x + \log B_0$$

$$= -kx\rho + \log B_0 \qquad (2)$$

With a radioactive source of very long half-life and using a standard geometry for the source-detector configuration, B_0 and therefore log B_0 are constants. Hence, by plotting a graph between log B (which is proportional to the logarithm of the counting rate observed in the radiation detector circuit) and ρ, a straight line should result. This is shown in Fig. 2. Clearly, if the apparatus is set up in an unknown soil and the counting rate observed, the calibration curve allows the density of the soil to be determined from the measured counting rate.

However, when the density of compacted layers is the requirement, it has to be appreciated that the back-scatter type of instrument is preferred because measurements can be made more quickly and it is not necessary to disturb the surface of the soil, pavement or road. As against this, the 'direct radiation' type of instrument is more sensitive, and because the density is measured more directly, maintains its calibration more reliably over a large range of soils, pavements and roads. For this reason, the Instrument Manufacturing Corporation of South Africa, one of the Plessey Group of firms, have introduced the technique of calibrating the back-scatter gauge with the 'direct-radiation' gauge for each new type of soil or pavement investigated before undertaking a series of tests using the back-scatter gauge.

For the radiation detector in both forms of instrument a Geiger counter can be employed, and the Geiger counter discharges each time a gamma-photon is detected, giving rise to a series of pulses being transmitted to the counting circuit. The instrument therefore measures the number of photons per square centimetre per second in terms of the counting rate; i.e., the number of pulses received per second. The counting rate is determined by means of a scaling unit, a series of five Dekatron tubes, one corresponding to the 'units' digit, the second the 'tens' digit, the third the 'hundreds' digit, etc., so that by using the electronic unit to count the pulses received in a given time, the number of photons detected per second (proportional to B) is determined.

The apparatus in use is shown in Fig. 3. This is the 'back-scatter' type of instrument with a surface probe containing the source and detector system and the counting circuit comprising the five Dekatron tubes. In most forms of the apparatus an automatic timer is incorporated. This

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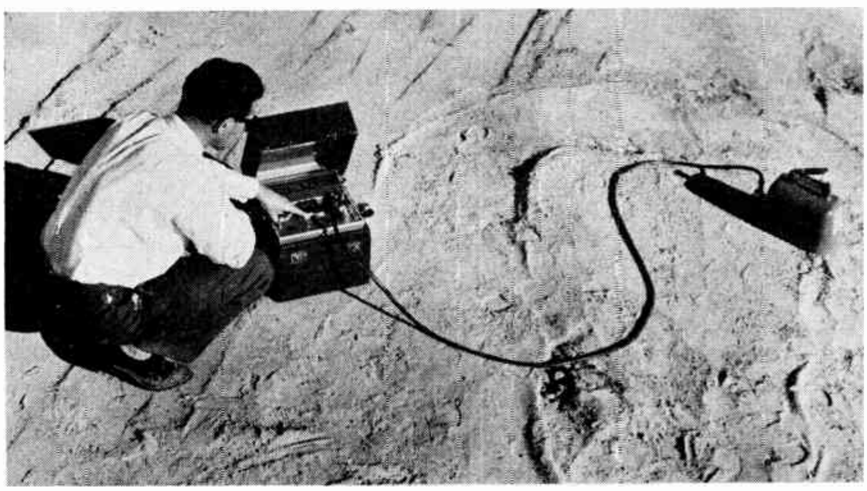
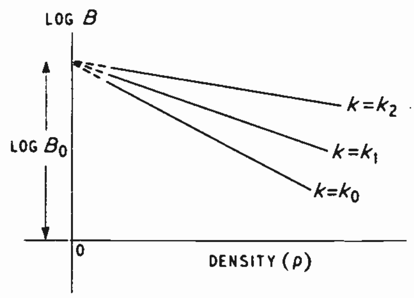


Fig. 3 (Left).—Back-scatter type of gauge in use in the field

Fig. 4.—Calibration curve for direct radiation gauge making allowance for the moisture content of soil



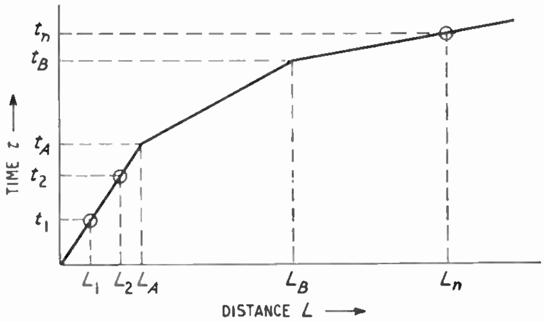


Fig. 5.—Typical graph of seismic hammer apparatus

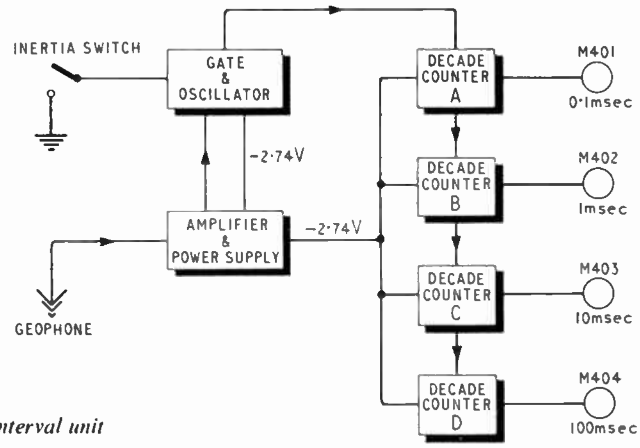


Fig. 6 (Right).—Schematic of time-interval unit

switches the counting circuit off after one minute. The count recorded on the Dekatron tubes after any measurement, therefore, corresponds to the number of gamma photons detected (say N) in this time. Therefore, the counting rate is $N/60$ counts per second.

Measurement of Moisture Content

For the measurement of the moisture content of soils, roads, etc., a radioactive source is also employed, but in this case a source of fast (i.e., high energy) neutrons is needed. These fast neutrons are slowed down by collision with the nuclei of atoms present in material. It turns out, however, that if the nuclei are of the same order of mass as that of neutrons, then the neutrons undergo inelastic collision and lose a large proportion of their energy in this way. Hydrogen nuclei are therefore very effective in slowing down neutrons, and are so much more effective than nuclei of the other types of atoms found in soil that measuring the slowing down effect of a particular sample of soil allows the determination of the amount of hydrogen, and therefore of the moisture content of soil.

For this purpose it is necessary to use a special type of radiation detector which responds to slowed-down neutrons, but does not respond to fast neutrons. Such a detector is the so-called proportional counter filled with boron trifluoride gas. The resulting train of pulses is transmitted by cable to the scaling unit, and a direct measure of the moisture content can be obtained from a calibration curve, which is a single straight line for most building materials. For some purposes it is convenient to have two probes and a common scaling unit. One probe contains a gamma-emitting source and a Geiger counter and is used for density measurements, while the other contains a fast neutron-emitting source and a proportional counter containing boron trifluoride gas. In other cases a composite source, emitting both gamma-rays and fast neutrons, is employed and two detectors, one for detecting gamma photons and other slow neutrons, are mounted together in the probe.

ELECTRONICS
INSTRUMENTATION
CONTROL

Returning now to the density determination it may be noted that we stated that $\mu = k\rho$ was a good approximation to the truth for most of the common elements found in soil. It is not, however, a good approximation in the case of hydrogen, for k works out to be about twice the value for the common elements such as silicon, oxygen, aluminium, etc. This means that while the method would be expected to work well for dry materials, the presence of water in the material would alter the k-value and therefore the calibration curve. This suggests, therefore, measuring the moisture content first and, according to the moisture content found, using the appropriate k-value in the density determination. This is illustrated in Fig. 4 which shows a series of calibration curves corresponding to different k-values. Note that all the calibration curves are straight lines crossing the vertical axis at a common point, but having different slopes. The appropriate curve to use for density determination is decided by the moisture-content determination. Naturally this procedure is only required in the case of very high precision measurements (say, better than $\pm 2\%$).

Seismic Waves for Sub-Surface Investigations

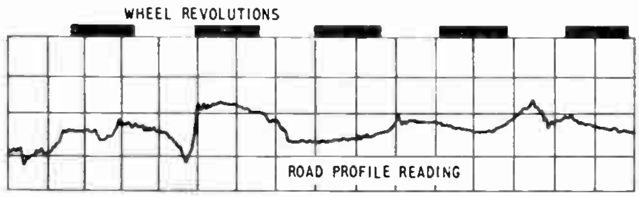
For depths of penetration less than 100 feet, a shock wave is generated by striking a metal plate, firmly embedded on the surface of the ground, with a 14-lb sledge hammer. The shock sets up a seismic wave through the sub-surface layers of the ground. For the purpose of timing the seismic waves it is necessary to operate a switch in the timing circuit when the hammer hits the plate. In the Instrument Manufacturing Corporation form of apparatus this is in the form of an inertia switch strapped to the hammer, which closes in turn an electric circuit when the hammer strikes the plate. The closing of the circuit sets the time-interval meter in operation.

For the purpose of detecting the shock wave at a distance a geophone is used. This is firmly embedded in the surface of the ground and detects the compressional wave after its passage through the sub-surface. The time-interval meter comprises a crystal-controlled oscillator, which supplies a very stable frequency, and a frequency-measuring circuit, which counts the number of pulses from the oscillator between the two time-marking signals.

In practice with a 14-lb hammer, a maximum depth of 60 to 100 feet can be reached and time measurements are needed to a maximum of 1 second with an accuracy of 0·1 msec. The usual method of test is to strike the hammer

Fig. 7 (Left).—Seismic hammer apparatus in use in the field (I.M.C.)

Fig. 8.—Typical display of road roughness indicator



on the plate at measured distances from the geophone. Convenient distances are 5 to 10 feet intervals. The average of three or more consistent time intervals for each distance is recorded. The distance can be increased until the compressional wave becomes too weak to stop the timer. When this happens the next wave, either the shear or the Rayleigh waves (which travel more slowly but carry greater energy) will stop the timer, an event which is easily recognised by the discontinuous jump in the time intervals.

The method is best explained by referring to some typical results. These are shown in Fig. 5 which gives the measured times plotted against the corresponding distances. It is usual to make two sets of measurements, a forward traverse and a reverse traverse. In the case of parallel rock strata or soil layers the two sets of measurements agree, but with non-parallel layers the forward and reverse traverses will be different. We will consider the case of parallel layers for simplicity. The three straight lines drawn through the experimental points (Fig. 5) correspond to the three strata. The velocity in each stratum corresponds to the slope of the line. The depth of the various strata below the surface can be calculated from a knowledge of the velocities in the strata and the distances L_A and L_B. The velocity in the first stratum is

$$V_1 = \frac{L_2 - L_1}{t_2 - t_1} \text{ ft/sec} \quad \ldots\ldots\ldots\ldots (3)$$

which is the slope of the first line.

The depths of the various layers are calculated from the respective velocities in the layers and the distances at which the velocity curves intersect. Thus the depth of the first layer for the case considered above is given by

$$d_1 = \frac{L_1}{2}\left[\frac{V_2 - V_1}{V_2 + V_1}\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots (4)$$

The actual arrangement of the time-interval measuring unit can take several forms, but in the I.M.C. form of apparatus meter displays are used, one for indicating the digits 0 to 9 × 0·1 millisecond, one the digits 0 to 9 × 1·0 milliseconds, one the digits from 0 to 9 × 10 milliseconds, and finally one the digits from 0 to 9 × 100 milliseconds. A schematic of the time interval unit is shown in Fig. 6. Finally, the apparatus in use in the field is shown in Fig. 7.

Road Roughness Measurement

An important need at the present time is for a piece of apparatus for measuring the surface smoothness of highways, roads, city streets and air strips. There are various forms of apparatus for making this sort of measurement, but the most popular is the electronic type of indicator. This comprises a recording instrument and a test tyre in a balanced frame. As the trailer carrying the test tyre moves along the road any variations of the surface of the road causes the test tyre to raise or lower its axis. In the usual form of apparatus the vertical movement of the axis is converted into electrical impulses of varying intensity which are transmitted to an instrument panel. The display is in the form of an oscillographic display of the type shown in Fig. 8.

Acknowledgments

I am indebted to the Directors of the Instrument Manufacturing Corporation (S.A.) Ltd., Cape, South Africa, who have allowed me to use Figs. 3 and 7.

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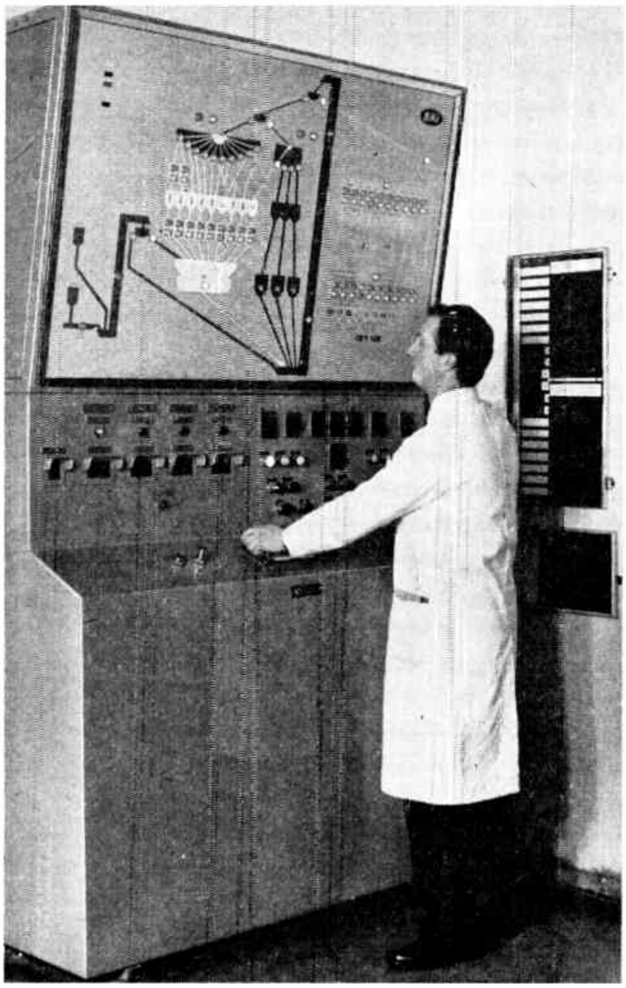


The main mimic diagram and control console

PROGRAMMED BREWING

MALT handling plant at Whitbread's brewery in Chiswell Street, London, has been modernized and converted to give greater efficiency of control with increased speed. Brookhirst Igranic has collaborated with Whitbread engineers and W. & T. Avery to provide the new system.

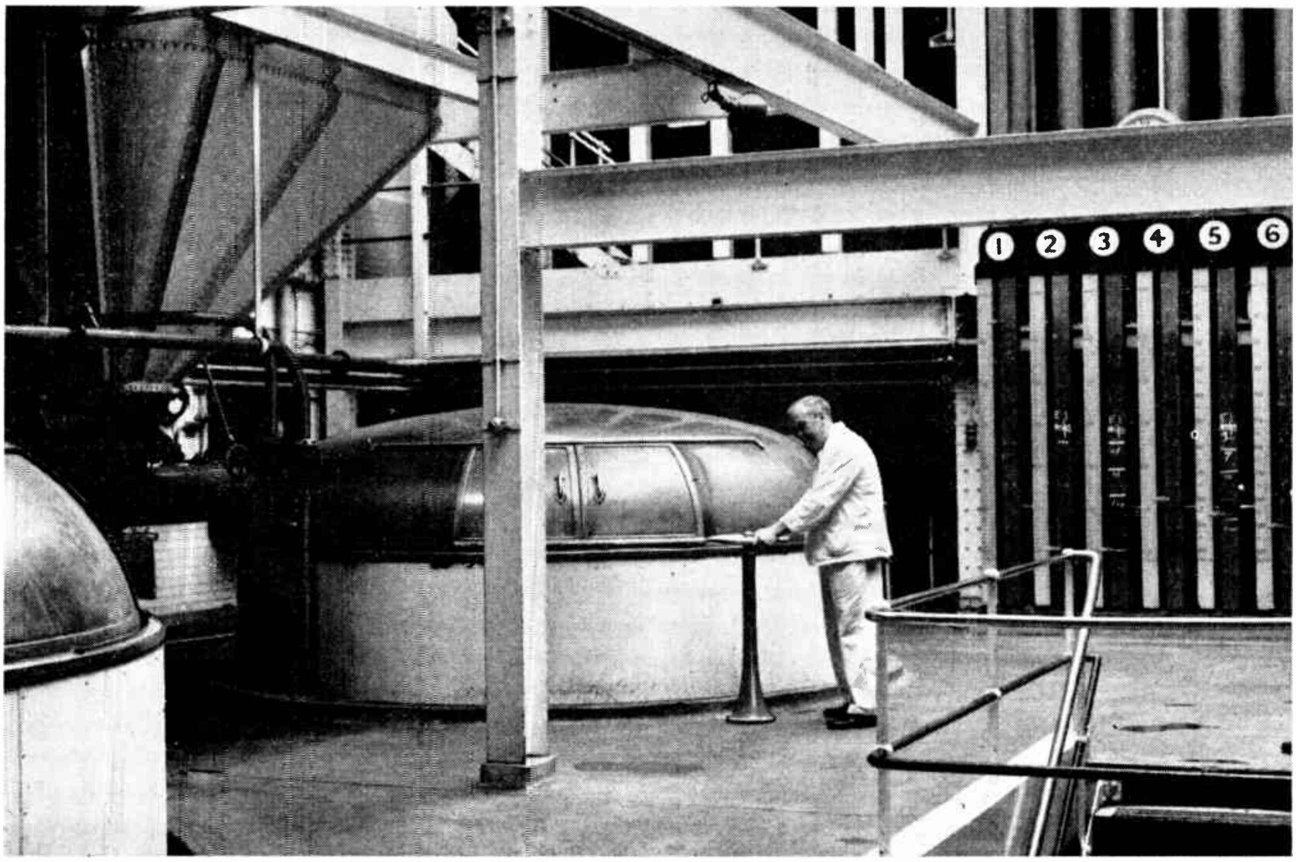
BHI Bistat static-switching controls co-ordinate the selection and sequence of the different valves, elevators and conveyors in association with Avery weighers, a weighing control console and a punched-card system.

Conventional BHI starters control the conveyors while solenoid-operated pilot valves serve the air-cylinder-operated slide and flap valves, the latter being controlled directly from the Bistat panel. One hundred BHI contactless proximity limit switches on the valves are interconnected by telephone-pattern multicore cables.

Indicating lamps on the main mimic diagram in the brewers' control room are duplicated on ancillary consoles to depict the routes—'intake to loft', 'loft to loft', 'loft to hopper'. At initiation of a route, a flashing signal is given but when the appropriate valve has reached the final position the light becomes steady so that a clear indication of the state of the plant is always available.

The brewer selects a card punched with the quantity and types of malt needed for the brew. Insertion of the card in the console causes the Bistat panel to select and control the correct conveyors and valves. Upon completion of service and checking, the plant closes down ready for the next brew instruction.

A view of the mash pan and level indicators



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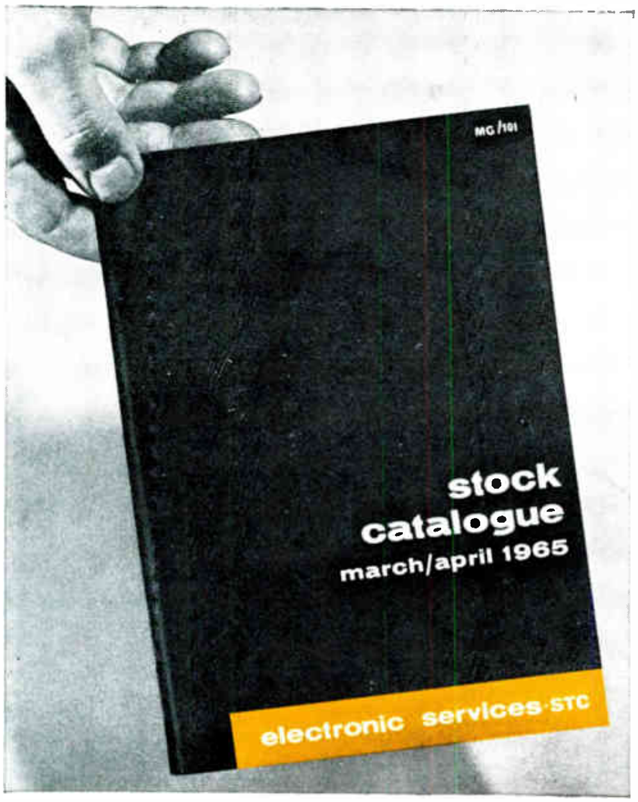

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A telemetry system, the transmitter of which is fixed to the piston of an i.c. engine, is described in this article. It is used for determining conditions inside an engine.

PISTON ENGINE TELEMETRY

By ***R. E. YOUNG,*** *B.Sc.(Eng.), M.I.E.E., A.F.R.Ae.S.*

PRECISE knowledge of the physical conditions existing inside an internal combustion engine has always been exceedingly difficult to obtain. This is, of course, particularly true of the various reciprocating elements in the engine, where direct measurement has proved virtually impossible.

Thus, for instance, piston temperatures have been deduced rather than measured by fusible plug interpolation and observation of metallurgical states. These methods are far from dynamic (instantaneous)—metallurgical observation only gives an end-point indication—and such measurements have had to wait for electronic systems to make them practicable.

Attempts have been made to bring out measurement data from pistons through bottom-of-stroke contacts and flying leads; but although some success has been achieved, these methods have definite limitations. Consequently, in order that further progress in research and development could be made, it was natural to turn to electronic techniques, and to telemetry in particular, to provide the advanced instrumentation facilities required.

Associated Engineering Ltd., a large group with major interests in pistons and allied i.c. engine components, have done a great deal of work in this field. Their group research and development organization at Cawston, near Rugby, has evolved an analogue telemetry system which gives graphical presentation of relative motion of, say, a piston with respect to the cylinder liner, in addition to temperature measurements at selected pick-off points in, for example, a piston crown.

The Sender

The engine sender installation is of particular interest because a number of unique problems have had to be solved. Among these is the adverse environment to which the sender is subjected. In this field of work, design is based on working temperatures up to 150 °C (taken as an appropriate maximum for silicon transistors in this case) and acceleration values of 500 *g* corresponding to 3,000 r.p.m. Acceleration forces are built up cyclically over each revolution of the crankshaft, and so the sender has been tested up to 2,000 *g* continuously-reversing acceleration.

In the final version of the sender installation, the two main capsules (potted in Araldite F) are mounted together on the connecting rod away from the piston. This has several advantages over the original placing within the piston skirt, including a better (less screened) radio path between the transmitter and the receiving aerial in the crankcase, and a reduction of the change in piston motion relative to its normal unloaded behaviour by virtue of the removal from it of the sender mass.

Data signals from the various probe and thermistor points are conveyed to the sender through a spring linkage system. P.t.f.e. sleeving, interposed between the spring and its supporting metal arc, provides insulation and, in effect, a lubricating action.

Sender power is supplied from six Mallory RM625R mercury cells with special high-temperature seals, mounted with their plates along the main direction of acceleration so that the liquid mercury is not forced away from the end plates in the cells. The battery-box is carried on the big-end bottom cap; and it has been found convenient to switch on by completing the big-end assembly, the power supply connection being made through a plug and socket as the bottom cap is attached to the main part of the connecting rod.

With cells somewhat larger than in the earlier models, their life is of the order of 24 hours with a current drain for the whole sender of about 10 mA. It has been found that the 24-hours' life given in a hot engine is about double that obtained at ordinary room temperatures. The exact mechanism involved is not fully understood; but it has been observed that if the cells are allowed to cool down, some form of irreversible action takes place and no further output is obtained when the temperature is raised again.

There are two main versions of the sender, for use with probes (Fig. 1) and thermistors (Fig. 2) to give data on mechanical movement and temperature respectively. Both versions employ the same modulator/oscillator transmitter block, the basic circuit diagram of which is shown in Fig. 3. The transistor Colpitts oscillator operates at 86 Mc/s, frequency modulated by a voltage unit (capacitive diode) with a deviation of 1 kc/s per millivolt. A transmitting aerial is not fitted, sufficient radiation being obtained from the oscillator tank coil. Carrier-frequency temperature compensation better than $\frac{3}{4}$ Mc/s per 100 °C is achieved by a method, of commendable simplicity, in which a silicon

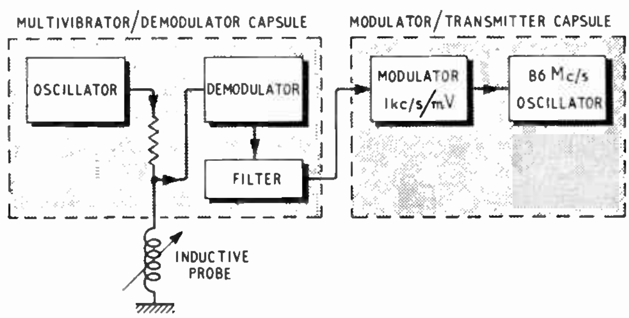
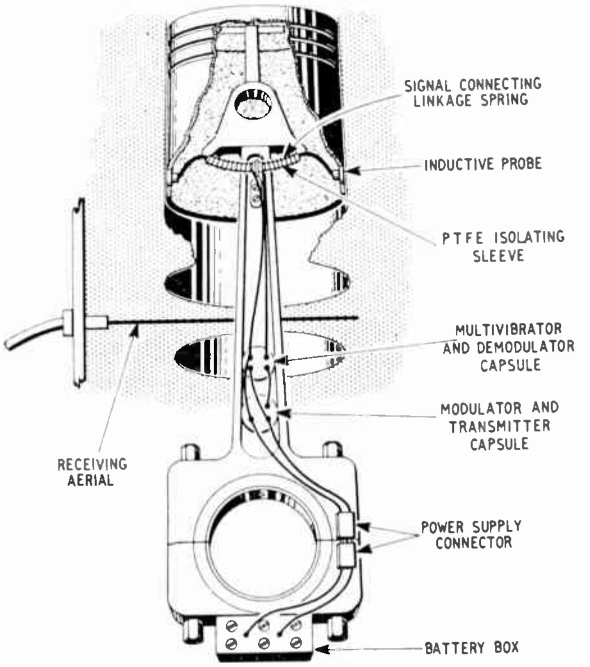


Fig. 1. Form of transmitter for an inductive probe



General form of piston and crank showing how the transmitting elements are situated and their relation to the receiving aerial

'Sensistor' junction capacitance, effectively in series with the silicon transistor oscillator, reduces the current in its own path with rise of temperature. Zener diode voltage stabilization is also applied.

Transducer Elements and Systems

To date, two basic types of transducer probe have been developed at Cawston for mechanical measurement. The first of these, a capacitive probe, consists of an insulated electrode placed in close proximity to the surface (e.g. the cylinder liner) relative to which motion is being measured. When used in the piston, this type of probe is connected directly to the transmitter oscillator, so that direct frequency modulation is obtained with variation in distance, and hence capacitance, between the piston electrode and the cylinder wall. With a special high temperature coaxial cable lead between the probe and the oscillator (brought to the transistor collector), giving a total standing input capacitance of some 13 pF, a change in spacing of 0·001 in. produces a change of 0·01 pF, resulting in turn in a carrier frequency change of 10 kc/s.

The main disadvantage of the capacitive transducer is that entry of oil into the gap between the electrode and the complementary surface produces an anomalous change in capacitance which is dependent on the degree of 'filling' and the dielectric constant of the oil. The errors thus produced are far from negligible especially when 'ring flutter'* is being investigated.

To overcome these difficulties an inductive probe has been developed by the Cawston team. The final design, possessing a number of novel features, has proved extremely satisfactory, and is now being made available commercially.

The construction is based on a core of iron wires which are oxidized to give surface insulation and thus prevent eddy currents from flowing. Individual wires are in the form of a U, and are pushed into the centre of the pick-up coil so that they envelop it except at the working face of the probe. The latter appears as a series of concentric regions. In the centre the iron wires form an armature-like core which is surrounded by the end of the cylindrical winding of the coil, and this is contained within an annulus made up of the outer limbs of the iron wire Us.

The coil winding is brought out through printed-circuit type connections, and the whole assembly is potted in Araldite F. A temperature rating of 150 °C is quoted for the probe, for which there is no appreciable change in sensitivity, and which is consistent with the high temperature properties of the potting material. As far as the soft iron itself is concerned, with a Curie Point of 770 °C it may be taken that its permeability will not change up to a value of two-thirds of this temperature; i.e., it is workable up to about 600 °C. In this connection, experimental probes are being made of ceramic construction embodying a special form of glaze, the whole unit being filled under vacuum and then baked.

A useful feature of the standard type of probe is that it can be used on a curved surface. After being inserted normal to the tangential plane, the end of the probe is machined off to give a flush surface. The probe is then re-calibrated with reference to a simulated curved liner, say, of the form with which it will be used.

The dimensions of the two sizes of probe, including printed circuit terminations, are: (a) large size: length 0·430 in., diameter 0·250 in., weight 0·7 gram; (b) small size: length 0·400 in., diameter 0·160 in., weight 0·5 gram. The core construction is such that energizing carrier frequencies up to 300 kc/s can be used with these instruments, enabling mechanical displacements at frequencies from zero (static position) up to 60 kc/s to be recorded.

* Ring movement in the piston groove leading to passage of oil past the piston into the combustion chamber.

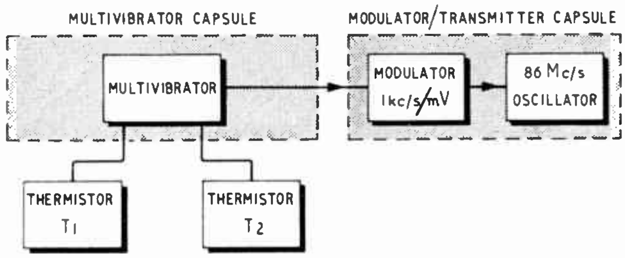


Fig. 2. Form of transmitter for temperature measurement

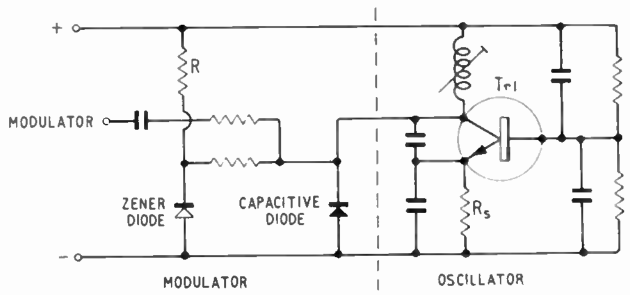


Fig. 3. Basic circuit of transmitter

The sender sub-system associated with the inductive probes is a rather more complex arrangement than that adopted for direct modulation by the capacitive probes. In this instance the inductive probe is put in series with a load resistor and connected across a sub-carrier oscillator running at about 200 kc/s. This modulated waveform at sub-carrier frequency is then demodulated to extract the original measurement (frequency) signal, which is applied to the final modulator through an RC filter.

As already indicated, temperature measurement involves a somewhat different approach, with thermistors (STC type M15) used as temperature sensing elements. The thermistor is arranged to control the pulse width of a multivibrator having a square-wave output with a nominal mark-space ratio of 1 : 1. Temperature calibration is given against pulse width in microseconds. Initial work was performed with a multivibrator repetition rate of 5 kc/s; but this is being reduced to 500 c/s to obtain higher reading accuracy on the wider pulse width. This reduction in rate is quite permissible in relation to the comparatively slow variations which take place in temperature.

Development is proceeding to produce a form of time-division multiplexing in which the two successive pulses of the multivibrator square wave are individually controlled by two thermistors T_1 and T_2. Identification of T_1 and T_2 readings can be achieved by relative biasing of the two parts of the waveform.

Receiving System

The receiver itself, fed from the aerial in the crankcase, employs a transistorized r.f. preamplifier and wideband i.f. amplifier covering some 5–6 Mc/s centred on the 86-Mc/s input signal. A.f.c. action is provided by a high-gain system with a time constant greater than the fluctuation periods of the wanted signal. Automatic gain control is necessarily extremely wide-range and rapid because of the huge variations (up to 60 dB) in r.f. signal strength between bottom and top dead-centre positions. In practice about 40 dB in the range is provided by the actual a.g.c. circuit, backed up by some 40 dB limiting; the post i.f. limiter is always held at saturation level. A Foster-Seeley discriminator, with linear output over an input range of 400 kc/s, feeds out through a cathode follower. The high input impedance of the latter enables a level response to be obtained from the discriminator up to 50 kc/s.

Measurements are presented by conventional graphical recording methods. In addition, the pulse-width temperature data, obtained from a counter as time readings (in microseconds), are also logged on a digital printer. An alternative method of display would be meter presentation obtained by integration. With multiplexed working for two thermistors, the integrator could be arranged to trigger from the positive-going edge of the pulse signal for one temperature reading and from the negative-going edge for the other.

Possibilities for the Future

The Associated Engineering team is continuing to look into the future and to work on relevant developments.

One ingenious idea for multiplexing is to move a mechanical sampling switch from step to step by utilizing the reversal of motion which is available within the engine from its reciprocating action. One signal step would presumably be allocated to identification and synchronization of the time-division cycle.

Various methods of obtaining a continuous power supply to the sender have been considered. Should the limited running time offered by the primary cells be replaced by an essentially unbroken period, the already extremely valuable results obtained could be extended in scope to a great degree, especially for high speed investigation.

Also if this power supply problem could be solved, there would appear to be an application for the system in marine engine work, where there is a demand for continuous information on big-end and other temperatures which cannot be satisfied at present.

Automatic Filling of Bulk Transporters

At the Rochester Works of Rugby Portland Cement they have developed and installed an automatic-loading plant for speedy and efficient dispatch of the bulk transporters. Working on a 24-hour day basis, lorries are tared off and automatically filled to a predetermined set weight.

The loading plant consists of four silos—each containing 250 tons of different grades of cement. Beneath the silos are two 32-ft long weighbridges both of which have a capacity of 30 tons. Each of the weighbridges is served by two silos.

When a bulk transporter drives on to the weighbridge a card is automatically printed with the tare weight.

At this stage the weighbridge attendant sends an electrical signal to the operator in charge of the silo valves to tell him from which of the four silos the bulk transporter is to be loaded. Once the signal has been sent it automatically blocks the other three silos to prevent the possibility of the wrong cement being loaded. The lorry driver then attaches a flexible trunking to the bulk transporter ready for filling.

Meanwhile the weighbridge attendant has set the indicator on the weighing machine to deliver the required gross weight. When the correct weight has been delivered the valve automatically closes. Cut-off of the cement at the predetermined weight is controlled by an electronic switch fitted to the scale, operation of which automatically stops the feed of material.

During the filling operation the valve operator on the silos can, if necessary, manually control the flow of cement within the limit set by the weighbridge attendant. It takes approximately the same time to fill both the 8- and 15-ton transporters, approximately 8 min.

On completion of loading the weighbridge attendant again presses the handle on the printing unit which then records the gross weight of the bulk transporter. As well as printing tare and gross weights on this card, the machine also prints internally on paper tape to produce another permanent record.

The plant can dispense between 200 and 250 tons of cement per hour with both weighbridges in operation. All the weighing equipment and its control gear were built and supplied by Henry Pooley & Son Ltd., of Birmingham.

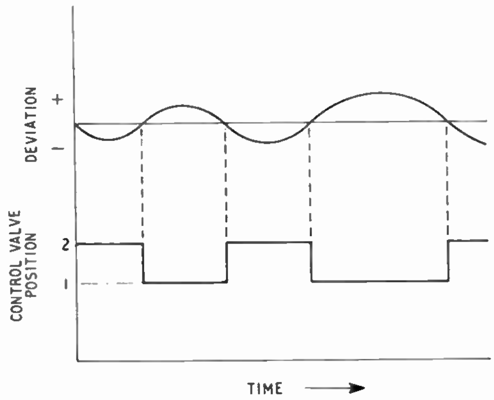
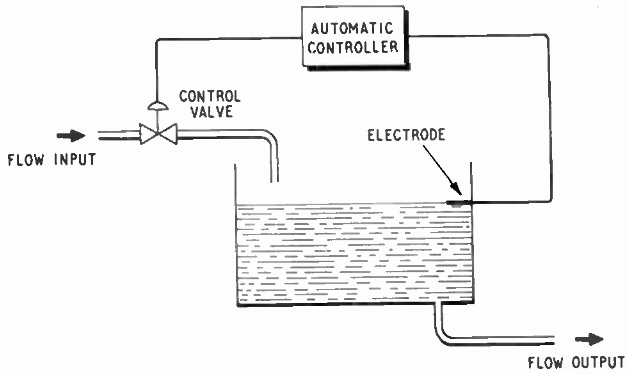


Fig. 1. Two-step control

Fig. 2. Two-step flow control using a liquid level controller



Some of the more important terms used in automatic control are explained in this article in relation to some simple examples of such control.

AUTOMATIC CONTROLLER ACTION

By *J. C. McVEIGH,*
M.A.(Cantab.), M.Sc, Ph.D., A.M.I.Mech.E., A.F.R.Ae.S.*

IN the automatic controller† a signal from the detecting element is compared with a signal representing the set value of the characteristic. The difference between the two signals is known as the deviation, θ, and the automatic controller transmits a control signal to the correcting unit which acts to reduce the deviation. The set value is the value of the characteristic to which the automatic controller is set and need not necessarily be the same as the desired or specified value of the controlled condition. In most flow-control problems the correcting unit is a control valve of the type discussed in last month's issue. The relationship between the deviation and the control signal depends on the type of controller selected for each particular application. One of the major factors influencing the choice of controller is the dead time or time interval between a change in the signal to the system and the initiation of a perceptible response to that change.

Two-Step Control

The control signal changes from one predetermined value to another when the deviation changes sign as in Fig. 1.

* Borough Polytechnic.
† The terms used in this article are those recommended in B.S. 1523: Section 2: 1960 'Glossary of Terms used in Automatic Controlling and Regulating Systems'.

Fig. 3. Two-step control with overlap — no controller action between levels h_1 and h_2

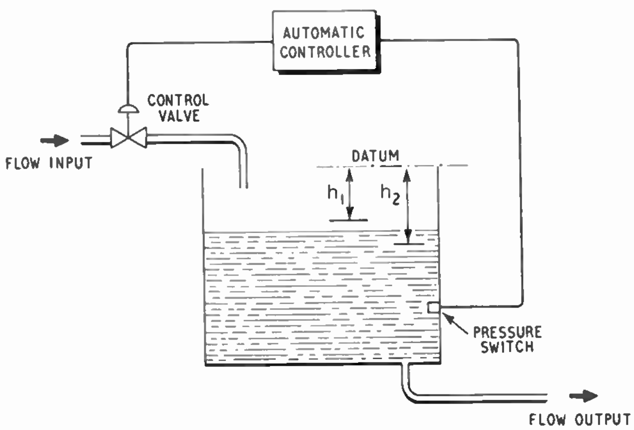
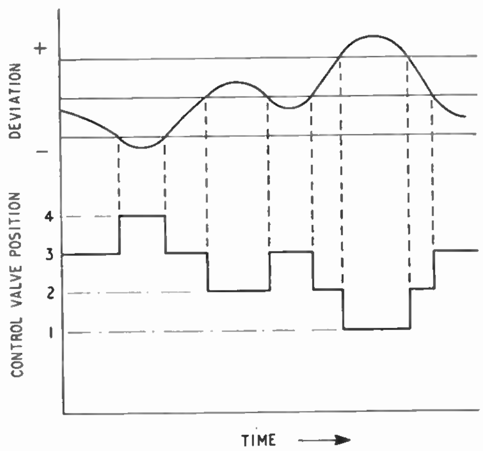


Fig. 4. Multi-step control



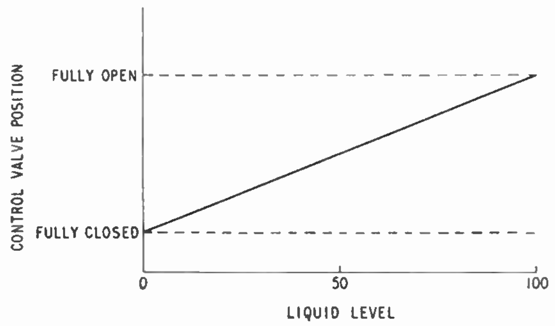
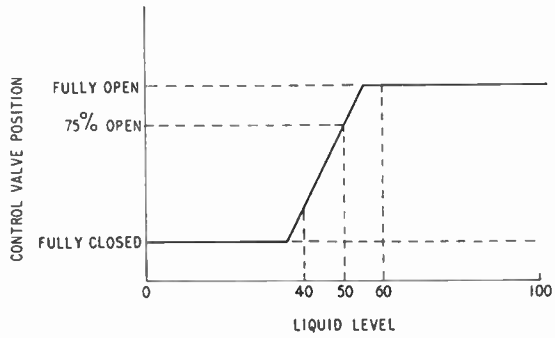


Fig. 5. A 100% proportional band

Fig. 6. A 20% proportional band



With this type of control a control valve could only take up two different positions and could not remain at any intermediate point. In the special case where the two positions are fully open and fully closed, the controller is appropriately called an on-off controller. Two-step control is the simplest form of automatic control and can generally be used where slow process load changes are anticipated provided the dead time is small, e.g. in keeping the flowrate constant from a vessel with a large capacitance by using a conductivity probe type of liquid level controller as in Fig. 2. This method depends on the presence or absence of a conducting path between the tank and an electrode inside it. The path only exists when the electrode is immersed in the liquid.

Valve wear that could be caused by rapid cycling between the two positions can be reduced by adding overlap to the two-step control. With overlap the control signal changes from one predetermined value to another only when the controlled condition alters from one to another of two chosen states. This is illustrated in Fig. 3 where the controlled condition is the head of liquid above a pressure switch. The pressure switch sends a signal to the controller which in turn opens the control valve when the liquid level falls below h_2 and closes it when it rises above h_1. The difference between these states determines the overlap. Any change in level which takes place between h_1 and h_2 does not cause a change in the control signal. Another term commonly used for this region is the dead zone.

Three-Step and Multi-Step Control

In some applications it is desirable to avoid the heavy fluctuations of input encountered with two-step control and the control signal changes in steps so that the control valve can stop in predetermined intermediate positions as in Fig. 4.

Floating Control

Another variation of two-step control is single-speed floating control in which the control valve is moved at a constant speed in a direction which depends on the sign of the deviation. When the controlled condition is outside the dead zone, valve movement occurs until the valve is either fully open, fully closed, or until the controlled condition has returned to the dead zone. With multi-speed floating control the valve speed changes in steps depending on the magnitude and sign of the deviation. Compared with two-step control, the main advantage of floating control is that cycling can be reduced under conditions of small process load changes as there is a correspondingly small alteration in the valve position. Both types of control are unsuitable for systems with a large dead time or rapid process load changes.

Proportional Control

The output signal from the controller is proportional to the deviation from the set value. This can be expressed mathematically by the equation

$$V = -K_1\theta$$

where V is the output signal and K_1 is the proportional action factor. The negative sign is conventional because as θ increases V must act in the opposite sense. It must also be emphasized that these mathematical expressions are ideal and real systems do not obey them exactly as V, K_1 and θ are not fundamental values. The effect of the output signal on the controlled condition depends on other factors such as the characteristics of the control valve in flow-control problems. A simple example of proportional control is the ball-cock and cistern found in the domestic water system. The water level in the cistern is the controlled condition and the rate of flow from the cistern is the process load. The position of the inlet flow control valve is approximately proportional to the water level and there is only one particular level which corresponds to each flowrate. It follows that with proportional control the controlled condition can only be at the set value for one process load. At any other sustained process load there will be a sustained deviation or offset from the set value.

The proportional band is that range of values of deviation corresponding to the full operating range of output signal from the controlling unit resulting from proportional action only. It is often expressed as a percentage of the range of values of the controlled condition which the measuring unit of the controller is designed to measure. For example, if the system shown in Fig. 3 has a proportional controller used with the pressure switch and the range that can be measured is 100 in. change of level from some datum, the relationship between control valve setting and liquid level might be as shown in Fig. 5 with

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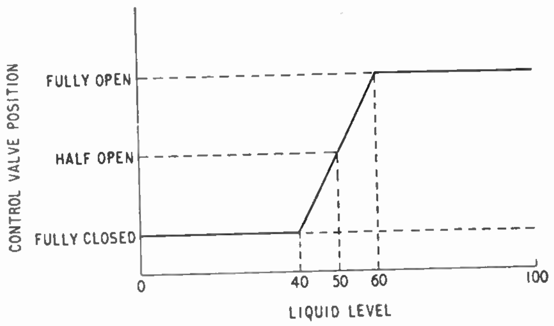
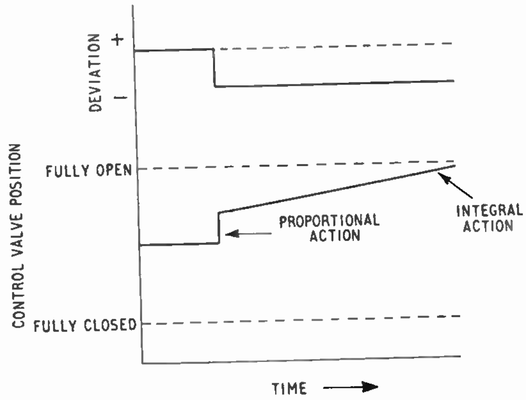


Fig. 7. A 20% proportional band moved down to eliminate offset

Fig. 8. Response to a two-term controller



the set value at 50 in. (assuming that the valve has a linear characteristic). This would be a 100% proportional band. The magnitude of the control valve movement for unit changes in the controlled condition depends on the width of the proportional band and if it was desired to have five times the valve movement for a change in level near the set value, the relationship would be altered as shown in Fig. 6, giving a 20% proportional band. Offset can be eliminated by moving the proportional band up or down the scale and this can be done manually or automatically. In Fig. 6 the control valve is half open when the level is at the set value. If there is a sustained process load change which results in a larger flowrate being demanded with a 75% valve opening, the proportional band will move down as shown in Fig. 7 to keep the level at the set value. It is clear that the use of a narrow proportional band leads to a quicker correction of the deviation and a smaller offset, but while this is theoretically desirable a wide proportional band is needed to deal with difficult conditions such as a small process capacitance or a large process load change.

Integral Control

The rate of change of the output signal from the controller is proportional to the deviation from the set value. The mathematical equation is

$$V = -K_2 \int \theta dt$$

where K_2 is the integral action factor. Integral control is usually combined with proportional control and has the effect of moving the proportional band to return the controlled variable to the set value as in Fig. 7. Also known as two-term or proportional-plus-reset control, the total valve movement is made up of a response due to proportional action and a response due to integral action as shown in the ideal diagram, Fig. 8. Compared with proportional control, the two-term controller can deal satisfactorily with the difficult conditions of a small process capacitance and a large load change mentioned above but neither can tolerate a large dead time.

ELECTRONICS
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Derivative Control

If a manual operator is controlling a process which has a large dead time he can anticipate and greatly reduce the effect of any deviation by opening or closing the control valve to give overcorrection. This slows down the rate at which the deviation is changing until the controlled condition starts returning to the set value and the control valve can be readjusted accordingly. The experienced operator bases the amount of valve alteration on this rate of change of deviation. When this type of correction is done automatically it is known as derivative or rate control. Derivative control cannot be used alone as the output signal is not directly dependent on the deviation but is proportional to the rate at which the deviation is changing. Mathematically the equation is

$$V = -K_3 \frac{\theta d}{dt}$$

where K_3 is the derivative action factor. Derivative control is combined either with proportional control or with two-term control. The great advantage of including derivative control is that it can deal with processes having a large dead time by providing an initial overcorrection. This is particularly valuable where temperature lags occur and a very wide proportional band setting would be needed with two-term control.

Conclusion

The types of controller action discussed in this article can provide a basis for further study of process control. Two special techniques are worth mentioning as they are widely used in process-control calculations. In the transient response method a step change is applied to the system and the data is presented in the form of curves relating the controlled variable or deviation to time. A sine-wave disturbance of varying magnitude and frequency is applied to the system in the frequency-response method. Curves relating the ratio of the output and input amplitudes to the frequency, and the phase angle shift to the frequency can be obtained. A more detailed discussion of the methods used to determine which type of control should be selected in any particular application is beyond the scope of this article, but it is always true to say that the best type of control is the simplest one which can satisfy the process requirements.

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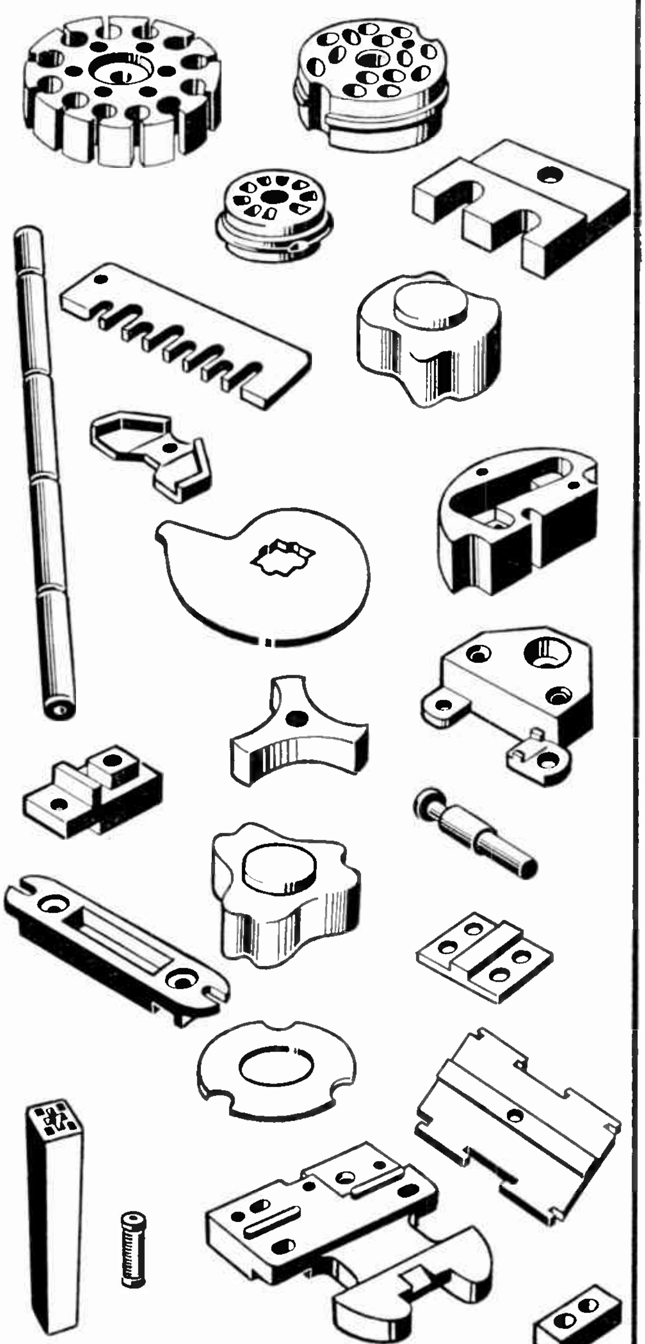

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NEW APPARATUS
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1. Dry-Transfer Lettering

Presletta, newcomers to the dry-transfer lettering market, offer a wide range of type faces and sizes, including many of the increasingly popular 'continental' type faces which are not currently available elsewhere in the form of dry-transfer lettering.

Presletta sheets are produced on non-stretch carrier film measuring 10 in. wide by 7½ in. deep, a size chosen for convenience in handling. As well as the normal sheets of alphabets, separate sheets of extra vowels and figures in all faces are available, together with a comprehensive variety of conventional and technical signs and symbols. An attractive individual protective-sleeve pack is provided for each set of sheets.—*Admel, 28 Victoria Street, London, S.W.1.*

For further information circle 1 on Service Card

2. Magnetic Tape Bulk Erasers

Harvey Electronics have announced that a full range of bulk erasers for recording tapes is now in production, and any of the twelve models can be obtained from stock. They will handle tape spools up to 12 in. diameter and 1-in. N.A.M. tape, both technical and audio.

Complete erasure of even the largest spools can be accomplished in seconds, the tape being left in a completely neutral condition. These instruments can also be used to demagnetize small parts such as hand tools, ball races, gears, etc., and watches. Prices range from £6 5s. to £15 10s. retail.—*Harvey Electronics Ltd., 308 Farnborough Road, Farnborough, Hants.*

For further information circle 2 on Service Card

3. Powerful Miniature Fan

A. K. Fans have introduced a robust miniature axial-flow fan measuring 2½ in. in diameter and 1¾ in. long, which will produce an output of 53 c.f.m. against a static pressure of 5 in. water gauge. The motor windings are completely encased in a plastic moulding, so that the motor is extremely robust and resistant to moisture. In fact, the manufacturers claim that one unit was run for several weeks under water.

The fan is designed for operation on 400 c/s a.c. supplies and the rotor speed is 22,000 r.p.m. It is dynamically balanced to within 10 mg cm at each bearing. A feature of the aerodynamic design of the fan is that it has a non-overloading power characteristic, so that should the airway in which the fan is operating become blocked, the motor becomes less heavily loaded, thus minimizing the chance of burn-out.—*A. K. Fans Ltd., 20 Upper Park Road, London, N.W.3.*

For further information circle 3 on Service Card

4. Ultra-Miniature Headset Microphone

S. G. Brown have announced an ultra-miniature headset microphone weighing under 1 oz and capable of withstanding 10,000 *g* instantaneous. This unit was originally developed for use in the Mercury space capsule.

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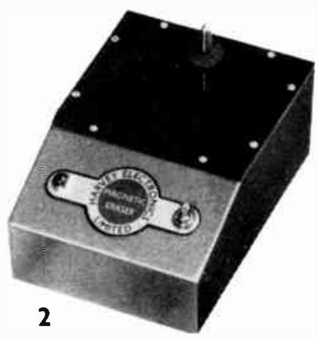
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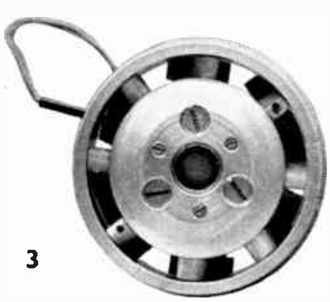
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NEW **ELECTRONICS INSTRUMENTATION CONTROL**

The headset consists of a small twin-transducer unit containing a miniature magnetic microphone and receiver. The capsule slips on to the user's spectacle frame, or on to the ultra-light-weight adjustable headband supplied. Alternative methods of mounting will enable the unit to be anchored to a helmet or other headgear. A double earpiece assembly is also offered.

Speech is conducted to the microphone via an acoustic tube attached to the transducer unit. This tube is highly efficient in attenuating sibilants and extraneous noise. The output from the magnetic receiver is conducted to the ear via a small flexible plastic tube terminated by a moulded germicidal plastic tip. The tip is heat-sensitive and moulds itself into the shape of the aural cavity through body temperature. An alternative earpiece is anchored just outside the ear. Foot-operated switches leave both hands free.

This headset microphone can replace the handset commonly used on mobile radio-telephone installations, thus overcoming objections to operation while the vehicle is in motion. The microphone output can be used directly for dynamic drive circuits, and amplifiers are available to match the microphone to carbon-microphone circuits.—*S. G. Brown Ltd., Communications Division, King George's Avenue, Watford, Herts.*

For further information circle 4 on Service Card

5. Changeover Relays

A range of a.c./d.c. relays which have a minimum mechanical life of 20 million operations has been introduced by Londex. The average life of the silver contacts used in these relays (type TOP) is 5 million operations on non-inductive loads at typical ratings of 6 A 240 V a.c. or 12 V d.c.

Two- and three-pole changeover models are available in either enclosed or unmounted forms. Enclosed relays are provided with Makrolon dust covers and are fitted to plug-in bases, standard octal in the case of two-pole relays and standard 11-pin for three-pole types. A connection diagram is imprinted on the top of the cover, which also carries lugs to locate a spring retaining clip. Unmounted relay contacts terminate in solder tags fitted in a contact panel.

Maximum contact ratings, non-inductive, are: a.c. 6 A, 440 V, 1,500 W; d.c. 6 A, 250 V, 75 W up to 50 V and 20 W at 100 V or over. Coils, which will operate the relay over the range +6% to −15% of the nominal voltage, consume 4 VA continuous, 7·5 VA inrush, at 50 c/s a.c., or 2 to 3 W on d.c. Operate and release times are 3 to 10 msec on a.c., 15 to 30 msec on d.c.—*Londex Ltd., 207 Anerley Road, London, S.E.20.*

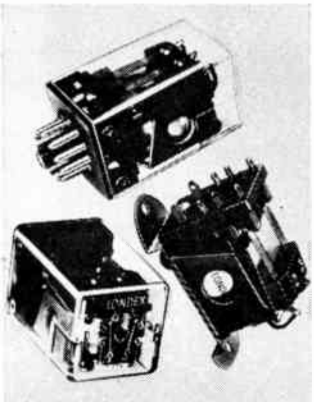
For further information circle 5 on Service Card

6. 80-Amp Synchronous Time Clock

Engel & Gibbs have introduced an 80-A time clock fitted with a single directly-operated mercury switch, which can be supplied in multiple versions when used in conjunction with a relay. The moulded bakelite case has a Perspex window so that the clock setting can be ascertained without removing the case. A special feature is the separate cover to enable wiring of the unit to be carried out without removing the main case which can be sealed if required.

The unit is available with or without spring reserve. Another feature is that the manual override switch operates instantaneously and resets automatically. The time clock can be supplied with a day omission device and up to three pairs of hands per dial, should these be required.—*Engel & Gibbs Ltd., Elstree Way, Boreham Wood, Herts.*

For further information circle 6 on Service Card



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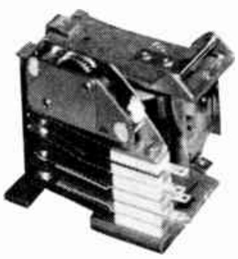


7. Impulse Relays

A range of relays with mechanical inertia impulsing contacts is announced by Elremco. Unmounted and plug-in versions are available and there are two basic frame sizes. The impulse contacts give positive operation on either energization or de-energization, ensuring that double or reverse impulsing cannot occur. Impulse duration is approximately 60–80 msec.

The range comprises types HR.111 and HR.114, both suitable for a.c. or d.c. operation. The HR.111 (illustrated) can be arranged with up to three contacts (including one impulse type) and the HR.114 with up to six (including two impulse types). Operating life of better than 20 million operations is claimed for both units, with switching capacities of 10 A at 440 V a.c. and a continuous-current carrying capacity of 5 A at 250 V a.c. resistive. The maximum operating rate is 200 per minute with average release times of 15 msec (HR.111) and 25 msec

(HR.114).—*Electrical Remote Control Co. Ltd., The Fairway, Bush Fair, Harlow, Essex.*

For further information circle 7 on Service Card

8. Field Telephones

'Stanofones', field telephones built to withstand the rigours of building sites, forest clearing, farms, shops and factories, are now to be marketed in the U.K. by F. W. Reynolds under a sole agency agreement with the manufacturers, Standard Telephones and Cables.

Stanofones are tough, one-piece telephones that will operate over distances of up to 60 miles using a pair of wires. They are completely self-contained with their own batteries and calling-signal device. Retail price is £4 16s. per instrument. All U.K. enquiries should be sent to *F. W. Reynolds Ltd., 170 Chiltern Drive, Berrylands, Surbiton, Surrey.*

For further information circle 8 on Service Card

ELECTRONICS

9. Automatic Voltage Regulator

An automatic voltage regulator incorporating thyristors has been developed by AEI Electronics Group for static excitation applications. The regulator consists of a voltage-sensitive circuit, transistor amplifier, and thyristor output stage all mounted in a ventilated sheet-steel case suitable for mounting on any vertical surface.

The equipment, known as the type FV67, has been designed for supplying power to a.c. generator fields without the use of exciters. It is for machines with ratings up to approximately 5,000 kVA, the standard accuracy of control being $\pm 1\%$ from no load to full load. Response times of the order of 0·1 sec are possible providing suitable forcing margins are allowed on the generator.—*Associated Electrical Industries Ltd., Electronics Group, New Parks, Leicester.*

For further information circle 9 on Service Card

10. 100-Watt Radio-Telephone

A 100-W marine transmitter/receiver for coastal telephony, the 'Velorum', is now marketed by AEI Marine Communications Department. For simplex or duplex operation, the equipment is approved by the G.P.O. and the M.o.T. for use in vessels which are required to be fitted with R/T facilities, and also complies with the requirements of the Great Lakes Treaty.

In addition to coastal telephony bands in which there are 12 crystal-controlled spot frequencies for reception, the receiver covers broadcast, trawler and beacon bands, and can also incorporate direction-finding facilities. The transmitter has a built-in two-tone R/T alarm generating device which automatically modulates the transmitter when the latter is switched to distress frequency. The Velorum radio-telephone is mounted compactly in a single rack of modern design. Transmitter, receiver and power units can be withdrawn individually for easy maintenance. — *Associated Electrical Industries Ltd., Telecommunications Division, Marine Communications Department, Woolwich, London, S.E.18.*

For further information circle 10 on Service Card

11. Bearing Telemetry Transmitter

Industrial Electronetics Corp. have developed a four-channel telemetry transmitter to fit on the race of a bearing. The unit, which weighs 2½ oz, is in the shape of a torus 2½in. i.d., 3 in. o.d., and 1¼ in. high. It may be used to measure vibration, end-thrust, and temperature. An extension of the bearing race pins holds the transmitter in place.

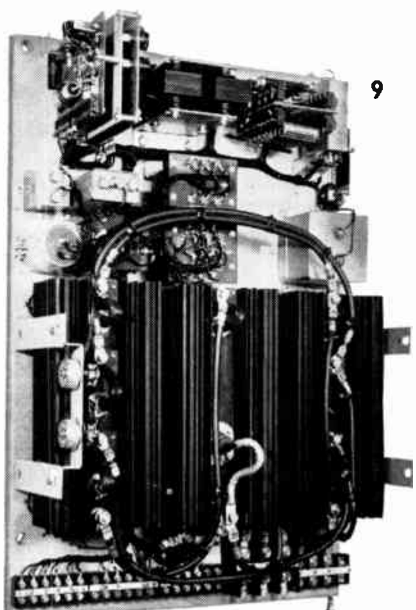
Data is transmitted without wire connections or slip rings to a nearby receiving station which monitors all of the channels simultaneously; vibration frequency response to 25 kc/s may be telemetered. Zero offset is provided to compensate for centrifugal force. The transmitter batteries may be recharged several hundred times in normal operation.—*Industrial Electronetics Corporation, Post Office Box 862, Melbourne, Florida, U.S.A.*

For further information circle 11 on Service Card

12. Six-Channel Amplifier

Fenlow Electronics are offering a 6-channel amplifier system, type R6, intended for amplification of low-level signals from thermocouples, strain gauges and transducers. The six amplifiers are contained in a standard 19-in. rack assembly, mains connections being made at the rear with the input and output available on the front panels.

The amplifiers, which have gains individually variable from 330 to 2,400,



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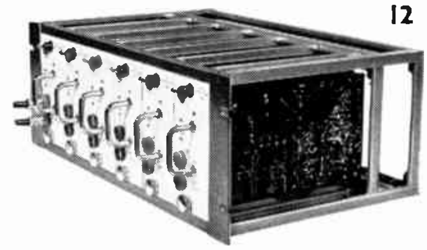


make use of photo-resistive choppers having a drift of less than 0·2 μV/°C. The high input impedance of 100 MΩ prevents loading of the source, and the high output current of 25 mA and bandwidth of 20 kc/s are suitable for driving ultra-violet recorders.—*Fenlow Electronics Ltd., Springfield Lane, Weybridge, Surrey.*

For further information circle 12 on Service Card

13. Automatic Electronic Switch

Panax have recently announced an addition to their range of PX plug-in nucleonic modules. The type PX.LMT.1 is an automatic electronic switch which is used in conjunction with a modular ratemeter to energize an internal relay. It can, for example, switch an external warning light or alarm bell when any preset level of radiation is reached. A single control on the front of the module is used to set the switching level, which can be any value between 10% and 100% of the ratemeter scale in use.

The uses for the new unit normally lie in radio-isotope laboratory radiation alarm systems, but an industrial application currently being developed employs it as part of a gamma liquid-level gauge for sealed pressure vessels, where indication of high and low levels is required by means of coloured lights. By changing a link in the PX.LMT.1, it may be made to operate in a reverse sense, so that an indication is given if the radiation falls below a preset level.

The output relay has two pairs of change-over contacts, one rated at 250 V 5 A a.c., and the other at 30 V 5 A d.c., the latter being intended for small signal currents. External connections to the relay are made via terminals on the rear panel, and to the ratemeter by a miniature jack socket and coaxial cable. In a typical system (illustrated) the PX.LMT.1, and ratemeter modules are mounted side-by-side in a case assembly which also houses a power-supply module.—*Panax Equipment Ltd., Holmethorpe Industrial Estate, Redhill, Surrey.*

For further information circle 13 on Service Card

14. Data-Circuit Matching Unit

Pulse Communications Inc. have recently introduced the Data Circuit Line Unit model 802-1, an inexpensive printed-card module for interfacing between data equipment and up to 0·01 μF cable capacitance, fully in accordance with the requirements of EIA Standard RS232A. Each unit provides two interfacing circuits combined on one board for economy of rack space.

The DCLU accepts polar signals of 3 to 25 V and delivers a polar 6-V output signal, at transmission speeds up to 2,000 bits per sec (higher with less than 0·01 μF load). Time delay between input and output is maintained at less than 6 μsec. When two DCLU circuits are driven from the same input signal, the output time delay difference is maintained at less than 2 μsec. A bias potentiometer permits shifting the input signal sampling point as much as $\pm$5 V about zero.

The DCLU is nominally 2 × 6 in., and up to twenty modules mount in the $5\frac{1}{4}$ × 19 in. mounting shelf model 10501-1, which also accommodates a plug-in power supply (model 5801-1) to operate from 115 V a.c. A second version of the DCLU, known as the Data Circuit Splitter model 803-1, provides a double output for each of two inputs; this also mounts in the 10501-1 shelf.—*Pulse Communications, Inc., 100 S. Early Street, Alexandria, Va., U.S.A.*

For further information circle 14 on Service Card

15. Display Modules for Binary Input

Integral translator-drivers now permit Dialco 7-segment display modules to operate from binary-coded decimal input. Translation is provided by diode gates. Standard circuits are available for many conditions, and translator-drivers with modified circuits can be designed to suit specific applications.

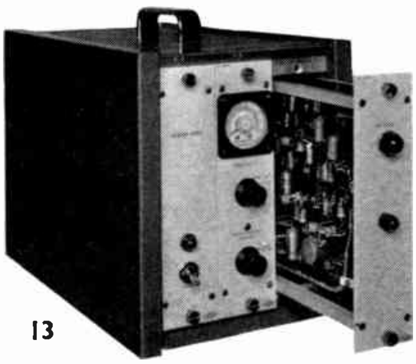
The components are compactly mounted on a glass-epoxy circuit board and securely attached to the separable rear portion of the display module. Memory circuits may be added if required. Amplification of the input signals is also provided when insufficient current is available from the logic circuit. — *Dialight Corporation, 60 Stewart Avenue, Brooklyn, New York 11237, U.S.A.*

For further information circle 15 on Service Card

INSTRUMENTATION

16. Automatic Radiation Counting Systems

A range of automatic solid-sample changing systems for use in medical, veterinary and other clinical and research applications which necessitate the automatic measurement of radiation energy, has been introduced by



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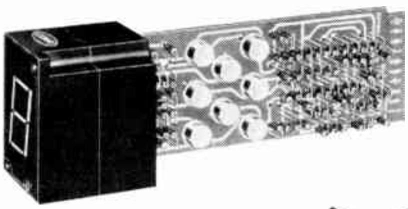

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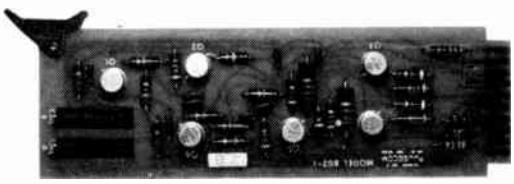

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Isotope Developments. The range comprises the Alphamat, Betamat and Lobetamat automatic counting systems for the measurement of alpha, beta and low-energy beta radiations respectively.

The Lobetamat system automatically feeds up to 50 separate samples consecutively to a lead-shielded Geiger-Muller twin-tube assembly. This consists of a thin end-window tube surrounded by a 'guard' counter which, in conjunction with an anti-coincidence circuit, provides additional shielding to eliminate the effects of background and cosmic radiation. A programme and read-out unit operates in conjunction with the scaler and a digital printer to provide a continuous record giving the sample number, the count and time.

The Lobetamat system can be pre-programmed in three modes: to switch off when all fifty samples have been counted; to re-stack the samples in their original order before switching off; or to re-stack and re-count, repeating this cycle automatically as often as may be desired.—*Isotope Developments Ltd., Bath Road, Beenham, Reading, Berks.*

For further information circle 16 on Service Card

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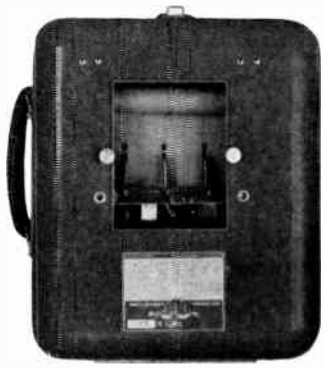

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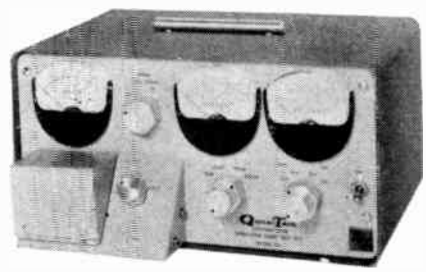

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17. Package Impact Recorder

Latter & Co. are now distributing in the U.K. a range of impact recording instruments which have been designed as an aid to better packing. These instruments are produced by Impact-O-Graph Corp., U.S.A.

The instruments are basically recording accelerometers which record shock and impact from three directions, longitudinal, lateral and vertical. Recording in three planes is achieved by the use of three independently-operating styli on a wax-covered chart. The chart can be static, moved in steps by a ratchet, or moved continuously by a battery or clockwork motor. A time scale or reference can be included.

A typical unit weighs 3¼ lb and measures 8×6×2¼ in. The range of recorders includes models with various motors and charts and with sensitivities from 2 *g* to 300 *g*.—*A Latter & Co. Ltd., 45 South End, Croydon, Surrey.*

For further information circle 17 on Service Card

18. Transistor Noise Test Sets

Quan-Tech Laboratories announce three noise test sets which offer an economical and convenient means for making rapid measurements of electrical noise in transistors as an aid to the elimination of failure-prone devices prior to installation, as well as to achieve optimum signal-to-noise ratio. These instruments are intended for applications where the full multi-point spectrum analysis of noise is not required as, for example, in production testing and quality control. They are readily adaptable to high-speed go/no-go test procedures, and may easily be integrated into existing component-testing programmes.

The three units are essentially similar except for their collector-current and frequency ranges. Designated models 510, 511, and 512, they have collector-current ranges of 0·1 to 10 mA, 3 to 300 μA, and 10 μA to 1 mA respectively. Noise voltage and current spectral densities are measured in the models 510 and 511 at 1 kc/s; in the model 512, broad-band noise figure measurements are made over a frequency range from 10 c/s to 15·7 kc/s. —*Livingston Laboratories Ltd., 31 Camden Road, London, N.W.1.*

For further information circle 18 on Service Card

19. Infra-Red Spectrophotometer

Hilger & Watts are now marketing the 'Infrascan' infra-red recording spectrophotometer, which covers wave numbers from 4,000 down to 650 in one scan on one chart. There are three sizes of charts and their ruled areas are 740 × 200 mm, 278 × 75 mm, and 139 × 38 mm; change of operation from one to another is by simple switching. Any part of the transmission scale can be expanded by ×5.

The standard scanning speeds are 4, 8, and 16 minutes for the full range; and for extra-high resolution a slow-scan motor, with speeds of 32, 64, and 128 minutes, is offered as an accessory. Automatic recycling of any region gives a record of spectral change with time. The operator can use, as standard, cells with up to 20-cm path-length: and, with a choice of three slit programmes, can adjust resolution as required for any particular programme.

The Infrascan has a double monochromator, with linked grating and prism, giving spectral purity and high resolution throughout the range. The electronics are transistorized and mounted on plug-in cards which fit into a rack at the back of the instrument. The rack hinges down, giving easy access for servicing and maintenance.—*Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.*

For further information circle 19 on Service Card

20. Marine Distance Recorder

An addition to their range of electronic aids for yachtsmen has recently been announced by Marine Electronics. Called the 'Sealog', it is a modestly priced (£45 retail) instrument for recording distance travelled. It can record nautical miles from zero to 9999·99 in divisions of 0·01 n.m.

The Sealog is fully splash-proof and contains 21 transistors. It is capable of operating from −5 °C to +40 °C, weighs 6 lb and measures $8\frac{1}{2}$ in. wide by 9 in. deep by $2\frac{1}{4}$ in. high. Powered by an ordinary ship's battery of 12 or 24 V, the Sealog obtains the required signal from the speedometer.

The controls are simple, consisting of two knobs: the first is the ON/OFF switch and dial illumination control and the second is an electrical reset which enables the operator to return the dial to zero at any time.—*Marine Electronics Ltd., Endeavour House, North Circular Road, London, N.W.2.*

For further information circle 20 on Service Card

21. Elapsed Time Indicators

A series of miniature elapsed-time and events indicators are now available from A. W. Haydon Co. of Connecticut, U.S.A., through Walmore Electronics. These have found general acceptance in the American missile and aircraft industry because of their small size, rugged performance and wide operating temperature range.

Both the elapsed-time and the events indicators weigh $\frac{3}{4}$ oz and have a $\frac{1}{2}$-in. square cross-section. The elapsed-time indicator (type 19200) is $1\frac{1}{16}$ in. long and the event indicator (type 19500) is $1\frac{5}{16}$ in. long. They are available in a variety of standard mountings.—*Walmore Electronics Ltd., 11-15 Betterton Street, Drury Lane, London, W.C.2.*

For further information circle 21 on Service Card

22. Wide-Range Capacitance Bridge

A 100-kc/s bridge providing capacitance measurements from 0·0002 pF to 110,000 pF with a basic accuracy of 0·1% is announced by Boonton Electronics Corp. The model 74D, which is available in the U.K. from Livingston Laboratories, also measures conductance from 0·001 μmhos to 1,000 μmhos and shunt resistance from 1,000 Ω to 1,000 MΩ.

The instrument may be operated in either the three-terminal (direct) mode in which measurements are essentially independent of capacitance to ground, permitting remote measurement, or in the conventional two-terminal (grounded) mode. Other features include: test signal continuously adjustable from 4 V down to 1 mV; internal d.c. bias adjustable from +110 V to −7 V; provision for external bias up to ±400 V; negligible warm-up drift; and capacitance drift less than 0·001 pF in 24 hr. The standard arm is accessible at the front panel, thus permitting use as a comparison bridge. A d.c. output directly proportional to bridge unbalance is also available for go/no-go testing.—*Livingston Laboratories Ltd., 31 Camden Road, London, N.W.1.*

For further information circle 22 on Service Card

23. Miniature Flaw Detectors

Wells-Krautkramer have announced two miniature ultrasonic flaw detectors, types USK5 and USK5M. Versatile and easy to operate, they are designed for accurate wall-thickness and corrosion measurement and for flaw detection in welds, tubes and plate.

The frequency range is from 0·5 to 12 Mc/s, the depth range is infinitely variable between 2 and 50 in. and the gain of the linear amplifier is controlled by a 0 to 120-dB attenuator. There are pulse energy and suppression controls, and the optional monitor enables flaws to be indicated audibly or visually.

Power supply is by rechargeable battery with a life of 10 hr, or alternatively by float charging from the a.c.

(*Continued on page 143*)

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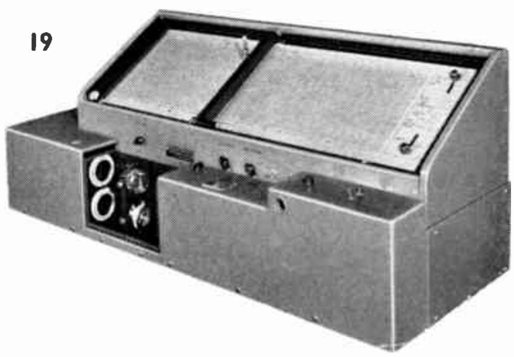

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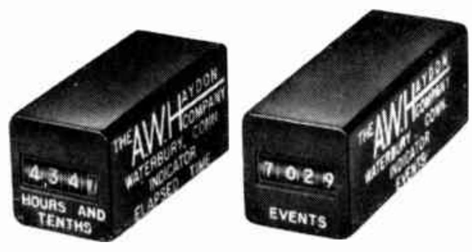

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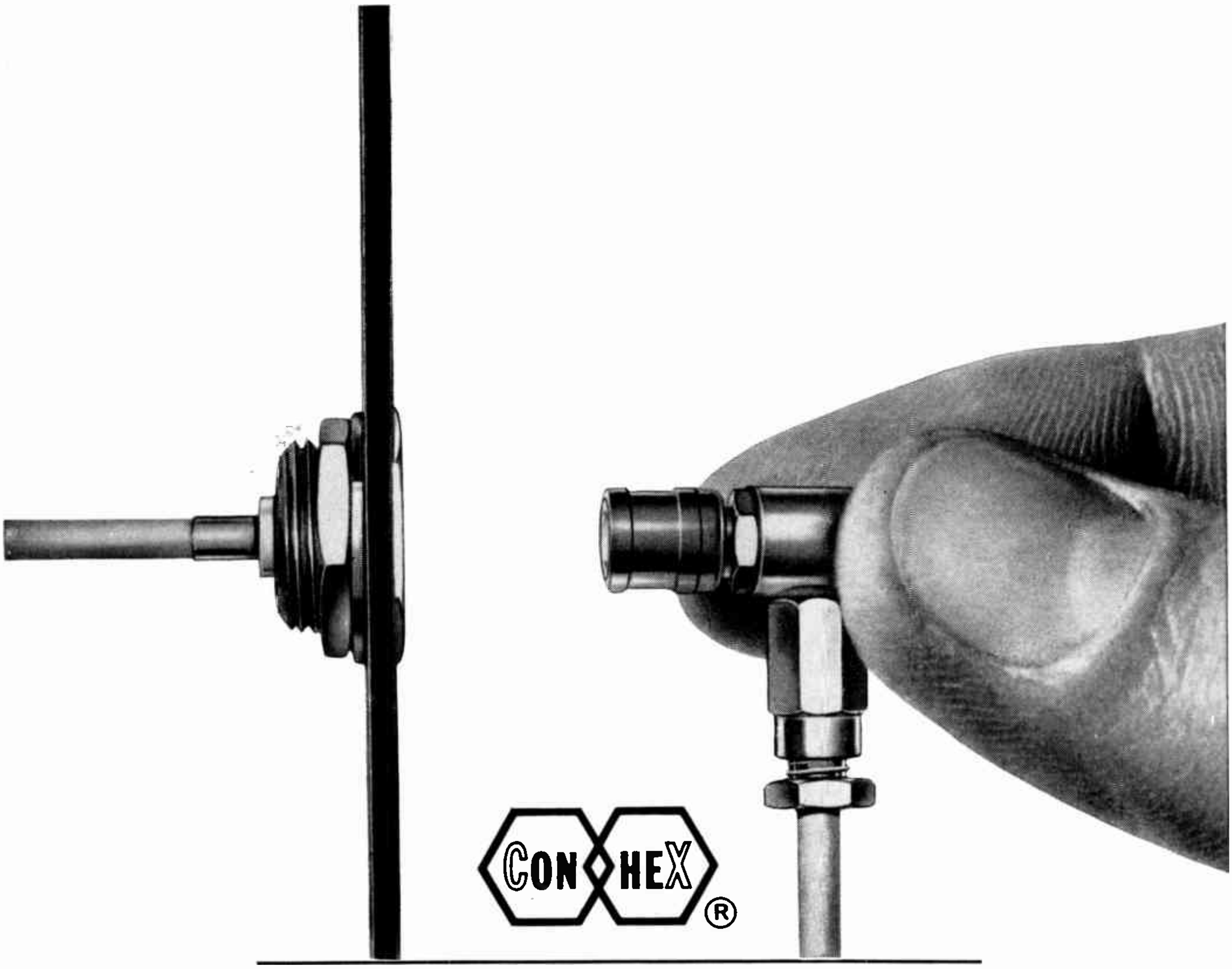
For further information circle 248 on Service Card



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PERFORMANCE—Optimum impedance matching with specified cables, very low contact resistance, suitable for use at frequencies up to 10 Gc/s.
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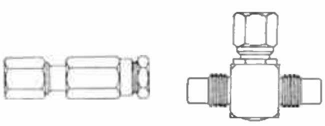

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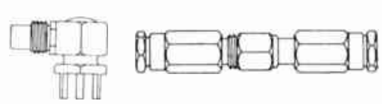

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mains. A front-mounted voltmeter indicates the charge of the battery which is automatically disconnected when discharged. The units weigh 11 lb with battery and monitor, and their overall dimensions are 4 × 7 × 15 in. A wide range of accessories is available.—*Wells-Krautkramer Ltd., Blackhorse Road, Letchworth, Herts.*

For further information circle 23 on Service Card

24. Spectrum Analyser

The Fenlow spectrum analyser type SA3 is an instrument designed to measure the spectral density of waveforms over the frequency range from 1·5 c/s to 5 kc/s. Fixed filter widths of 0·3, 1·5, 37·5 and 187 c/s are available. The noise power being passed by the filters is measured by use of thermocouples, the output of which is indicated on a meter and is also available to drive the automatic plotter.

The analyser makes use of the heterodyne principle in which the incoming signal is multiplied by the oscillator signals in quadrature. The multiplier outputs are passed through low-pass filters, the outputs of which drive the thermocouples. Six operational amplifiers are used to give a high degree of accuracy. Digital methods are employed to provide the internal oscillator signals for the two quadrature channels. Facilities are provided for monitoring the signals at all key points in the instrument. — *Fenlow Electronics Ltd., Springfield Lane, Weybridge, Surrey.*

For further information circle 24 on Service Card

CONTROL

25. Proportional Temperature Controllers

C.N.S. Instruments announce that their 'Sirect' proportional temperature controller which employs thyristors can now be made available in 60-A and 100-A models in addition to the previous standard ranges of 15 and 30 A.

Typical recommended minimum furnace resistance with an a.c. supply of 250 V is 5 Ω and 3 Ω in the case of 60-A and 100-A units respectively. These figures are based on a 10% safety factor and allow for a mains voltage variation of ±10%.—*C.N.S. Instruments Ltd., 61 Holmes Road, London, N.W.5.*

For further information circle 25 on Service Card

26. Pivotless Instruments

Crompton Parkinson announce a further addition to their range of pivotless instruments.

All their 'Fiesta' short-scale moving-coil instruments supplied against orders received will now have taut-band suspension movements which, by eliminating pivots, jewel bearings, and control springs, provide improved accuracy maintenance and resistance to shock and rough treatment.

The picture shows a Fiesta pattern moving-coil voltmeter. — *Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2.*

For further information circle 26 on Service Card

27. Needle Valves

The Hoke 100 series forged needle valves are primarily intended to perform throttling and shut-off functions and are designed for use with water, oil and gas. Now available in the U.K. from George Meller, these weldable

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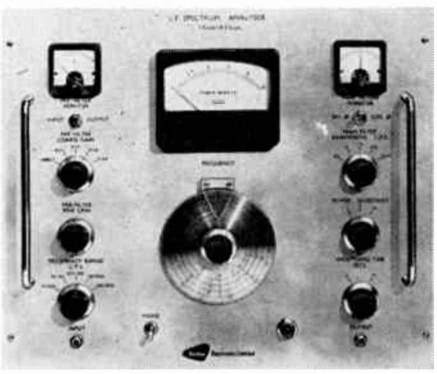

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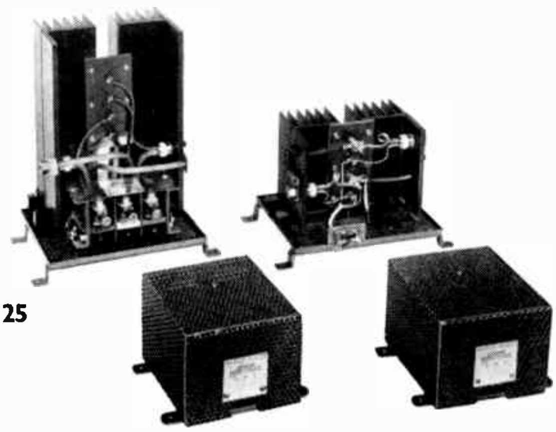

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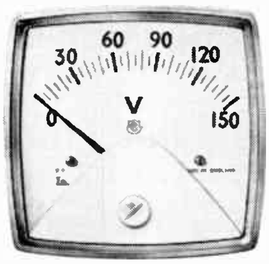

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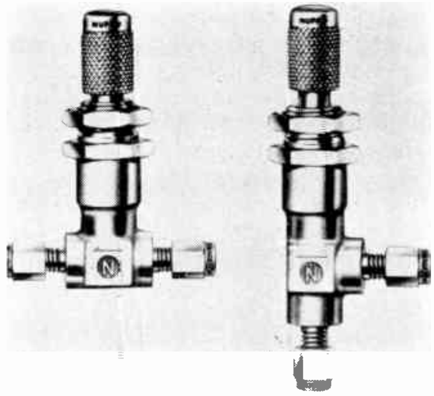
forged carbon-steel valves (in globe or angle pattern) are rated for service from vacuum to 10,000 p.s.i., and temperatures from −40 to +450 °F.

Guaranteed leak-tight at the stem, they are 'O' ring packed and protected by a special nylon stem wiper. Teflon packing is available as an optional feature for temperatures of −60 °F. Connections are $\frac{1}{8}$ in. to $\frac{1}{2}$ in. NPT. An integral bonnet ensures maximum safety at elevated pressures. Panel-mounting versions with cross handle are available.—*George Meller Ltd.*, *26 Hallam Street, London, W.1.*

For further information circle 27 on Service Card



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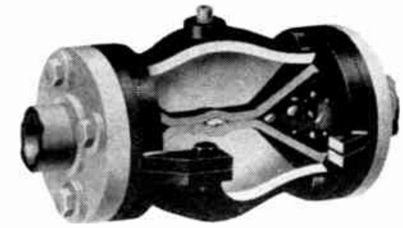

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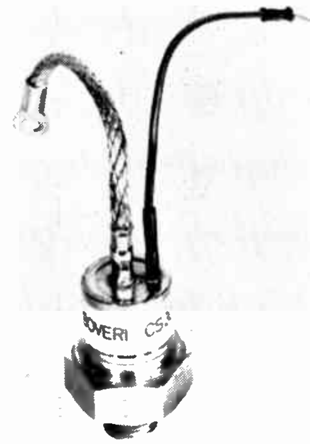

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28. Valves and Filters

A range of components for control of liquid and gas flows is now available in the U.K. from Techmation. Manufactured by the Nuclear Products Co., of Cleveland, Ohio, the range includes fine metering valves, hermetically-sealed bellows valves, non-return valves, filters incorporating sintered-steel elements, and adjustable safety relief valves.

Many different versions and materials of construction are available (brass or stainless steel being the most popular) and sizes range from $\frac{1}{16}$ to 1 in. tube or pipe connection (including Swagelok fittings).

Illustrated is a member of the range designed for metering very low flows (0–50 c.c./min, air) with minimum dead space. Small valve capacity provides a choking effect to fluid flow, eliminating flow surge on initial adjustment. This valve is available in cadmium-plated brass or 316 stainless steel, and can be supplied with a micrometer-type vernier handle.—*Techmation Ltd., 19 Carlisle Road, Colindale, London, N.W.9.*

For further information circle 28 on Service Card

29. Novel Flow-Control Valve

The 'Red Jacket' flow-control valve, now available in the U.K. from G. A. Platon, features a moulded rubber sleeve which is pinched by the action of compressed air, or another preferred hydraulic fluid. The sleeve is designed so that the pinch is effective despite the presence of solid particles.

The sleeves are available in a variety of materials (e.g., natural rubber, Neoprene, etc.) and the selection depends on the nature of the fluid, flow operating temperature, pressure and the character of the solid particles. The most abrasive slurries can be handled, also dry powders. The valve is ideal for the control of liquids that deposit scale such as lime milk.

The advantages inherent in the simple design are: unobstructive flow pattern, only one wearing part, remote operation facility and blow-out protection provided by the valve body. The Red Jacket valve is available for pipe sizes from 1 in. to 72 in.—*G. A. Platon Ltd., 281 Davidson Road, Croydon, Surrey.*

For further information circle 29 on Service Card

30. Photoelectric Switch

The D.T.V. Group have been appointed U.K. distributors for the Autronica FB-4 fully-transistorized photoelectric switch designed for general applications where automatic switching of lights is required. The light intensity at which the unit operates is adjustable by means of a screw on the front of the container. The switching contactor has four contacts, each of which can be loaded with a maximum of 6 A.

The container is made of die-cast Silumin and finished in pearl-grey baked enamel. The container is supplied with a rubber gasket to make it watertight; the cable entrance has a nylon nipple. The electronic unit is impregnated against corrosion. —*D.T.V. Group, 126 Hamilton Road, West Norwood, London, S.E.27.*

For further information circle 30 on Service Card

31. High-Accuracy Feedback Resolver

A 400-c/s size 11 compensated resolver, series 11RSF, for precision computing, is now in quantity production by Moore, Reed & Co. These units are low priced and are available with flying leads or with a 12-way terminal block.

Deviation from a sine wave of under 0·05%, with an inter-axis error of less than 4 minutes of arc, is claimed for this resolver which, in production, has achieved a high proportion of units with deviations of under 0·03% and with fundamental noise levels between 1 and 3 mV. The transformation ratio of stator and compensation windings is 0·97.—*Moore, Reed & Co. Ltd., Woodman Works, Durnsford Road, London, S.W.19.*

For further information circle 31 on Service Card

32. Thyristor

Brown-Boveri have recently introduced a new thyristor into their manufacturing programme. This device, designated CS.30, has a mean forward current of 70 A at a stud temperature of 80 °C and a conduction angle of 180°.

The CS.30 is available for rated voltages in the range from 100 V to 600 V at 100-V intervals, and minimum forward breakover will not occur below voltages which are 40% above these rated values. The peak one-cycle (20-msec) surge current is 1,300 A.—*British Brown-Boveri Ltd., Glen House, Stag Place, London, S.W.1.*

For further information circle 32 on Service Card

PRODUCTION AIDS

33. Surface/Profile Projector

The Nikon range of shadowgraph instruments, for surface and profile projections, has been extended to include an economically-priced model for quick and accurate measurement and inspection of large components in the industrial and medical fields. The U.K. distributor is Rank Pullin Controls.

The model 7 is accurate to 0·00005 in., has a maximum throat clearance of 7 in. and features a 16-in. protractor screen. Magnifications of between ×5 and ×100 are possible and a 3-lens revolving turret, giving quick changes in magnification, is supplied as standard equipment.

A built-in zoom condenser ensures that focusing error does not affect the measuring accuracy on contour inspection. Surface and profile inspection is possible either independently or simultaneously. The instrument also has a positioning control for the light source giving accurate optical alignment. Accurate focusing allows for depth measurement using clock gauges.

A lockable built-in cabinet, accessible from two sides of the instrument, has adjustable shelves for storage. Accessories include a wide range of micrometer stages, holding fixtures, photographic attachments and direct-reading scales.—*Rank Pullin Controls, Phœnix Works, Great West Road, Brentford, Middlesex.*

For further information circle 33 on Service Card

34. Mineral-Insulated-Cable Stripper

Spembly Technical Products are now offering cable-stripping tools for use in conjunction with their range of mineral insulated cables.

The tool is operated by screwing it on to the cable, in a similar fashion to a button die, causing the sheath to be cut away in a continuous spiral, thus exposing the conductors. It is principally designed for use in the hand, but where large quantities are involved, the operation can be mechanized by mounting it in a slow-running lathe.

This stripper is of rugged construction, being made from case-hardened mild steel and fitted with an easily replaceable cutting tool which, if necessary, can be made from a piece of hacksaw blade. The tools currently marketed cover three sizes: 0·125, 0·062, and 0·040 in. diameter.—*Spembly Technical Products Ltd., New Road Avenue, Chatham, Kent.*

For further information circle 34 on Service Card

35. Card Selection Table

Up to 30,000 punched or index cards are placed within immediate and easy reach of a single clerk by the Remington card-selection table. The basis of the table is a steel desk-shaped unit, 54¾ in. wide, 31 in. deep and 38¼ in. high, with a recessed instead of a solid top. During work, two lockable protective covers fold back to the rear of the table to reveal trays of cards arranged in rows facing the user.

One model offers two tiers of trays, with the upper tier sliding sideways for access to any of the lower ones. In the other two models there is only one tier

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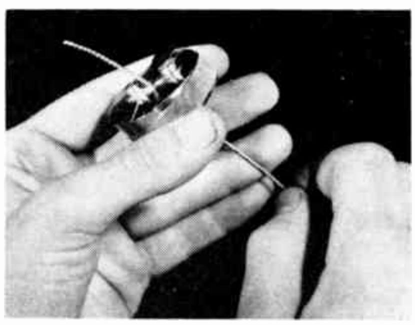

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of trays. All models have a moveable posting board which fits over the top of the unit to provide a writing surface, can be slid to any point during work, and fits between the other two covers when the table is locked.—*Remington Rand Ltd., Remington House, 65 Holborn Viaduct, London, E.C.1.*

For further information circle 35 on Service Card

36. Shaper with Copying Control

An Elliott 30-in. 'Major' shaping machine has been fitted with Hepworth hydraulic copying equipment to enable copying control to be applied to the vertical movement of the table. The form is traced from a template rigidly attached to the side of the machine table.

The hydraulic control valve mounted to the frame of the machine is provided with vertical and longitudinal adjustment. The stylus operates on a flat template, allowing the machine to produce any component of uniform section throughout its length. The full copying stroke of 3 in. is available at any table position.

A hydraulic counter-balancing cylinder is operated through an independent pressure supply from the free-standing hydraulic power unit. The elevating screw of the standard machine is built into a hydraulic ram in a way that allows normal hand operation to be made effective simply by releasing a lock nut.—*The Hepworth Iron Co. (Engineering) Ltd., Hazlehead, Stocksbridge, Sheffield.*

For further information circle 36 on Service Card

37. Large Stirling-Cycle Refrigerator

A Philips Stirling-cycle refrigerator, believed to be the largest of its kind in the world, is now available in Britain from The M.E.L. Equipment Co. The model C has a refrigerating capacity of 20 kW at 77 °K (−196 °C).

Applications include liquefaction of gases, low-temperature gas separation and purification, cryopumping and low-temperature chemical processing. The machine can be fully integrated in major projects where it will, for instance, continually recondense nitrogen in a closed system. Space simulation chambers and other environmental test facilities can thus be made independent of external supplies of liquid gases.

In addition to the extra large output of the machine, a feature of special interest to potential industrial users is that it can be operated continuously for periods of up to 4,000 hours. It is comparatively simple to operate and requires little supervision. Liquid nitrogen temperatures are reached within 15 minutes of switching on.

The drive motor is a 170-h.p., 3-phase induction type, and power requirements are approximately 140 kW. The total weight of the machine is nearly 5 tons and its overall dimensions are: width 10 ft, height 6 ft 6 in., and depth 5 ft 4 in.—*The M.E.L. Equipment Co. Ltd., 207 King's Cross Road, London, W.C.1.*

For further information circle 37 on Service Card

38. Portable Automatic Wire Cutter

A portable automatic measuring cutter, the Western Electronic Products Co. model MC-2, for use where moderate quantities of accurately-cut wire or tubing are required, is now being marketed by Roberts Electronics. Housed in a metal case measuring 4 × 8 × 12 in., the MC-2 weighs 12 lb. It can be set up in 30 sec by unskilled labour.

This unit is especially suitable for operations requiring small quantities of different colour-coded wires of various lengths. It cuts and measures from $\frac{1}{2}$ in. to 10 ft, with an accuracy of 1%. Maximum wire diameter is $\frac{1}{8}$ in. and sizes smaller than 30 a.w.g. can be handled easily with no adjustment. Wire is advanced continuously at a single speed for cutting and more than 10,000 one-inch pieces can be produced in an hour.—*Roberts Electronics Ltd., 17 Hermitage Road, Hitchin, Herts.*

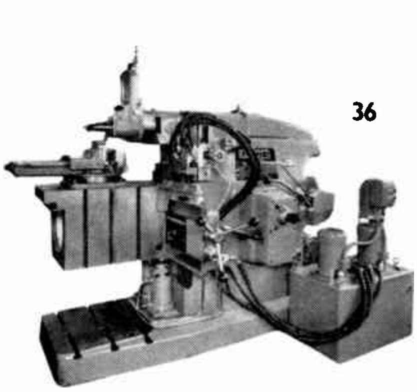
For further information circle 38 on Service Card

39. Compact High-Vacuum Furnace

Ad. Auriema, U.K. distributors to Richard D. Brew & Co., of America, announce a laboratory high-vacuum furnace which is sufficiently compact for bench mounting. The complete furnace, mounted in a console, is 45·9 cm high × 76·2 cm wide × 66·0 cm deep.

The Brew model 224 furnace performs all types of high-temperature high-vacuum operations, such as sintering, thin-film deposition, bright annealing, and melting. It features a 5·1-cm diameter × 10·1-cm high workzone with an operating vacuum range of 10^{-3} to 10^{-6} torr, and temperature capability up to 2,200 °C. Heating is by a refractory-metal resistance element. Full access is provided from the top through a quick-release combination loading port and sight glass.

Power requirement is a 230-V, single-phase, 50/60 c/s supply capable



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of delivering 6 kW at full temperature. Cooling water required: 2·65 l/min at 21·1 °C inlet temperature. A manually-set voltage adjustment provides infinitely-variable temperature control. —*Ad. Auriema Ltd., 125 Gunnersbury Lane, London, W.3.*

For further information circle 39 on Service Card

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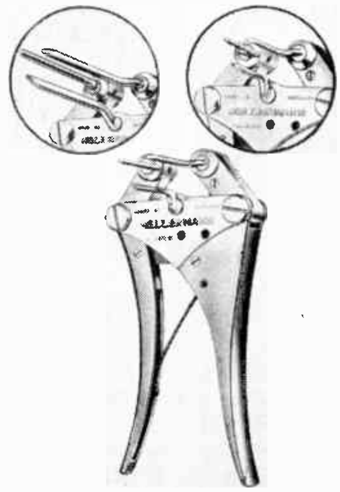
40. Universal Sleeve-Fitting Tool

Hellermann Electric have introduced a universal tool for fitting sleeves and cable markers to wires and cables. Interchangeable prongs cover the whole range of sleeve sizes, and built-in 'stops' control the opening of the sleeve. The tool is about half the weight of similar tools, with improved styling of the handles to enable operators to grip it easily and comfortably.

The universal sleeve-fitting tool is supplied in kit form comprising the body of the tool, three sets of prongs ('DS', 'DK', and 'DG'), an Allen key for changing the prongs and a small bottle of Hellerine lubricant.—*Hellermann Electric Ltd., Gatwick Road, Crawley, Sussex.*

For further information circle 40 on Service Card



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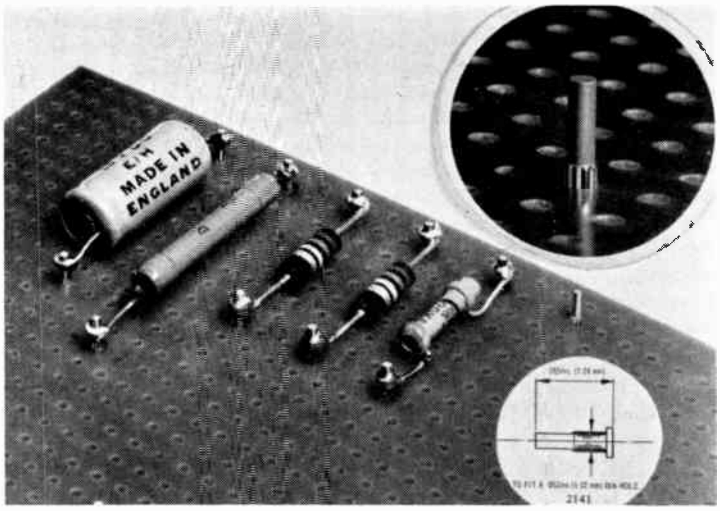
COMPONENTS



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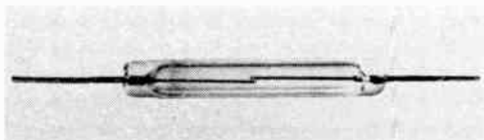
41. Terminal Pins

Vero Electronics have introduced a terminal pin, part No. 2141, which can be used with any Veroboard (with or without copper strips) that has a hole diameter of 0·052 in., or with any printed-wiring or terminal board drilled or pierced with holes of the same diameter.

The head and self-cutting serrations under it assure an extremely tight fit without fear of the pin falling out of the board during or after soldering. These pins are manufactured from brass, with a tin-dipped finish to facilitate soldering. The picture shows the pins in use, with (inset, top right) a photograph of the pin itself and (inset, bottom right) a scale drawing.—*Vero Electronics Ltd., South Mill Road, Southampton.*

For further information circle 41 on Service Card



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42. Dry-Reed Switch

The M-O Valve Co. has introduced a dry-reed capsule switch, type RC1, with an average life expectancy of 10^8 operations under low-level signalling conditions when operated in a solenoid. At full ratings the life expectancy is 10^7 operations. By use of a permanent magnet, the reed may be used as a proximity switch for a wide variety of control purposes.

The contact is single-pole, normally-open, with a resistance of less than 100 mΩ and an operating time of less than 2 msec including bounce. The overall length of the switch is 46·1 mm.

Maximum ratings with resistive load are as follows: switched voltage, 50 V; switched current, 100 mA; switched power, 5 W. The closed contact will pass a maximum current of 1 A.—*The M-O Valve Co. Ltd., Brook Green Works, London, W.6.*

For further information circle 42 on Service Card

43. Light-Dependent Resistor

An inexpensive light-dependent resistor recently announced by Mullard will, it is claimed, reduce the cost of card and paper-tape readers for computers, harbour signalling systems, train indicator boards and other photo-conductive applications. Because the resistors have a relatively fast recovery rate they can also be used in moving displays such as animated strip, news and advertising signs, with moving punched paper-tape or film placed between the light-source and the resistors.

In harbour signalling systems, for example, a number of light-dependent resistors would be connected so that they switch on the signal lamps whenever light falls on them. They would be illuminated by light passing through holes punched in a card, the pattern of the holes corresponding to the configuration of lamps required to be lit. By maintaining a stock of cards each punched with a different configuration a rapid change of signalling codes could be effected.

The light-dependent resistor, type number RPY30, is in effect a small photo-conductive cadmium sulphide cell housed in a robust clear-plastic encapsulation measuring 10·8 × 12·2 ×3·6 mm. The dark resistance is 10 MΩ and the light resistance at 1,000 lux is between 75 Ω and 300 Ω. The maximum applied voltage is 150 V and the continuous power dissipation 200 mW. The RPY30 will work over an ambient temperature range of −30 to +60 °C.—*Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.*

For further information circle 43 on Service Card

44. High-Output Pressure Transducer

Consolidated Electrodynamics have introduced the type 4-390 high-output pressure transducer designed to perform reliably under extreme conditions of acceleration, vibration, and shock.

The 4-390 comprises an unbonded strain-gauge sensing element with an integral semiconductor amplifier and power supply and provides a 5-V d.c. output signal. It is designed for absolute and gauge measurements of fluids and gases compatible with 416 stainless steel, and is available in pressure ranges from 100 to 5,000 p.s.i. The power supply allows considerable fluctuation of the input power without degradation of the data signal.

Other design features include low-pass filtering to suppress high-frequency noise in the output, a high degree of isolation between power input and signal output, and provision for prohibiting output voltages from exceeding a pre-set level.

The instrument is fully protected from accidental reversal of input power polarity, and electrical components are temperature compensated as an integral unit. Rated electrical excitation is 28 V d.c., with 50 mA maximum drain. Linearity and hysteresis are ±0·5% of full-range output, output impedance is less than 250 Ω, and weight is 10 oz.—*Consolidated Electrodynamics Division of Bell & Howell Ltd., 14 Commercial Road, Woking, Surrey.*

For further information circle 44 on Service Card

45. Marine Connectors

Lectropon have announced the Souriau 82 series marine connectors. These connectors are designed specially for use with multi-way alloy conductors in marine applications. There are five shell sizes containing 7, 19, 27, 37, 48 and 61 contacts. The contacts, which are demountable, are 1 mm in diameter and cables up to maximum section 0·93 sq mm can be used; these are attached by crimping.

Maximum contact current is 7·5 A and maximum contact resistance is 3 mΩ. Insulation resistance: 5,000 MΩ. Temperature range: −40 °C to +85 °C.—*Lectropon Ltd., Kinbex House, Wellington Street, Slough, Bucks.*

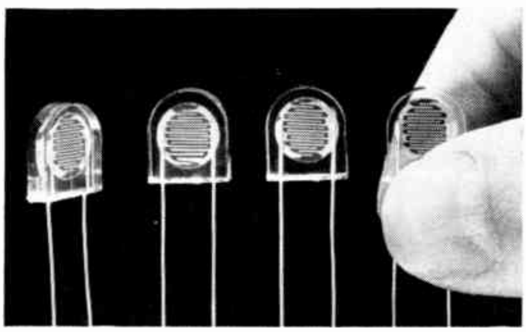
For further information circle 45 on Service Card

46. Pressure Transducers

The Saunders-Roe division of Westland announce the introduction of three pressure transducers for liquids or gases, all embodying bonded-foil strain gauges in a full-bridge configuration. These transducers feature small physical size, low volumetric change with pressure, very high natural frequency and the ability to withstand high acceleration without effect on the electrical output.

Three types cover the ranges from 0–30 up to 0–40,000 p.s.i. gauge; one model can be used as a differential transducer in the ranges 0–50 up to 0–1,500 p.s.i. Maximum applied voltage is 10 V into a 220-Ω bridge, and a sensitivity in excess of 2 mV/V is obtainable on most ranges. Other resistance values can be supplied if required. — *Electronics Department, Westland Aircraft Ltd., Saunders-Roe Division, Osborne Works, East Cowes, Isle of Wight.*

For further information circle 46 on Service Card



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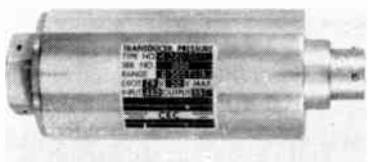

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46

CONTROL DESIGN DATA

Simplified Gain and Root Evaluation Procedures for Third-Order Systems

By N. G. MEADOWS, B.Sc., A.M.I.E.E.*

A control system with open-loop transfer function $GF(s)$ and closed-loop output/input transfer function

$$H(s) = \frac{GF(s)}{1 + GF(s)} \quad \ldots (1)$$

where G is the open-loop gain, has root loci which are solutions of the characteristic equation (C.E.)

$$1 + GF(s) = 0 \quad \ldots (2)$$

$$\text{for } G \geqslant 0$$

Since the analytic evaluation of the closed-loop transient response depends on the C.E. being expressed in factored form, the roots of equation (2) must be found. This then enables equation (1) to be expressed in partial fractions. The roots can be found graphically if the root locus is plotted.[1]

The conventional method is illustrated with reference to Fig. 1, which shows a root locus for a third-order system with

$$GF(s) = \frac{G}{s(s^2 + s + 1)} \quad \ldots (3)$$

with the C.E.

$$s^3 + s^2 + s + G = 0 \quad \ldots (4)$$

The open-loop poles are shown at P_1 and P_2 in the figure, with a pole at the origin. If A and its conjugate A′ represent a desired operating condition for the closed-loop system, the gain necessary to achieve this is given by

$$G_1 = |OA| \times |AP_1| \times |AP_2| \quad \ldots (5)$$

If $s = \sigma_1 \pm j\omega_1$ specify the poles at A and A′, these yield the quadratic $s^2 + 2\sigma_1 s + \omega_1^2 + \sigma_1^2$ by which equation (4) must be factorizable to give the third real root at $s = -a$. Hence

$$(s + a)(s^2 + 2\sigma_1 s + \omega_1^2 + \sigma_1^2) = 0 \quad \ldots (6)$$

and this must agree with the characteristic equation (4). Equating coefficients of equations (4) and (6), with $G = G_1$ gives

$$a = \frac{G_1}{\omega_1^2 + \sigma_1^2}$$

But

$$\omega_1^2 + \sigma_1^2 = |OA|^2$$

so that

$$a = \frac{|AP_1| \times |AP_2|}{|OA|}$$

gives the third root, using equation (5).

An alternative and simplified method of gain and root evaluation is now presented.

*Battersea College of Technology.

Condition for Complex Open-Loop Poles

If

$$F(s) = \frac{G}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)} \quad \ldots (7)$$

the non-zero open-loop poles will be complex for $\zeta < 1$. Design calculations can be simplified by using the non-dimensional form of transfer function for which $S = s/\omega_n$. Then

$$F(S) = \frac{g}{S(S^2 + 2\zeta S + 1)} \quad \ldots (8)$$

where

$$g = G/\omega_n^3$$

The C.E. is then

$$S^3 + 2\zeta S^2 + S + g = 0 \quad \ldots (9)$$

The complex open-loop poles are at

$$S = -\zeta \pm j\sqrt{1 - \zeta^2}$$

Writing

$$S = X_1 \pm jY_1$$

gives

$$X_1 = -\zeta \quad \ldots (10)$$

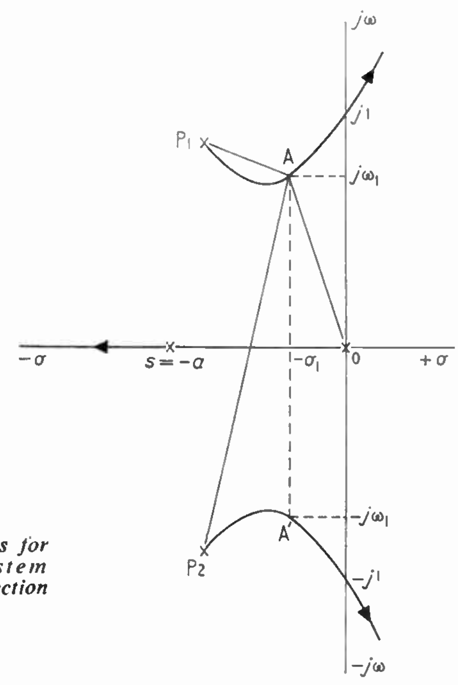


Fig. 1. Root locus for third-order system (arrows denote direction of G increasing)

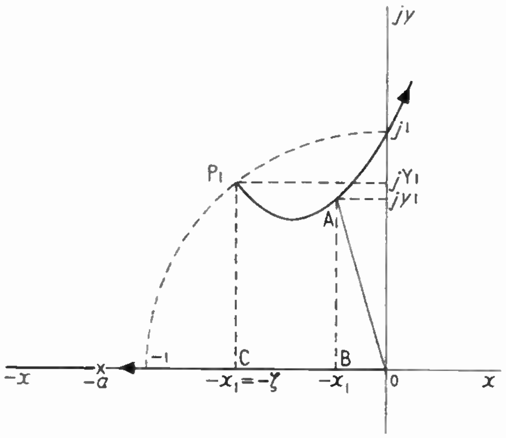


Fig. 2. Gain and root evaluation

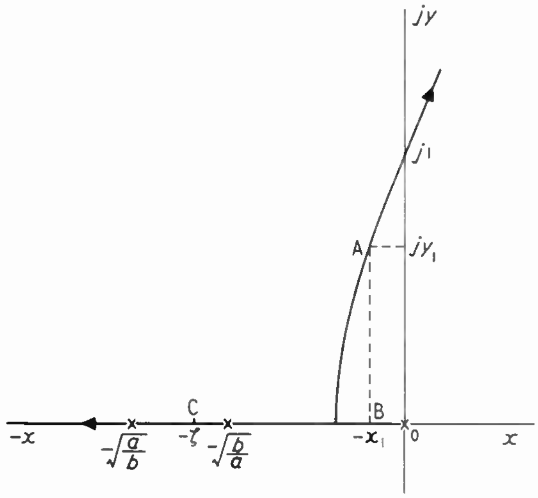


Fig. 3. Locus for ζ ≥ 1

and

$$Y_1 = \pm\sqrt{1-\zeta^2} \qquad \ldots (11)$$

Then

$$X_1^2 + Y_1^2 = 1$$

so that stable complex open-loop poles, for various values of $\zeta < 1$, lie on a unit semi-circle in the l.h.s. of the S plane.
If

$$S = -x_1 \pm jy_1$$

represent the desired locations of a pair of closed-loop poles, and $S = -a$ is the third root, to be found, then

$$(S^2 + 2x_1S + x_1^2 + y_1^2)(S + a) = 0 \qquad \ldots (12)$$

is to be compared with the C.E. (9). This yields

$$a = 2(\zeta - x_1) \qquad \ldots (12)$$

and

$$g = 2(\zeta - x_1)(x_1^2 + y_1^2) \qquad \ldots (13)$$

In Fig. 2, which shows a typical upper half-section of a root locus,

$$|\zeta - x_1| = |BC|$$

by virtue of equation (10), giving the third root as

$$a = 2|BC| \qquad \ldots (14)$$

Also

$$x_1^2 + y_1^2 = |OA|^2$$

so that

$$g = 2|BC| \times |OA|^2 \qquad \ldots (15)$$

Equations (14) and (15) involve fewer measurements than the conventional method and have the further advantage that upper half sections only of the root loci need be plotted. This simplifies the design procedure and also enables larger scales for the root locus axes to be used. Further, as normalized root loci are presented, changes of ω_n merely alter the scale values on the axes.

Real Open-Loop Poles

Desired Complex Closed-Loop Poles

For $\zeta \geqslant 1$ the open-loop transfer function may be written as

$$F(s) = \frac{G}{s(s+a)(s+b)}$$

where a and b are real. For $\zeta = 1$, $a = b$.
With $\omega_n = \sqrt{ab}$, $g = G/\omega_n^3$ and $S = s/\omega_n$ as before, the C.E. (9) may be used. Here

$$\zeta = \tfrac{1}{2}[\sqrt{a/b} + \sqrt{b/a}]$$

For a desired pair of complex closed-loop poles at $S = -x_1 \pm jy_1$, with a third pole to be determined at $S = -a$, equations (12) and (13) give a and g or equations (14) and (15) may be used. A typical upper section of a root locus for $\zeta \geqslant 1$ is shown in Fig. 3.

Desired Closed-Loop Poles All Real

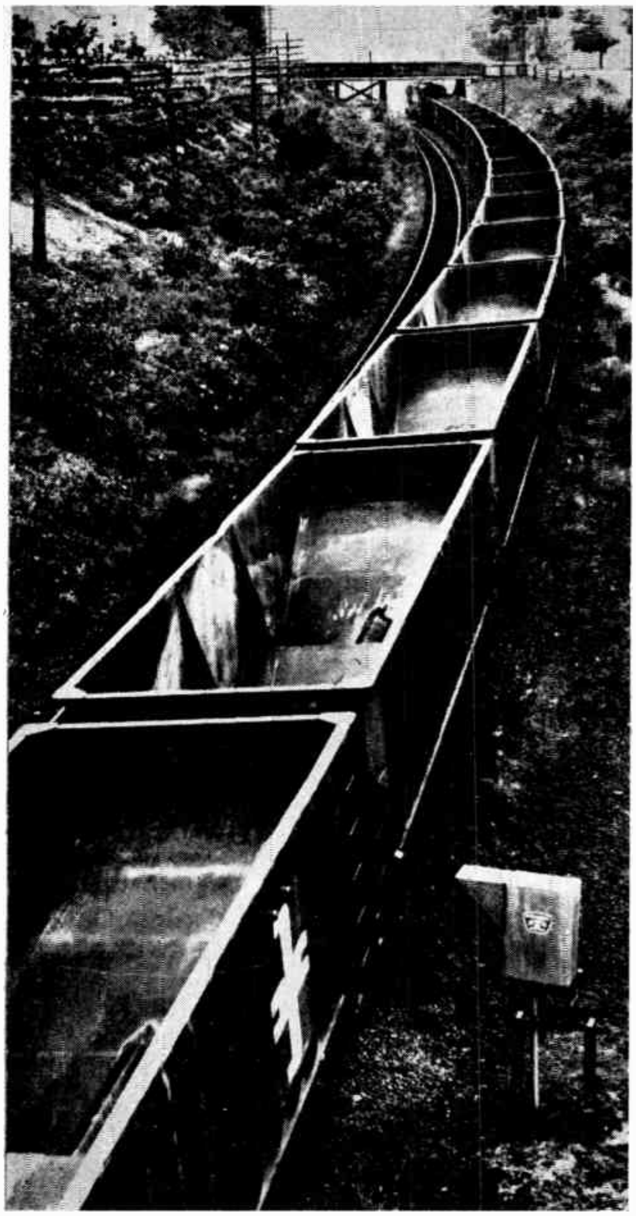
With $S = -x$ as a specified closed-loop pole location and $S = -y$, $S = -z$ as the other two real poles to be located, the equation $(S + x)(S + y)(S + z) = 0$ is to be compared with the C.E. (9). This results in $g = xyz$ and $2\zeta = x + y + z$. The gain g is derived from equation (9) with $S = -x$ to give

$$g = x(x^2 - 2\zeta x + 1)$$

With g calculated, since the above equations give $y + z = 2\zeta - x$ and $yz = g/x$, the values of y and z for a given ζ can be obtained by solving between these two equations.

Reference

[1] 'Control System Synthesis', J. G. Truxal, McGraw Hill, 1955.



RAILWAY TRUCK IDENTIFICATION

A MINNESOTA railroad will be the first in the United States to identify and sort its rolling stock by means of high-speed electronic recognition.

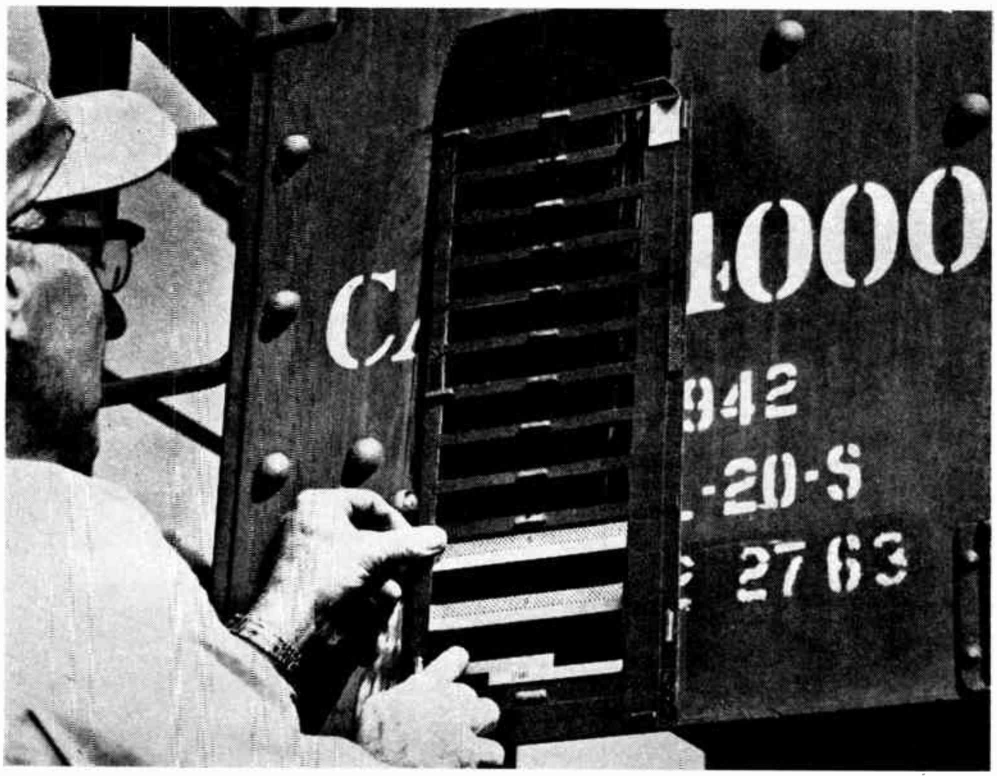
The Duluth, Missabe and Iron Range Railway Company (DM & IR) will use an electronic recognition system, developed and produced by Sylvania Electric Products Inc., to identify and record 9,500 cars that haul iron ore from the mining regions of north-eastern Minnesota to loading docks on Lake Superior.

The Sylvania system called 'Kartrak' utilizes an unmanned, weather-proof, trackside scanner which sends out beams of white light and receives coloured reflected light from strips of durable reflective material. The strips, attached to each car, are arranged to form a colour code representing the identification number of the car and its weight when empty. For example, a combination of orange and white strips represents a '7'.

The signals returned from the label translate into a format of digital data suitable for immediate print-out, operation of a paper-tape punch, magnetic recording, direct teletype transmission, or computer input.

The system can reliably identify and record cars travelling at 100 miles per hour (160 km/hr) even in heavy rain and snowstorms, day or night. The scanner operates effectively even when snow, ice or dirt make the car markings 'unreadable' to the human eye. It also notes the passing of any unmarked cars.

Shown here (left) is a scanner mounted alongside a rail track



A close-up view of the colour-strip coding arrangement on the side of a railway truck

Industrial News

Personal News

The Postmaster General has approved the appointment of **Dr. J. R. Tillman** as Deputy Director of Research at the Post Office Research Station, Dollis Hill.

The Council of the British Computer Society announce the appointment of **J. G. Mackarness, M.A.,** as secretary of the Society. **Professor Stanley Gill,** who took up the chair of computing science at Imperial College, London, last October, has resigned as chairman of the Executive Committee and is succeeded by **P. G. Barnes,** who was previously honorary secretary of the Society.

The British Iron and Steel Research Association announce that **S. A. R. Gray,** director, John Summers and Sons Ltd., has accepted appointment as chairman of BISRA's Council. Mr. Gray takes over from **Sir Charles Sykes, C.B.E., F.R.S.**

A. C. Quarterman has been appointed manager of the electronic data processing department at **AEI Rugby.**

British Insulated Callender's Cables Ltd. announce that J. A. McCleery, BICC executive director, has become chairman of Telcon Metals Ltd. in succession to C. O. Boyse.

Brigadier J. D. Haigh, O.B.E., M.A., M.I.E.E., F.Inst.P., has been appointed director and general manager of **Semiconductors Ltd.**

R. David Lindsay has been appointed marketing manager of **U.S. Industries Inc. Great Britain Ltd.**

B. R. Goddard has joined **Racal's** Australian organization as technical director.

C. M. Benham has relinquished the office of managing director of **Painton & Co. Ltd.;** he remains as executive chairman of the board. J. B. Kaye and R. W. Addie are appointed joint managing directors. In addition, G. J. Thompson-Gordon, production manager, and C. L. Richards, chief engineer, have been elected to the board.

Johnson, Matthey & Co. Ltd. announce the following appointments: P. D. F. Varrall, A.C.I.S., has been elected to the board and becomes a member of the executive committee, and Bernard Ince, A.C.C.A., is appointed to the newly-created post of group controller.

Intertherm Ltd. (combining the Philips and Redifon electroheating interests) have appointed Peter E. M. Sharp, A.C.G.I., B.Sc.(Eng.), A.M.I.E.E., commercial manager, to the board.

John Delany has been appointed works manager at the Chester works of **Brookhirst Igranic.**

J. C. Prichard, A.M.I.P.E., has been elected to the board of **A. P. Besson & Partner Ltd.**

Obituaries

Charles Reginald Belling, one of the founder directors of Belling & Lee Ltd., died at sea on 8th February in his 81st year.

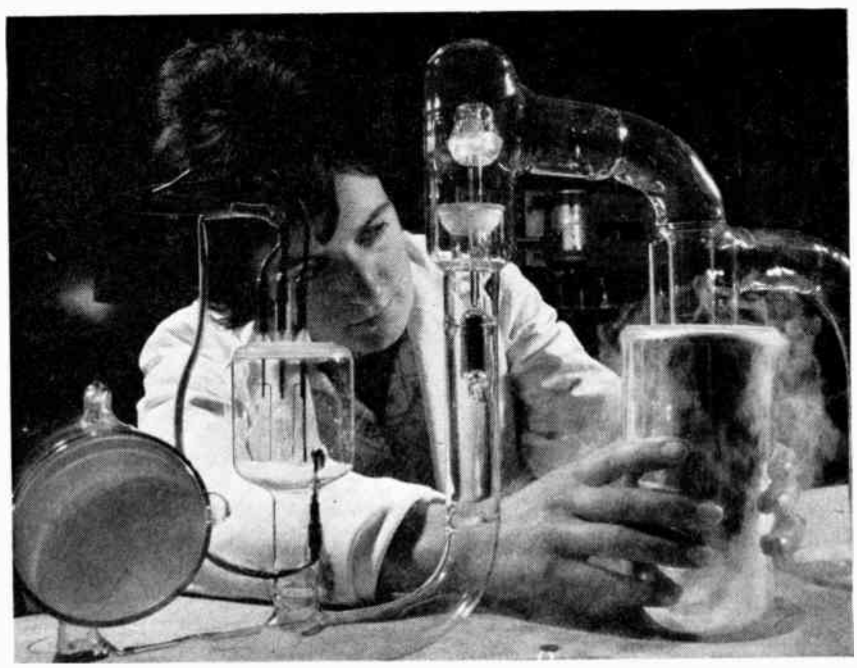
W. H. Harrison, director of Rank-Bush-Murphy, died on 5th February aged 58. Formerly chief engineer of Bush Radio, he became a director in 1952.

Company News

The Thomson Organization Ltd. has purchased d-mac ltd. (formerly Dobbies McInnes Ltd.). Dr. A. R. Boyle of d-mac will continue as managing director on the new board with James M. Coltart, managing director and deputy chairman of the Thomson Organization, as chairman and Dr. S. C. Curran, M.A., F.R.S., principal of Strathclyde University, and Dr. Tom Margerison, scientific and technical adviser to the Thomson Organization, as fellow directors.

The Plessey Group has acquired the entire share capital of Communication Systems Ltd., a private company regis-

SURFACE IMPURITY INVESTIGATION—*This apparatus at Standard Telecommunication Laboratories in Harlow, Essex, produces on a fluorescent screen greatly magnified (× 500,000) images that reveal minute impurities on the surface of materials under study. Intensive research into surfaces at STL is part of a programme aimed at improving micro-circuits, transistors and other electronic devices. The surface to be examined consists of a small tip, 5,000 Å in diameter, mounted 10 cm behind the fluorescent screen (left). The sample can be heated by passing a current through its support wires. With about 5,000 V applied between the sample and the screen a greatly enlarged picture representing the emission pattern characteristic of the crystal facets on the surface is projected on to the screen. The nature of this pattern indicates the type and extent of the contaminant*



tered in Dublin and carrying on business in the rental, sale and maintenance of private telephone equipment and similar apparatus. T. P. Hogan will become chairman of the company and M. P. Murphy and M. J. MacCormac, the existing directors, will remain on the board.

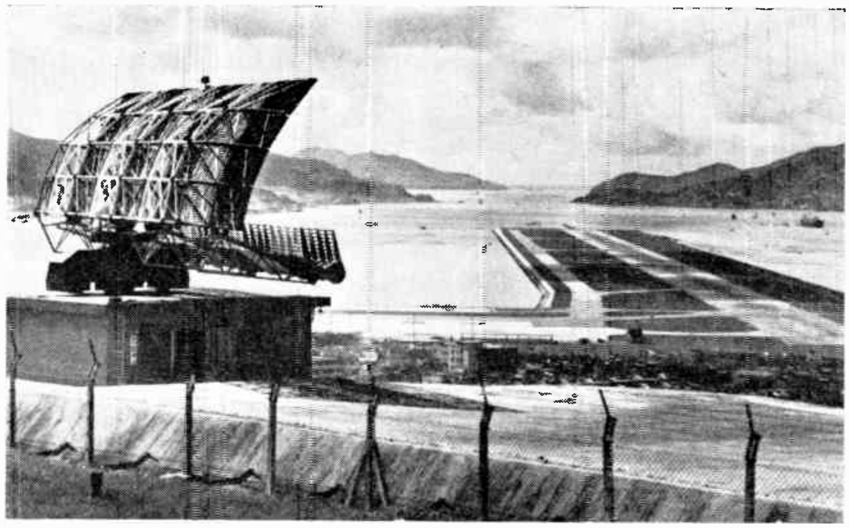
Under the terms of a recent agreement, technical information on satellites and other spacecraft will be exchanged between TRW Space Technology Laboratories of Los Angeles, U.S.A. (part of Thompson Ramo Wooldridge Inc.), and **Hawker Siddeley Dynamics.**

The Univac division of **Sperry Rand Corporation** of U.S.A. and **J. L. Kier and Co. Ltd.,** civil engineers, of London, have joined the consortium formed last September by Litton Industries, U.S.A., to bid for the £110 million NATO Air Defence Ground Environment (NADGE) project. The consortium now consists of AEI, Compagnie Générale de Télégraphie Sans Fil of France, Elliott Automation, ITT Europe, J. L. Kier and Co., Litton Industries Inc. and Univac. The consortium headquarters are located at 120 Champs Elysees, Paris 8.

International Telephone & Telegraph Corporation has concluded its acquisition of the assets of Clevite Corporation's semiconductor division. Involved in the transaction is Clevite's semiconductor subsidiary, Intermetall, G.m.b.H. in Freiburg, Germany, and the semiconductor inventory and equipment of Brush-Clevite Ltd., England. STC Ltd. have assumed responsibility for future orders for Brush Clevite semiconductor products. All existing orders will be fulfilled, and customers are being informed of any revised handling and billing arrangements. Brush Clevite will continue to deal with orders for imported items for the time being.

The Brimar industrial c.r.t. (home) sales department has moved from Brimsdown to the head office of **Thorn-AEI Radio Valves and Tubes Ltd.** at 155 Charing Cross Road, London, W.C.2. Telephone: Gerrard 9797.

C-E-I-R Inc., of Washington D.C., an associate company of **C-E-I-R Ltd.,** has purchased the Radio Corporation of America's Electronic Data Processing Centre in Washington. The centre is located at 1725 'K' Street, N.W., and has been in operation more than four years, providing data processing services for banks, associations and a wide range of business enterprises.



DAYLIGHT RADAR DISPLAYS—*Hong Kong harbour and Kai-Tak airport showing the approach to the runway through the steep and narrow Lye-U-Mun gap. In the foreground is the aerial head of the Marconi S 264 50-cm radar used for air traffic control. Marconi daylight radar displays, ordered for Hong Kong and Jersey airports and the R.A.E. Farnborough, will present an accurate display of all aircraft positions within 10 miles of the runway during landing and take-off procedures. These displays are visible under all lighting conditions, even direct sunlight, and will be used as 'distance from threshold indicators' (DFTI's) in the 'glasshouse' at the top of the airfield control tower where the ambient light level is very high. By giving the aerodrome controller an easily-read radar display, landing and take-off procedures can be speeded up and better runway utilization achieved*

A range of hydraulic and pneumatic rotary valve actuators is to be marketed in the U.K. by **Rotork Engineering Co. Ltd.** of Bath, as the result of an agreement with the Bettis Corporation of Houston, Texas. The actuators are for ball, butterfly, or plug valves, or any other 90–180° rotating mechanism. With inputs varying from 40 to 250 p.s.i., torque output ranges from 400 to 152,400 lb in.

Vactric Control Equipment Ltd. and Rotron Manufacturing Co. Inc., of Woodstock, New York, U.S.A., are forming a joint company which will be known as **Rotron-Vactric Europe Ltd.** to manufacture a range of Rotron fans and blowers in Europe. Until the new plant is established, the manufacture of these products will be carried out at Vactric's Morden factory.

The Bellows Division of Teddington Aircraft Controls Ltd. has become a separate company within the Teddington Group. Named **Teddington Bellows Ltd.,** it is a wholly-owned subsidiary of the British Thermostat Co. Ltd.

Peto Scott Electrical Instruments Ltd. of Weybridge have opened a service department at Croydon. The manager is K. D. Rawlings. All service communications should be addressed to Peto Scott Electrical Instruments Ltd., Beddington Lane, Croydon, Surrey. Telephone: Thornton Heath 9433-5.

A.E.P. International Ltd. announce that their address is now Grove House, London Road, Isleworth, Middlesex. Telephone: Isleworth 7447. The branch manager is Clement W. Fowler.

The electronic data processing divisions of **Honeywell** and of **Svenska Aeroplan Aktiebolaget** (SAAB) today announced a new two-way marketing agreement covering the distribution and sale of computers and EDP equipment.

F & M Scientific Europa N.V. have moved to larger premises, which include a demonstration laboratory. The new address is: 40–48 High Street, London, W.3. Telephone: Acorn 5221/5222.

Varian Associates Ltd. have moved to Russell House, Molesey Road, Walton-on-Thames, Surrey. Telephone: Walton-on-Thames 28766.

A vacancy exists for the position of Editorial Assistant on the staff of *Industrial Electronics*. Applicants should be able to write clearly and have had some formal training in electronics together with some experience in the electronics industry. They should preferably be 25-30 years old. Applications should be addressed to the Editor.

'Technitest'—An Industrial 'Which?'

A new company has been formed to provide industry with independent and frank comparative reports on industrial and commercial equipment and services. It is called Equipment Comparison Ltd. and is headed by Caspar Brooks who, until recently, was the director of the Consumers' Association, the publishers of 'Which?'.

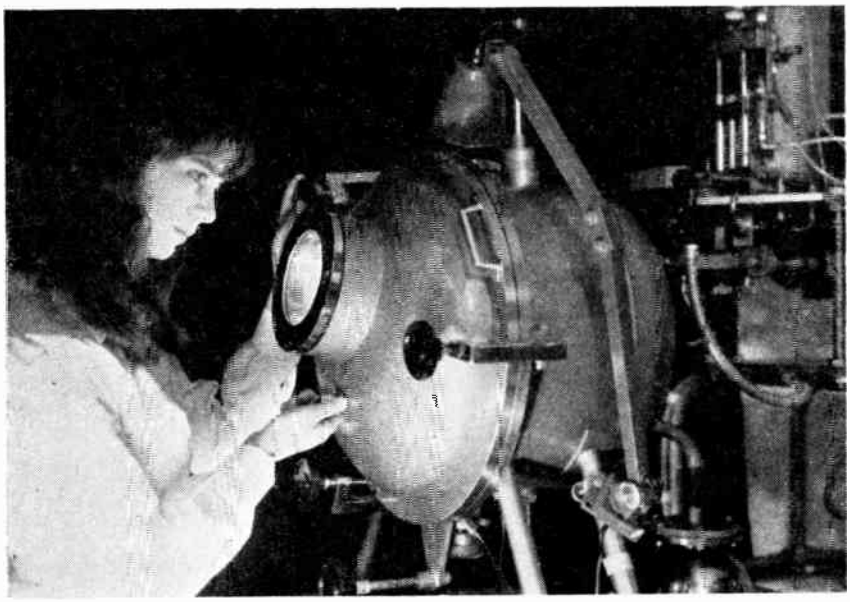
This company is entirely independent and has no connection with the Consumers' Association. Its objects are to assist corporate buyers like commercial and industrial firms, local authorities and professional organizations rather than individual shoppers. Initially it will deal with office equipment but there are plans to expand its activities later to include other types of industrial equipment and services. The first report is planned for April and will be on electric typewriters.

The results of tests and investigations are to be published in the form of comparative reports to be known as 'Technitest' reports, which will mention the brand names of products examined.

'Technitest' reports will be sold on a subscription basis and individually, and will be available to anyone including commercial and industrial firms, local authorities and professional bodies.

The company will not undertake development testing and other work for manufacturers. The company plans initially to issue a report every two months but expects eventually to publish on a monthly basis.

The head office and test house are 153 Hertingfordbury Road, Hertford. Herts. Telephone: Hertford 5461.



SEMI-AUTOMATIC EPOXY-RESIN PLANT—The photograph illustrates the semi-automatic epoxy-resin moulding plant recently installed at the Coventry factory of Lexor Electronics. Designed and manufactured by Bir-Vac Ltd. and Becker Equipment and Lifts Ltd. in collaboration with Lexor engineers, it allows the complete manipulation of precision and complex epoxy-resin mouldings under constant high vacuum. The leading operational feature is that the plant runs continuously without the need of frequent dismantling to clean the resin vessels and conduits which, hitherto, has always been the most serious drawback of epoxy-resin moulding machines. Lexor produce high-grade mouldings almost exclusively for the encapsulation of their own delay lines and similar components ; the installation of this new machine has raised the output from an original 75 units a week to over 6,000 units a week

A New Exhibition for Industry

Industry '65, the International Industrial Equipment and Services Exhibition, and the first of its type, will be held at Earls Court, London, from 15th to 20th November 1965.

Representing a new departure from the conventional type of exhibition it incorporates a specially-designed format, new sectionalization and presentation.

Planned on the lines of a typical modern industrial plant. Industry '65 will enable exhibits to be pin-pointed quickly against their own working background.

Eight main sections corresponding to major industrial departments and fields of activity will cover the needs of office and administration ; specialist services and management ; design and development ; production services ; industrial handling ; warehousing, storage and despatch : canteen, welfare and safety ; and building and maintenance. These, in turn, will be divided into various headings covering associated spheres and further subdivided under individual product headings.

Industry '65 is sponsored by The London Chamber of Commerce, *The Financial Times* and *Industrial Equipment News* and organized by Industrial and Trade Fairs Ltd., Commonwealth House, 1–19 New Oxford Street, London, W.C.1 (Telephone: Chancery 9011).

Industrial Silencers

Made-to-measure acoustic silencing units with applications in the mechanical services of hospital, building and industrial organizations are now available from a new company, Sound Attenuators Ltd. The company will design and manufacture individual silencers to solve noise problems associated with air conditioning, ventilating and heating systems.

The administrative headquarters of Sound Attenuators Ltd. is at 49 Crouch Street, Colchester, Essex.

For further information circle 50 on Service Card

Royal Festival Hall Installs Closed-Circuit TV

Concertgoers who arrive late at the Royal Festival Hall can now see and hear the opening item on a closed-circuit television system installed by E.M.I. Electronics.

At most concert halls, latecomers are not admitted to the auditorium until the end of the first item. At the Royal Festival Hall, they can follow the programme on four 23-in. television receivers, in the foyer on level four (red and green side) and in the two bars on level six. These continue to operate throughout the concert.

Unobtrusively mounted in the circle spotlight housing, a type 6 Minicamera is fitted with a wide-angle lens to transmit a picture of the entire stage. An Autolight unit allows the camera tube's sensitivity to be adjusted automatically to compensate for the wide disparity in ambient lighting when the house lights are turned up before and after the performance and during the intervals.

Additional 19-in. receivers provide a service to the general manager's office, and the office of the Director of Scientific and Industrial Research where some acoustic research is carried out. All control equipment for the television system is housed in a single cubicle in the sound control room.

For further information circle 51 on Service Card

NEW BOOKS

Current Research in Machine Tools 1964-65

To help co-ordinate the research in the machine-tool field D.S.I.R. formed, in 1960, the Machine Tools Co-ordinating Committee. One function undertaken by this Committee is to collect and publish details of machine-tool development in D.S.I.R., research associations, universities and technical colleges.

Recently they have produced a booklet entitled 'Current Research in Machine Tools 1964-5' This describes in 76 pages some of the work going on in the U.K. Each item is dealt with in a concise way. Establishment names, addresses and telephone numbers are included.

The booklet is available from D.S.I.R., State House, High Holborn, London, W.C.1.

Computer Typesetting Conference Proceedings

Pp. 245 + viii. Published by The Institute of Printing Ltd., 44 Bedford Row, London, W.C.1. Price 60s.

This book includes the text of the talks given at The International Computer Typesetting Conference held at London University from 7th to 9th July 1964. It also provides a full record of the interesting discussions which took place at each session.

This is an easy-to-read book which should interest all who are concerned with the future of printing.

American Microelectronics Data Annual : 1964-65

Edited by G. W. A. DUMMER and J. MACKENZIE ROBERTSON. Pp. 941 + xvii. Pergamon Press, Headington Hill Hall, Oxford. Price £8.

This volume presents data on major thin-film semiconductor integrated and hybrid circuit assemblies currently available from sources in the U.S.A.

The information for each item is given in data-sheet form, with circuit diagrams (or where applicable logic diagrams), dimensions and specifications. Application information is also included.

This is necessarily a reference book for those working in the field of microelectronics.

Dictionary of Electronics

By HARLEY CARTER, A.M.I.E.E. Pp. 410 + vi. George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Price 35s.

Annual Review in Automatic Programming, Vol. 4

Edited by RICHARD GOODMAN. Pp. 263 + vii. Pergamon Press, Headington Hill Hall, Oxford. Price 70s.

Dielectrics

By J. C. ANDERSON, Ph.D. Pp. 171 + viii. Chapman & Hall Ltd., 11 New Fetter Lane, London, E.C.4. Price 28s.

This book is based 'upon third-year undergraduate and postgraduate courses of lectures delivered at Imperial College by the author'. The reader is said to need little prior knowledge but a familiarity with elementary electrostatics, the differential calculus, with j-notation, vector algebra and 'a brief acquaintance with classical statistics'.

This all sounds rather formidable but, in fact, the book can be read and understood to a large extent without a profound mathematical knowledge. Mathematical expressions occur on most pages, it is true, but the majority are fairly simple. It is definitely, however, a book for the serious student.

After the introductory chapter, the measurement of permittivity is discussed and this is followed by a chapter on equivalent circuits. Mechanisms of polarization, the effective field, orientational polarization, distortional and interfacial polarization all have chapters. The book concludes by treating dielectric breakdown, piezoelectricity, ferroelectricity and dielectric devices.

Electronics and Instrumentation

By ROBERT L. RAMEY. Pp. 321 + x. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 55s.

Of American origin, this book starts with physical electronics and progresses through conduction in the solid state, electric circuit analysis and a whole gamut of amplifiers to electronic instruments and transducers. The amplifiers include valve and transistor types and, of course, feedback. It is unusual to find trigger and flip-flop circuits treated under the heading of feedback amplifiers, but it is not illogical since these are actually based on amplifiers having positive feedback.

The usual, fairly elementary, algebra of circuit analysis is freely used and will cause few people much difficulty.

Pulse Technology

By WILLIAM A. STANTON. Pp. 255 + xi. John Wiley & Sons Ltd., Glen House, Stag Place, London, S.W.1. Price 53s.

As one might expect from the title, this book deals with the generation and shaping of pulses. It is not highly mathematical, the explanations being mainly of a physical nature. The treatment is by no means elementary, however, and both valves and transistors are used in the examples included.

After the first five chapters there is a shift of content away from pulses per se and in the final chapters subjects such as numbers, codes, logic and programming are discussed. These are, of course, what might be termed the applications of pulses.

Infrared and Its Thermal Applications

By M. LA TOISON. Pp. 147 + x. Macmillan & Co., Ltd., 10-15 St. Martin's Street, London, W.C.2. Price 42s.

This book is one of the Philips' Technical Library and almost the first half deals with infrared radiation itself, its measurement and generation. The second half deals mainly with applications, which include drying and evaporation. The construction of equipment is covered, as well as many industrial, domestic and medical applications, to say nothing of livestock rearing.

Wave and Diffusion Analogies

By RICHARD K. MOORE. Pp. 130 + xi. McGraw-Hill Publishing Co. Ltd., McGraw-Hill House, Shoppenhangers Road, Maidenhead, Berks. Price 38s. 6d.

This book contains a discussion of waves of all sorts in all sorts of media. The treatment is mathematical but the starting point is the familiar one of electromagnetic waves on lines and in space. Other waves, such as acoustic, mechanical and thermal waves, and diffusion processes, are treated by analogy as far as this is practicable.

Bibliography on Medical Electronics

Pp. 31. Published by Pye Instrument Group, Cambridge. Price 5s.

Under 40 main headings, some 800 references to papers and books are given in this publication. This is not a learned Bibliography. Its aims are to acquaint readers with papers dealing with more recent advances in medical electronics, especially from the viewpoint of special engineering and electronics.

Physics of Semiconductors

By JOHN L. MOLL. Pp. 293 + viii. McGraw-Hill Publishing Co., Ltd., Shoppenhangers Road, Maidenhead, Berks. Price 92s.

This is a serious and quite mathematical treatment of semiconductors. It is carried out by quasi-classical methods which are justified in the first three chapters by a quantum-mechanical discussion.

Wire Braid Reinforced Rubber Hose Type 2

British Standard 3832 : 1964. Pp. 14. British Standards Institution. 2 Park Street, London, W.1. Price 5s.

Hose intended for use with common hydraulic fluids such as mineral oils. soluble oils and water is covered by this Standard.

This specification is complementary to B.S. 3640 for type 1 hose issued in 1963, but it covers hose intended for more rigorous conditions of service, at temperatures ranging from −30 °C to 100 °C. Full details are provided of construction, materials, dimensions and tolerances, and marking and test requirements.

Manufacturers' Literature

Temperature Measurement and Control for Industry. Piston-sealed mercury-bulb instrumentation for temperature measurement and control is discussed in this 22-page booklet (Partlow bulletin No. 102) available from *Ad. Auriema-Europe S.A., Electronics House, 172a Rue Brogniez, Brussels 7, Belgium.*.

For further information circle 52 on Service Card

Solartron Digital Data Systems. This 24-page booklet gives an outline of the Solartron philosophy of building custom-built logging systems from standard modules. It also describes a number of applications of logging systems.

The Solartron Electronic Group Ltd., Victoria Road, Farnborough, Hants.

For further information circle 53 on Service Card

Digitizers and Other Equipment for Data Processing. Details of a range of digitizers and resolvers are contained in this 44-page looseleaf catalogue. Also included is information on transistorized logic systems for decoding and recording any form of rotation.

Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.

For further information circle 54 on Service Card

Ten New Products from Imhofs. Fourteen additional instrument cases have been added to the Imhof range. These and many new cabinets, chassis runners and handles are described in this 8-page leaflet.

Alfred Imhof Ltd., Ashley Works, Cowley Mill Road, Uxbridge, Middlesex.

For further information circle 55 on Service Card

Sub-Miniature Indicator Lights. This catalogue L-178 presents in 12 pages a range of sub-miniature indicator lights which have been designed to meet U.S. military specifications. These panel lights mount in $\frac{15}{32}$ or $\frac{11}{32}$ in. clearance holes and are available with a wide choice of lens cap.

Dialight Corporation, 60 Stewart Avenue, Brooklyn, New York 11237, U.S.A.

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Dials, Voltmeters and Phase Shifters for Test Consoles. Full descriptive data is given in this 28-page catalogue No. 3-11 for a range of dial assemblies, voltmeters, phase-sensitive voltmeters and phase shifters.

Theta Instrument Corp., Saddle Brook, New Jersey 07663, U.S.A.

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Rotary Meters. A range of rotary meters for the measurement of most industrial gases at flows from 150 cu ft/hr to 20,000 cu ft/hr is described in this 4-page leaflet.

Parkinson Cowan Measurement, Talbot Road, Stretford, Manchester.

For further information circle 58 on Service Card

Semiconductor Parameters. In 25 pages this leaflet lists definitions for over 80 symbols used in transistor and semiconductor diode specifications. Also included are methods of measurement of transistors parameters.

SGS-Fairchild Ltd., 23 Stonefield Way, Ruislip, Middlesex.

For further information circle 59 on Service Card

BICC Thermocouple Extension and Compensating Cables. This 8-page publication No. 452A describes thermocouple cables manufactured by the *Wiring and General Cables Division of British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London, W.C.1.*

For further information circle 60 on Service Card

Mullard Valves and Tubes for Industry: 1965. This edition has been produced in two separate sections, publications 3462X and Y. The equivalent guide, comprising 103 pages, contains an index of all Mullard industrial valves and tubes together with a comprehensive guide to various valves and tubes for which Mullard types may be used as replacements. Abridged data on all current Mullard industrial valves and tubes is included in a separate 39-page booklet.

Mullard Ltd., Industrial Markets Division, Mullard House, Torrington Place, London, W.C.1.

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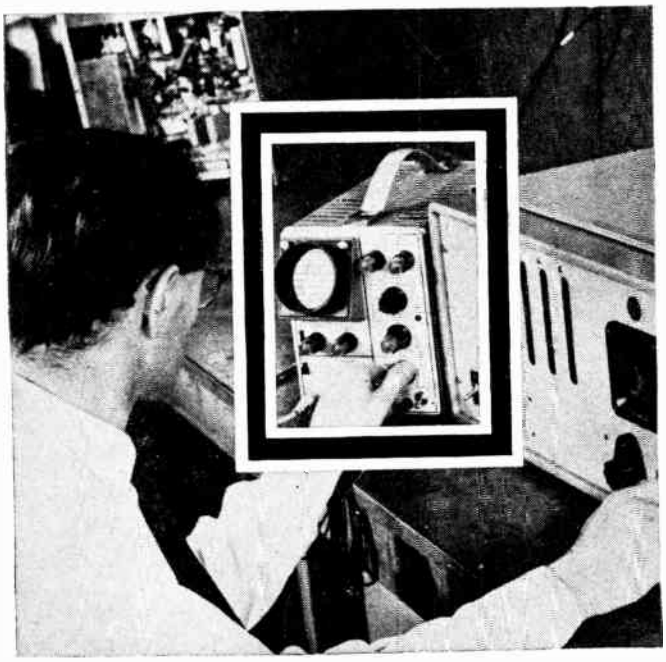

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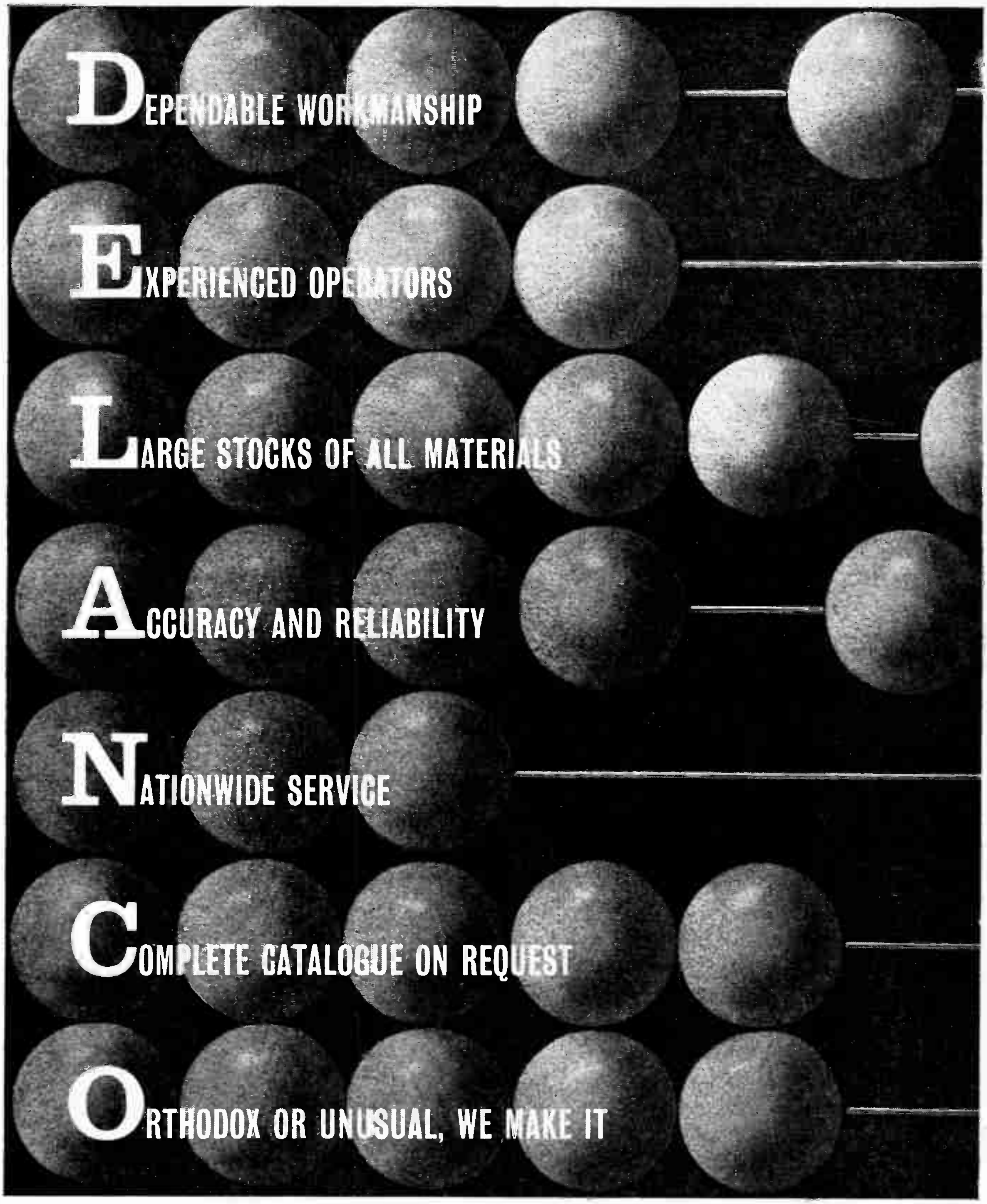
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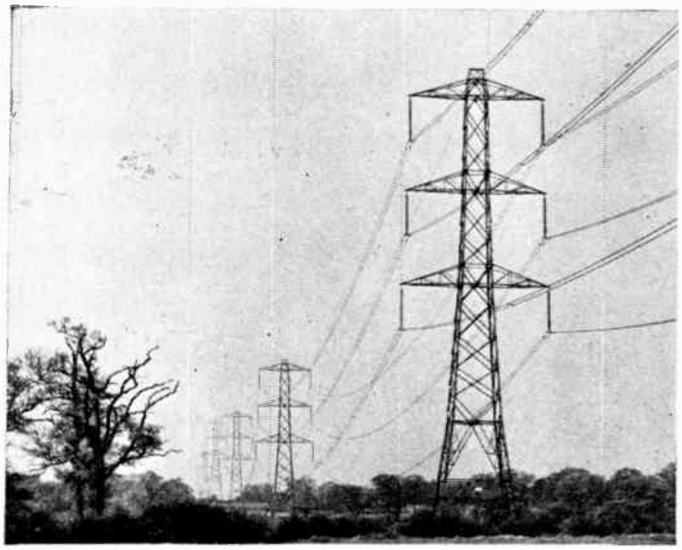

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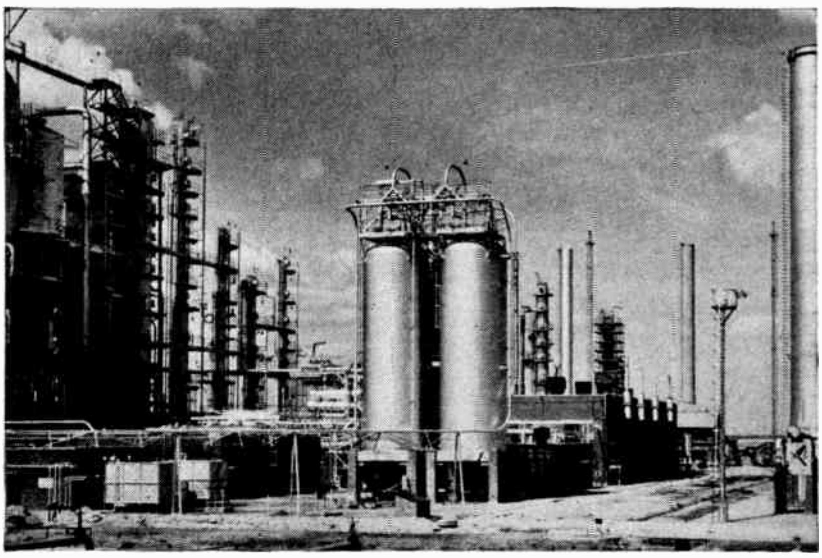

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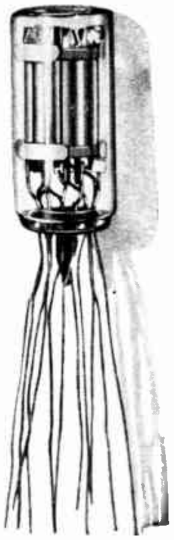

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C70042C	¾"	S-20	3000-8000	4200	19	1500	2.6×10^{3}	4×10^{4}	2.3×10^{-13}	5.9×10^{-15}
4460	¾"	S-11	3000-6500	4400	14	1250	6×10^{3}	1.25×10^{5}	1×10^{-12}	3.7×10^{-15}
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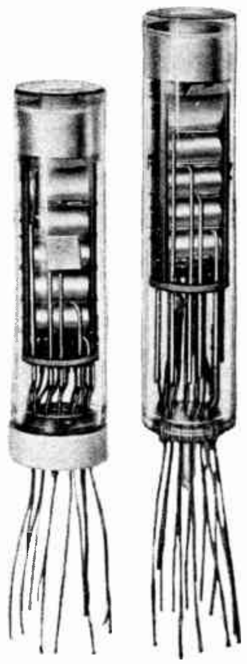

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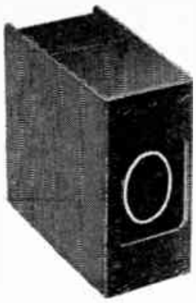

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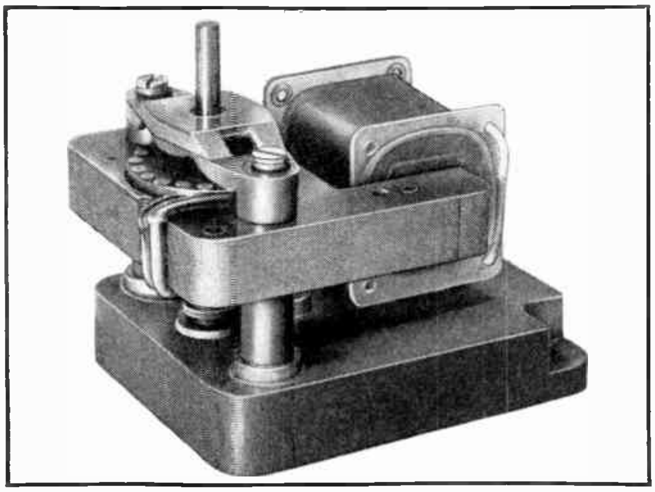

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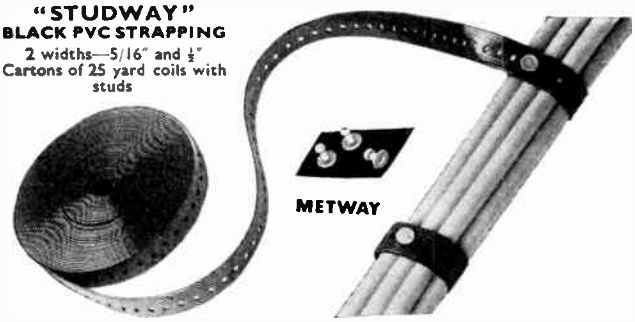

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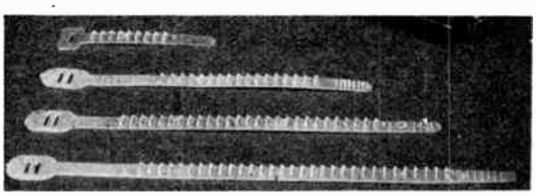

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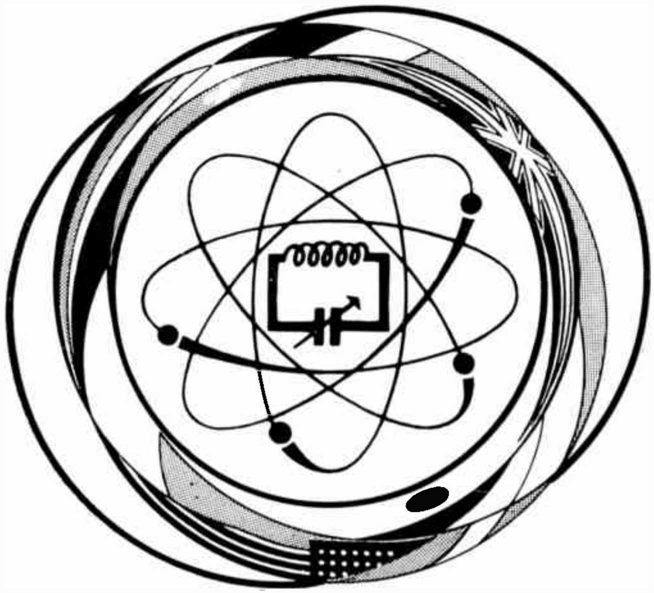

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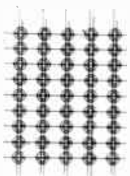

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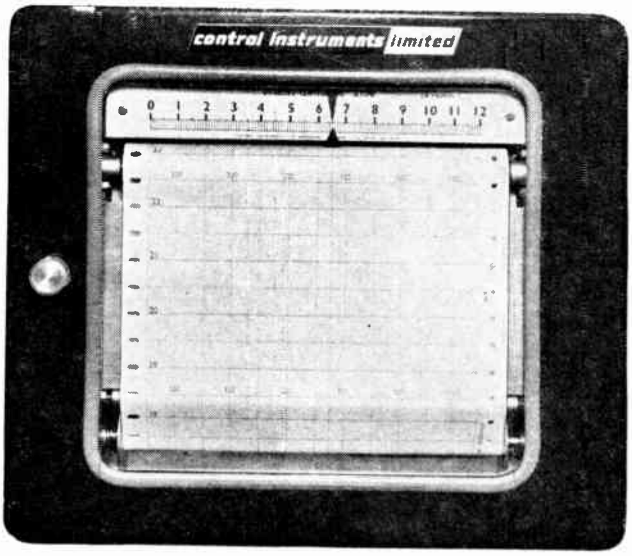

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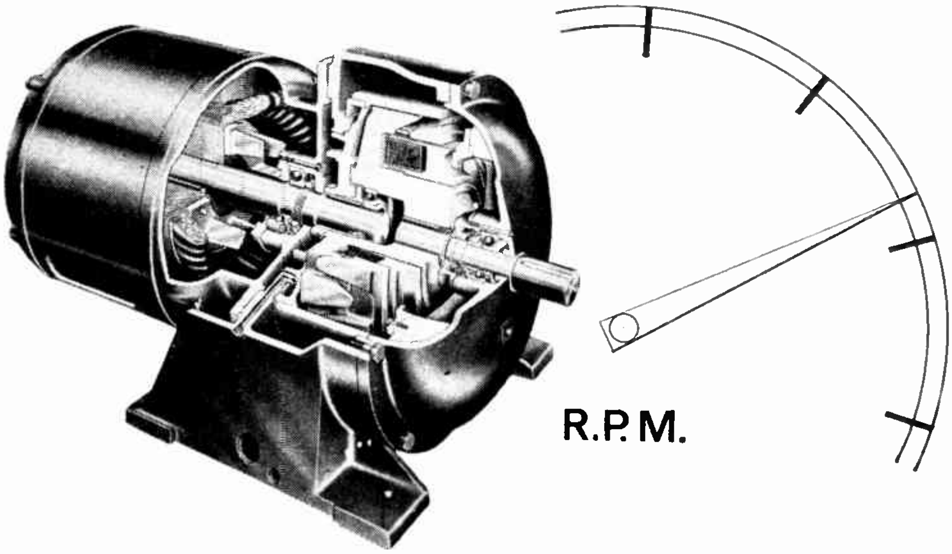

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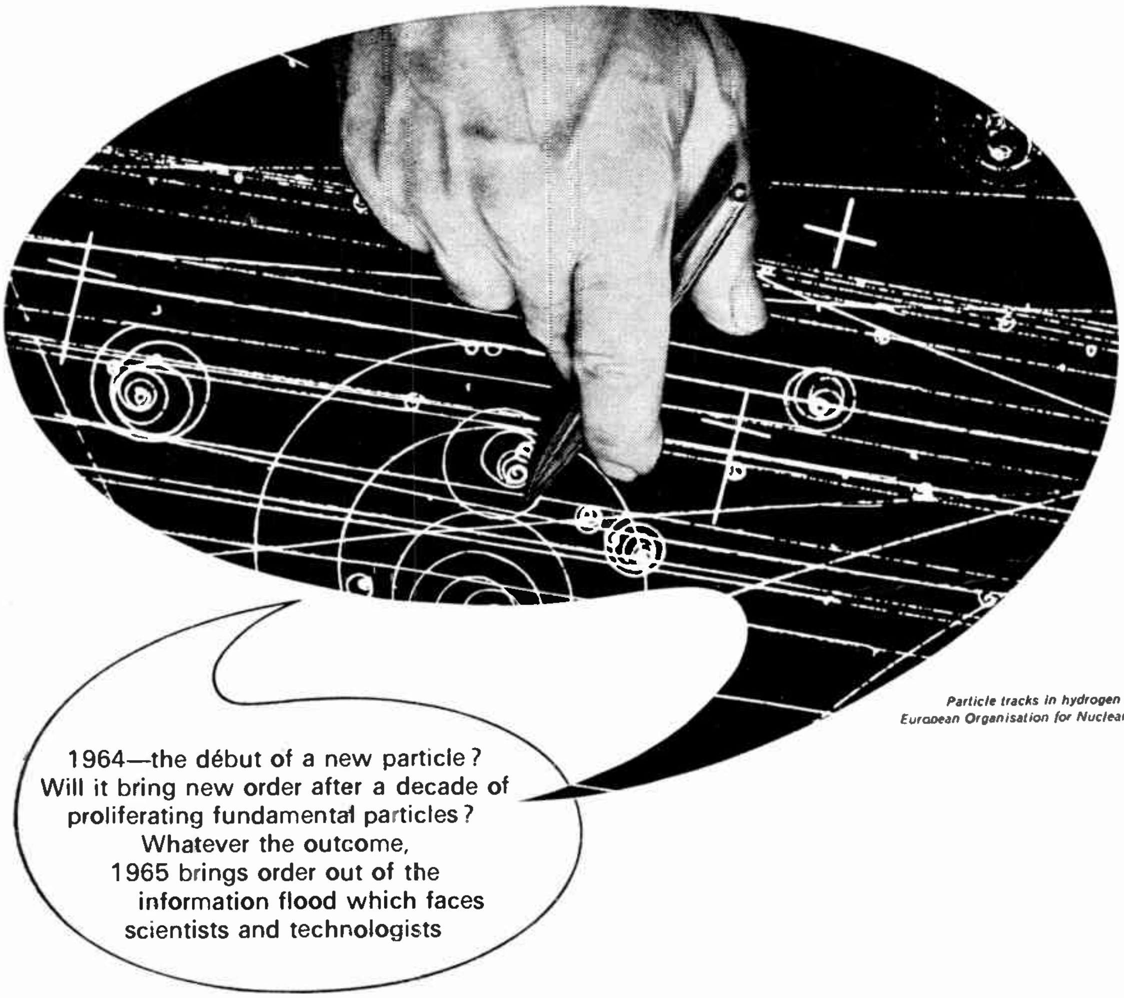

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BOOKS

"ABACS or Nomograms." By A. Giet. Translated from the French by H. D. Phippen and J. W. Head. Most engineers have made use of nomograms at some time in their careers, and are fully alive to the fact that they are a very convenient tool when the same formula has to be solved repeatedly for several sets of variables. It is fair to say, however, that only a small proportion of even those who habitually employ nomograms know how to construct them for their own use. Most of the comparatively small literature on the subject is written for mathematicians and is extremely difficult for the practical engineer to comprehend. This book is essentially practical, and not only demonstrates the many and varied applications of the abac or nomogram, but shows how even those without highly specialised mathematical knowledge may construct their own charts. 35s net from all booksellers. By post 36s from Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1.

"RADIO Circuits: A step-by-step Survey." By W. E. Miller, M.A.(Cantab.), M.Brit.I.R.E. Revised by E. A. W. Spreadbury, M.Brit.I.R.E., associate editor of Wireless & Electrical Trader. This established introduction to superheterodyne receiver circuits has been greatly enlarged and brought completely up to date with the inclusion of transistor and f.m. receivers; there are new chapters covering battery receivers and car radio sets, while the modern a.m./f.m. receiver is fully described. Mathematics and obscure theoretical considerations are entirely omitted, and over 80 easy-to-follow circuit diagrams are explained in a simple but practical manner, splitting up the circuit into sections and working from the aerial terminal through to the loudspeakers. 15s net from all booksellers. By post 15s 10d from Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1.

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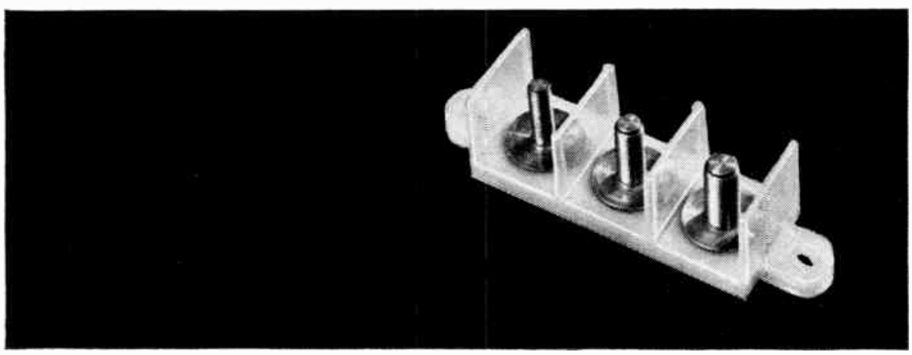

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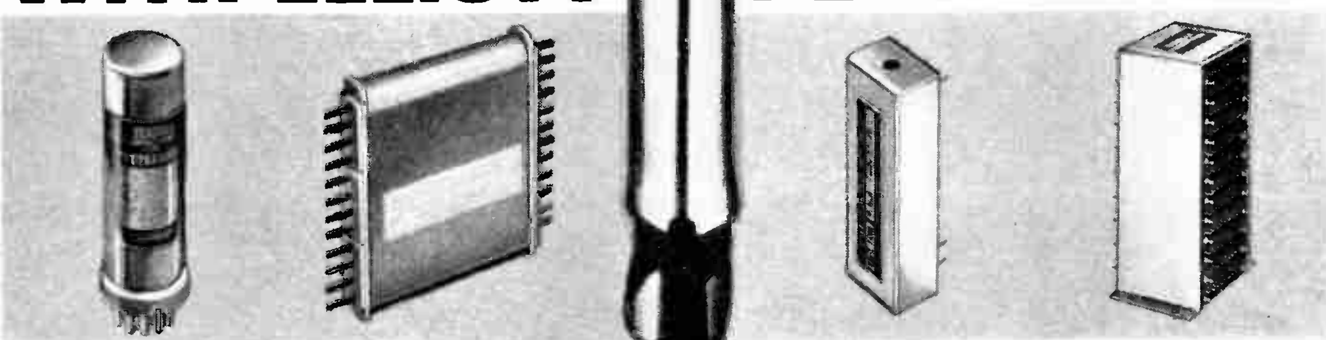

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WHAT'S ON AND WHERE

The previously announced joint I.E.R.E./I.E.E. meeting 'The Training of Computer Engineers' which was to be held on 12th March is now cancelled.

Meetings

Institution of Electronic and Radio Engineers

All meetings will be held at 9 Bedford Square, London, W.C.1, and tickets will be required, unless otherwise stated.

17th Mar. 6 p.m. Joint I.E.R.E./I.E.E. discussion on 'Implanted Stimulators for Bladder and Rectum'.

7th Apr. 6 p.m. 'Inertial Navigational Systems for Airborne and Shipborne Uses'.

14th Apr. 6 p.m. at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street. London, W.C.1. 'Solid State Scanning Circuits'.

21st Apr. 6 p.m. at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1. 'Effect on the Ionosphere of Nuclear Explosions'.

28th Apr. 6 p.m. 'Synchronously Tuned Methods of Harmonic and Intermodulation Distortion Analysis'.

12th May, 6 p.m. Joint I.E.R.E./I.E.E. meeting at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1. 'Random Access Mass Stores'.

19th May, 6 p.m. 'A Groove Control System for Phonograph Disc Cutting Equipments'.

Institution of Electrical Engineers

All meetings will be held at 5.30 p.m. at Savoy Place, London, W.C.2, unless otherwise stated.

17th Mar. 6 p.m. at I.E.R.E., 9 Bedford Square, London, W.C.1. Joint I.E.R.E./I.E.E. discussion on 'Implanted Stimulators for Bladder and Rectum'.

12th May, 6 p.m. at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1. Joint I.E.R.E./I.E.E. meeting. 'Random Access Mass Stores'.

Institution of Mechanical Engineers

All meetings will be held at 6 p.m. at 1 Birdcage Walk, London, S.W.1, unless otherwise stated.

11th Mar. Discussion on 'Gear Pumps Versus Vane Pumps'.

22nd Mar. Discussion on 'New Teaching Techniques in Engineering Laboratories'.

23rd Mar. Discussion on 'Trends in Machining Techniques and Processes'.

24th Mar. 11th Graham Clark Lecture (joint meeting with Institutions of Civil and Electrical Engineers) 'Incentives to Invention and Innovation'.

1st Apr. Discussion on 'Economics of Automatic Control in Shipping'.

The Television Society

All meetings will be held at 7 p.m. in the Conference Suite, I.T.A., 70 Brompton Rd., London, S.W.3, unless otherwise stated.

18th Mar. 'Video Storage for Standard Converters'.

2nd Apr. 'Advanced Television Technical Problems in Japan'.

Conferences, Symposia and Colloquia

23rd–25th Mar. Conference on 'Automating Engineering Manufacture'. Held by PERA at Melton Mowbray, Leics. ('Phone: Melton Mowbray 4133).

25th–26th Mar. at 1 Birdcage Walk, London, S.W.1. Conference on 'Vacuum Technology' to be held by the Institution of Mechanical Engineers in conjunction with the Joint British Council for Vacuum Science and Technology.

5th Apr. 2.30 and 5.30 p.m. at the I.E.E., Savoy Place. London, W.C.2. Joint I.E.E./I.E.R.E. colloquium on 'Design of Real Time Computer Systems.'

5th–7th April. Symposium on 'Vibration in Civil Engineering' at Imperial College, London. Enquiries to: International Association of Earthquake Engineering, c/o Institution of Civil Engineers, Great George St., London, S.W.1. ('Phone: Whitehall 0485).

5th–9th Apr. at Nottingham University. Conference on 'Advances in Automatic Control', held by Institution of Mechanical Engineers.

11th–13th May. Conference on 'Financial Management and Post Control'. Organized by the Production Engineering Research Association of Great Britain (PERA) and held at their headquarters at Melton Mowbray, Leicestershire. ('Phone: Melton Mowbray 4133).

13th–14th May. Conference on 'New Materials and Processes in Instrument Manufacture'. Held by British Scientific Instrument Research Association at Grand Hotel, Eastbourne. Applications for registrations to: SIRA, South Hill, Chislehurst, Kent. ('Phone: Imperial 5555).

17th–20th May at the I.E.E., Savoy Place, London, W.C.2. Joint I.E.E./I.E.R.E. international conference on 'Components and Materials used in Electronic Engineering'. Registration forms and further information from I.E.R.E., 9 Bedford Square, London, W.C.1.

18th–20th May. Conference on 'Design Engineering and Management'. Organized by the Production Engineering Research Association of Great Britain (PERA) and held at their headquarters at Melton Mowbray, Leicestershire. ('Phone: Melton Mowbray 4133).

30th June–2nd July at University College, London. Joint I.E.R.E./I.E.E. symposium on 'Microwave Applications of Semiconductors'. Papers and requests for further information should be sent to The Secretary, Joint Organizing Committee, Symposium on Microwave Applications of Semiconductors, The Institution of Electronic and Radio Engineers, 8–9 Bedford Square, London, W.C.1.

WHAT'S ON AND WHERE

Continued

5th–6th July. Conference on 'Low Level Radioactivity Measurements—Limitations and New Techniques'. Held at The Imperial College of Science and Technology, London, by The Institute of Physics and The Physical Society. Applications for tickets to: I.P.P.S., 47 Belgrave Sq., London, S.W.1. ('Phone: Belgravia 6111).

13th–18th Sept. Engineering Materials and Design Conference. Held in conjunction with an exhibition at Olympia, London. Organized by Industrial & Trade Fairs Ltd., Commonwealth House, 1–19 New Oxford Street, London, W.C.1. ('Phone: Chancery 9011).

21st–24th Sept. First European Conference on Magnetism. Vienna. To be held at Technischen Hochschule, Vienna. Conference Secretariat: Verein Deutscher Eisenhuttenlente, 4 Dusseldorf, Breite Strasse 27.

Exhibitions

8th–16th Mar. Utrecht
International Spring Trade Fair, Utrecht. U.K. representatives Exhibition Consultants Ltd., 11 Manchester Square, London, W.1. ('Phone: Hunter 1951).

15th–19th Mar. London
International Reprographic Exhibition, Earls Court, London. Organized by Industrial Exhibitions Ltd., 9 Argyll St., London, W.1. ('Phone: Gerrard 1622).

29th Mar.–2nd Apr. London
LABEX—Laboratory Apparatus and Materials Exhibition at Earls Court. Sponsored by Scientific Instrument Manufacturers Association, 20 Peel St., London, W.8. ('Phone: Park 2614).

5th–8th Apr. Manchester
The Physics Exhibition, Manchester (College of Science and Technology). Organized by the Institute of Physics and the Physical Society, 47 Belgrave Square, London, S.W.1. ('Phone: Belgravia 6111).

8th–13th Apr. Paris
Salon International des Composants Electroniques in Paris. Organized by Fédération Nationale des Industries Electroniques (FNIE), 16 rue de Presles, Paris, 15e. ('Phone: 273-24-70).

21st–30th Apr. London
International Engineering Exhibition, London (Earls Court and Olympia). Organized by F. W. Bridges & Sons Ltd., Commonwealth House, 1–19 New Oxford Street, London, W.C.1. ('Phone: Whitehall 1353).

24th Apr.–2nd May. Hanover
Hanover Fair. U.K. representatives Schenkers Ltd., Royal London House, 13 Finsbury Square, London, E.C.3. ('Phone: Metropolitan 9711).

17th–22nd May. Birmingham
Business Efficiency Exhibition, Birmingham (Bingley Hall). Organized by the Business Equipment Trade Association, 64 Cannon Street, London, E.C.4. ('Phone: Central 7771).

18th–21st May. London
Radio and Electronic Component Show at Olympia, London. Organized by Industrial Exhibitions Ltd., 9 Argyll Street, London, W.1. ('Phone: Gerrard 1622).

19th–25th May. Amsterdam
Electronic Exhibition, Amsterdam. Organized by Elvabé, Molenallee 63A, Wilp, Gld., Netherlands.

15th–19th June. London
1st Pumping Exhibition, Earls Court, London. Organized by Iliffe Exhibitions Ltd., Dorset House, Stamford St., London, S.E.1. ('Phone: Waterloo 3333).

15th–19th June. London
NAVREX—Noise and Vibration Reduction Exhibition, Earls Court, London. Organized by Iliffe Exhibitions Ltd., Dorset House, Stamford St., London, S.E.1. ('Phone: Waterloo 3333).

16th–26th June. London
Interplas 65—The International Plastics Exhibition in Europe for 1965, Olympia, London. Organized by Iliffe Exhibitions Ltd., Dorset House, Stamford St., London, S.E.1. ('Phone: Waterloo 3333).

25th Aug.–4th Sept. London
Radio Show, Earls Court, London. Organized by Industrial and Trade Fairs, 1–19 New Oxford Street, London, W.C.1. ('Phone: Whitehall 1353).

7th–11th Sept. Basle
INEL 65 International Exhibition of Industrial Electronics, Basle, Switzerland. 61 Clarastrasse, 4000 Basle. ('Phone: Basle (061) 323850).

9th–19th Sept. Paris
Salon International de la Radio et de la Télévision, Paris.

13th–18th Sept. London
Engineering Material and Design Exhibition. Held in conjunction with a conference at Olympia, London. Organized by Industrial & Trade Fairs Ltd., Commonwealth House, 1–19 New Oxford Street, London, W.C.1. ('Phone: Chancery 9011).

14th–22nd Sept. Utrecht
HET Instrument 1965 Exhibition, Royal Dutch Industries Fair, Utrecht. Further details from: Cooperative Vereniging, 'HET Instrument' u.a., Sparrenlaan 2, Soest, Holland. ('Phone: Soest (02955) 3047).

28th Sept.–1st Oct. Brighton
Medical Electronic and Instrumentation Exhibition (in conjunction with The European Symposium on Medical Electronics) at Exhibition Hall, Brighton, Sussex. Organized by Events Promotions Ltd., Ashbourne House, Alberon Gardens, London, N.W.11. ('Phone: Meadway 5555).

4th–13th Oct. London
Business Efficiency Exhibition, London (Olympia). Organized by Business Equipment Trade Association, 64 Cannon Street, London, E.C.4. ('Phone: Central 7771).

13th–19th Oct. Dusseldorf
3rd International Congress and Exhibition of Measuring Instrumentation and Automation (Interkama). Dusseldorf, Germany. Represented by John E. Buck (Trade Fair Agencies) Ltd., 47 Brewer Street, Piccadilly, London, W.1. ('Phone: Gerrard 7576).

27th–30th Oct. London
R.S.G.B. Radio Communications Show, Seymour Hall, London. Organized by P. A. Thorogood, 35 Gibbs Green, Edgware, Middlesex.

15th–20th Nov. London
Industrial Photographic and Television Exhibition at Earls Court, London. Organized by Industrial & Trade Fairs Ltd., Commonwealth House, 1–19 New Oxford Street, London, W.C.1. ('Phone: Chancery 9011).

Courses

Commencing 30th Mar. 'Production Inspection'. One of a number of refresher courses being held by the Production Engineering Research Association at their headquarters at Melton Mowbray, Leics. ('Phone: Melton Mowbray 4133) for personnel of member-firms.

20th–23rd July. 'Valve Analysis'. I.Prod.E. Summer School 1965 at Loughborough College of Technology. Further details from: The Institution of Production Engineers, 10 Chesterfield St., London, W.1. ('Phone: Grosvenor 5254).

Two-week Tektronix Instrument Courses. Three separate courses repeated at intervals of approximately one month. Held at Guernsey. Full details from Tektronix U.K. Ltd., Beaverton House, Station Approach, Harpenden, Herts. ('Phone: Harpenden 61251).

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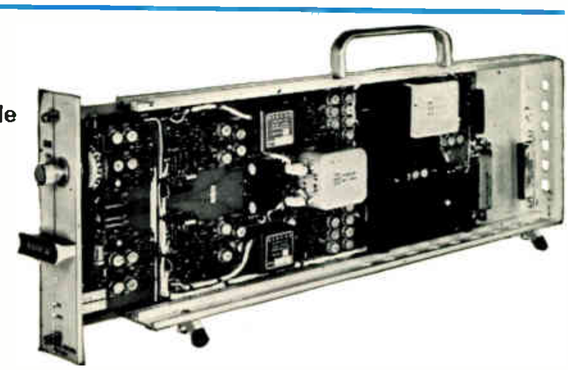

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