INDUSTRIAL ELECTRONICS

DECEMBER 1963 5s 0d

For further information circle 200 on Service Card

LOOK–NO CONTACTS!

NORBIT STATIC SWITCHES for automatic control systems NEVER NEED MAINTENANCE

No maintenance, no 'sneak circuits', operation in *any* position, constant speed and a life unaffected by the number of operations.

These are only some of the many reasons why electrical and electro-mechanical engineers, in increasing numbers, are using Norbit static switches instead of relays in a wide variety of automatic control and alarm applications, from lift systems to food processes.

Since they use no moving parts contactless Norbit switches need no adjustments, no cleaning and suffer no mechanical wear or variation in operating speed. Time wasting 'cut and try' methods are also eliminated during system design—using Norbits you can plan your complete system on paper and know that what you plan will work in practice.

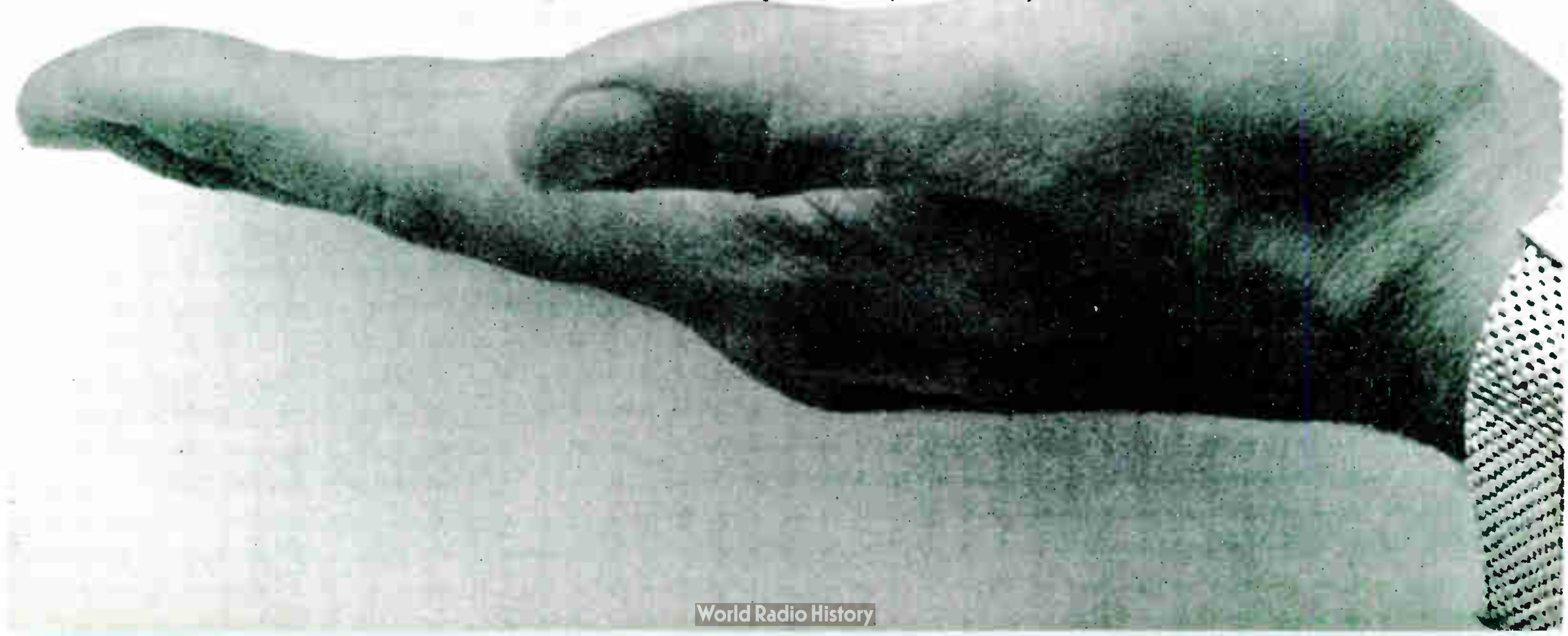
Furthermore, one basic Norbit gives you any switching function you need. No contacts, no sparking, no heat to dissipate, unaffected by detrimental atmospheres—dust, abrasive particles, humidity, corrosive fumes, hazardous atmospheres—the reliability of Norbit static switches has been proven in practice and by exhaustive quality testing.

Here's all you need to know How does the Norbit switch if it uses no contacts? Just regard the Norbit as a switch which does not open or close, but one which either conducts or does not conduct. Furthermore, there's *no need* for you to know any electronic theory to understand Norbits and apply their many advantages.

Free to the practical engineer Write for a free copy of 'Static Switching Simply Explained'. This booklet gives you a completely non-mathematical explanation of Norbit static switches—what they can do and how they can be used. Write today for this practical guide to contactless switching using Norbits.

MULLARD EQUIPMENT LIMITED

MANOR ROYAL, CRAWLEY, SUSSEX
Telephone Crawley 28787



INDUSTRIAL ELECTRONICS

incorporating *ELECTRONIC TECHNOLOGY*

Volume I Number 15 December 1963

contents

Editor **W. T. COCKING, M.I.E.E.**

Assistant Editor **T. J. BURTON**

Advertisement Manager **G. H. GALLOWAY**

continued overleaf

Published on the first Thursday after the 5th of each month by
ILIFFE ELECTRICAL PUBLICATIONS LTD.
Managing Director: W. E. Miller, M.A., M.Brit.I.R.E.
Dorset House, Stamford Street, London, S.E.1.
Telephone: Waterloo 3333.
Telegrams: Wirenger, London, Telex
Cables: Wirenger, London, S.E.1.

ANNUAL SUBSCRIPTION, HOME £3 0s. 0d.
OVERSEAS £3 10s. 0d.
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contents continued

FEATURES

OUR COVER

This shows a motor grader with electronic blade control preparing a new road formation to the fine limits required by modern specifications. It is an Aveling-Barford all-wheel drive and all-wheel steering grader equipped with Sperry 'Grademaster' automatic blade control. Elsewhere in this issue an article describes the control system

Next Month

The January issue will contain an article discussing the mechanical requirements for the automatic control of machine tools. Other articles will deal with the measurement of vibration in the development of steam turbines and with the recording of level and temperature in storage tanks.

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 to be found in the front and back of the journal.

CHOOSE G.E.C. FOR

DISC SEAL VALVES

(take your pick from this complete and remarkable range)

Here is a complete range of disc seal valves offering powers to 1kW and frequencies up to 4000 Mc/s.

In co-axial circuits over the frequency range 500–2000 Mc/s the DET24 gives outputs of 15W to 1W, but several DET24's paralleled in a radial cavity will give increased output at television UHF frequencies. Below 500 Mc/s, simple lumped circuits can be used to give a performance superior to double tetrodes of comparable rating.

	DET22	DET23	DET24	DET29	ACT22	ACT28A
Pout (W)	2.5	2.5	10	1.5	35	1000
frequency (Mc/s)	1500	1500	1000	4000	1000	350
Va (V)	350	350	400	450	600	1500
Pa (W)	10	10	20	10	75	1500

Our technical information centre is ready to help with your application problems. Write for full data sheets on these or other M-O V products, or telephone RIVerside 3431. Telex 23435.

G.E.C.

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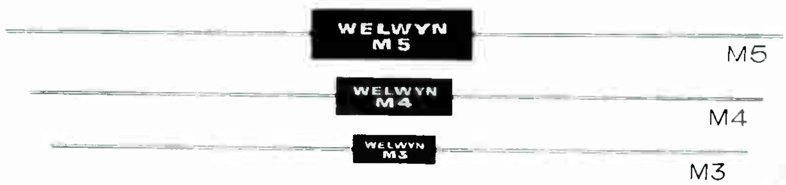
M3	100Ω-250K	1/8	0·437″	0·165″	1·625″	23
M4	100Ω-250K	1/4	0·615″	0·200″	1·625″	23
M5	100Ω-250K	1/2	0·820″	0·258″	1·625″	21

SELECTION TOLERANCE: ± 1%

TEMPERATURE COEFFICIENT: ± 100 p.p.m. /°C OVER THE AMBIENT TEMPERATURE RANGE. − 55°C TO 125°C AT WHICH THESE RESISTORS CAN BE OPERATED.
± 50 p.p.m. /°C TO SPECIAL ORDER

STABILITY: AFTER 2,000 HOURS FULL LOAD AT 70°C IN CONFORMANCE WITH DEF 5114 THE MAXIMUM CHANGE IN RESISTANCE WILL NOT EXCEED 0·25%.

NOISE: LESS THAN 0·1 μv PER VOLT



WRITE NOW FOR FULL DETAILS

WELWYN ELECTRIC LIMITED

BEDLINGTON · NORTHUMBERLAND · ENGLAND

FACTORIES IN AUSTRALIA AND CANADA

Miniature multi-aperture core provides simple and reliable magnetic logic element

Mullard introduces Laddic

An important contribution towards the development of logic systems has been made by the availability of laddic. Laddic is a miniature ladder-shaped core of square-loop ferrite material which, by means of suitable winding configurations, can perform logic functions. It is simple in construction (being merely a ferrite core with windings), has an extremely high reliability, and can be easily arranged to fail to safety.

The Mullard laddic core is 0·8 × 0·13in and 0·08in thick. It has eleven apertures and the geometry has been designed to give a good signal-to-noise ratio.

OPERATION

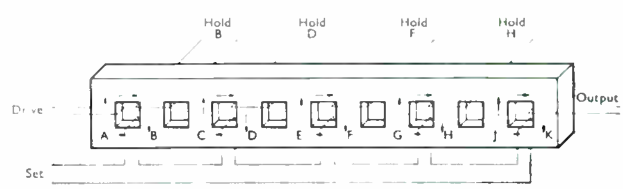
There are many possible winding configurations for laddic cores but a simple configuration enabling the logic function AND to be performed is shown in the diagram. A current pulse in the 'Set' windings of sufficient amplitude to saturate the material produces, for example, the magnetic flux pattern shown. A pulse of opposite polarity in the 'Drive' winding will reverse the flux in the shortest closed path. In this case, the flux will be reversed in rungs A and B and the sections of the side rails joining them. There will be little flux change in other parts of the core.

If, however, 'Hold' winding B is energised so that it opposes the flux reversal in rung B produced by the 'Drive' pulse, the reversal will have to take place along the next shortest path. Rung C is already saturated in the 'reverse' direction by the 'Set' winding, so the flux reversal will occur in rung D. By also energising 'Hold' winding D to oppose the flux change, the reversal will occur in rung F, and when all the intermediate 'Hold' windings are energised, the reversal will be transferred to rung K and so induce a pulse in the 'Output' winding.

LOGIC FUNCTIONS

An output pulse will occur if, and only if, all the 'Hold' windings are energised. In other words, the laddic performs the logic function AND. More than one 'Hold' winding can be wound on one rung but as the flux reversal in that rung can be prevented by energising only one, the logic function OR can be performed. Other logic functions can be performed by suitably designed winding configurations.

As long as the 'Hold' and 'Drive' pulses overlap for a time greater than the material switching time, the pulses need not be accurately defined. This is advantageous in, for example, industrial control equipment where the pulses for the 'Hold' windings could be produced by transducers a considerable distance from the laddic. The only requirements for the pulses are that the amplitude is sufficient to switch the core, and the pulse duration is greater than 2μs. There is no lower pulse repetition limit and the present upper limit of a laddic is 40kc/s.



Magnetic flux patterns in an eleven-aperture laddic core produced by the current pulses in the 'Set' winding

FAILURE TO SAFETY

In many applications, it is necessary for the equipment to fail safe, that is, any conceivable fault must lead to the logic circuits assuming a particular output condition which is chosen as safe. An example of this is in railway signalling where any fault must result in the affected signals being set to danger. By choosing the no-output state as the safe condition, the laddic can satisfy the fail-safe conditions.

Mullard are introducing an encapsulated general-purpose wound laddic. By suitable interconnection of the windings, most logic functions can be performed. Laddic cores are also available for systems engineers to wind to their special requirements.

For further information on laddics, please use the reader reply card of this journal (see reference number opposite).

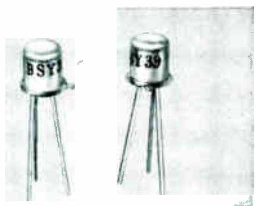
What's new from Mullard

TWO NEW PLANAR TRANSISTORS FOR HIGH-SPEED LOGIC CIRCUITS

Low saturation voltage a special feature

Two n-p-n silicon planar epitaxial transistors specially designed for high-speed logic circuits are now available. These two transistors, types BSY 38 and BSY39, have a maximum desaturation time constant of 16ns, a maximum saturation voltage of 0·25V at a collector current of 10mA, and a collector-to-emitter rating of 15V.

The BSY38 and BSY39 are introduced to fulfil economically the requirements of logic circuits with propagation delay times of 10 to 25ns. In these circuits, the voltage swing of the signal must be kept as low as possible consistent with maintaining an adequate margin between the voltage levels used to represent '0' and '1', and providing an adequate margin against induced noise pulses. The transistors used should therefore have a low saturation voltage, a small desaturation time, a high cut-off frequency at low voltage, and a small depletion capacitance. In addition, the spreads on current gain and input voltage should be narrow. The abridged data shown below shows how the BSY38 and BSY39 meet these requirements.



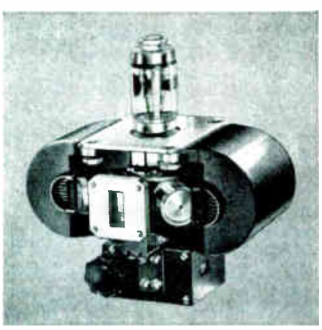
ABRIDGED DATA FOR BSY38 AND BSY39

$V_{CB\,(max)}$ (I_E = 0mA)	+20 V
$V_{CE\,(max)}$ (cut off)	+15 V
$I_{CM(max)}$	200 mA
$P_{tot(max)}$ (T_{amb} = 25°C)	300 mW
h_{FE} (I_C = 10mA)	
BSY38:	30 to 60
BSY39:	40 to 120
f_T (V_{CE} = 2V, I_C = 10 mA)	> 200Mc/s

TUNABLE X-BAND MAGNETRON WITH 225kW PULSE OUTPUT

An X-band packaged magnetron designed for use as a pulsed oscillator in ground-based and airborne radar equipment is now available from Mullard. This magnetron, the YJ1010, is servo-tunable over the frequency range 8·5 to 9·6Gc/s, and is the electrical equivalent and near mechanical equivalent of the 4J50.

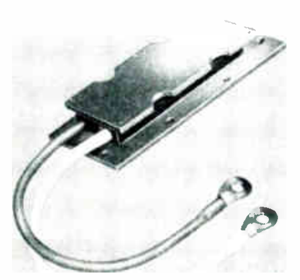
With an anode pulse current of 27·5A the peak output power is 225kW for a pulse duration of 1·0µs and a duty cycle of 0·001. The average output power under these conditions is 225W. Natural cooling can be used unless other items of equipment impede the air flow round the magnetron. In these cases, low-velocity forced-air cooling is necessary.



Large-capacitance electrolytics for computers

A range of large-capacitance electrolytic capacitors for use in computers and other professional equipment is now available. The range of capacitance values is from 900 to 31 500µF with voltage ratings from 6·4 to 100V. These capacitors, the C432FR series, are intended for use in power supply units in professional equipment where a long service life and high reliability are required.

The operating temperature range of these capacitors is from −40 to 70°C. In practice, the lower temperature limit depends on the increase in losses and decrease in capacitance value that can be tolerated, and will therefore vary with the application. The maximum value of impedance, measured at 100kc/s and 20°C, is 0·1Ω for all capacitors in this range. The tolerance on the capacitance value is −10 to +50%.



New pot-core material extends frequency range up to 15Mc/s

A new ferrite material has been introduced which will enable Vinkor pot-core assemblies to be used at frequencies up to 15Mc/s, the previous frequency limit being 2Mc/s. The new material will be of particular interest to designers of h.f. communications equipment, enabling them to incorporate the benefits of Vinkors into their equipment.

Pot-cores using the new material, which has the designation B10, are available in the 10, 12, 14, 16, and 18mm sizes and all the accessories for these sizes of Vinkor can be used with the new material. By careful winding of the coils, Q-factors of 300 to 400 can be obtained.

The new range of Vinkors is colour coded blue and joins the three existing ranges—red, yellow, and violet—to provide a complete range of adjustable inductors covering frequencies from 400c/s to 15Mc/s. Inductors incorporating these Vinkors are highly stable, and high Q-factors can be obtained. Both standard housings and clip-mounting versions are available.

COLOURED CONTROL KNOBS

Complementary range to F111 series

A range of coloured control knobs for use with professional equipment has recently been introduced. These knobs are available in four styles and in three colours with a range of interchangeable coloured centre caps to facilitate easy identification. Spindle sizes of ⅛ and ¼in, and 4 and 6mm can be accommodated.

At present, the knobs are available in three colours—black, grey, and white. The centre caps are available in black, grey, white, and red.

COMPACT COOLING WITH PELTIER BATTERIES

Three Peltier batteries are now available for a wide range of cooling applications where a compact 'cold source' is required. In applications where space is strictly limited, the Peltier battery offers considerable advantages over refrigerators requiring compressors or heating units. Typical examples of the use of Peltier batteries include heat sinks for transistorised equipment, medical and biological research applications, and small-scale refrigeration.

The batteries, which use bismuth telluride as the thermoelectric element, operate on the Peltier principle in that when a direct current is passed through a junction of dissimilar metals or semiconductor materials, a temperature gradient is established across that junction.

Peltier battery PT11/20 is designed for an operating current of 18 to 22A at 1·0 to 1·2V, and has a maximum cooling capacity of 16W. Battery PT20/20 has an operating current of 20A at 2V and has a cooling capacity of 23W, while battery PT47/5 operates at 5 to 6A and 5·0 to 5·4V with a cooling capacity of 16W. Batteries PT11/20 and PT47/5 can be supplied with either a flat copper plate for use with solid surfaces or with fins for the cooling of gases or liquids. The battery, PT20/20, is supplied complete with flat copper plates, and all types are ready for immediate use.

Reader Enquiry Service

Further details of the Mullard products described in this advertisement can be obtained through the Reader Enquiry Service of Industrial Electronics, using the appropriate code number shown below.

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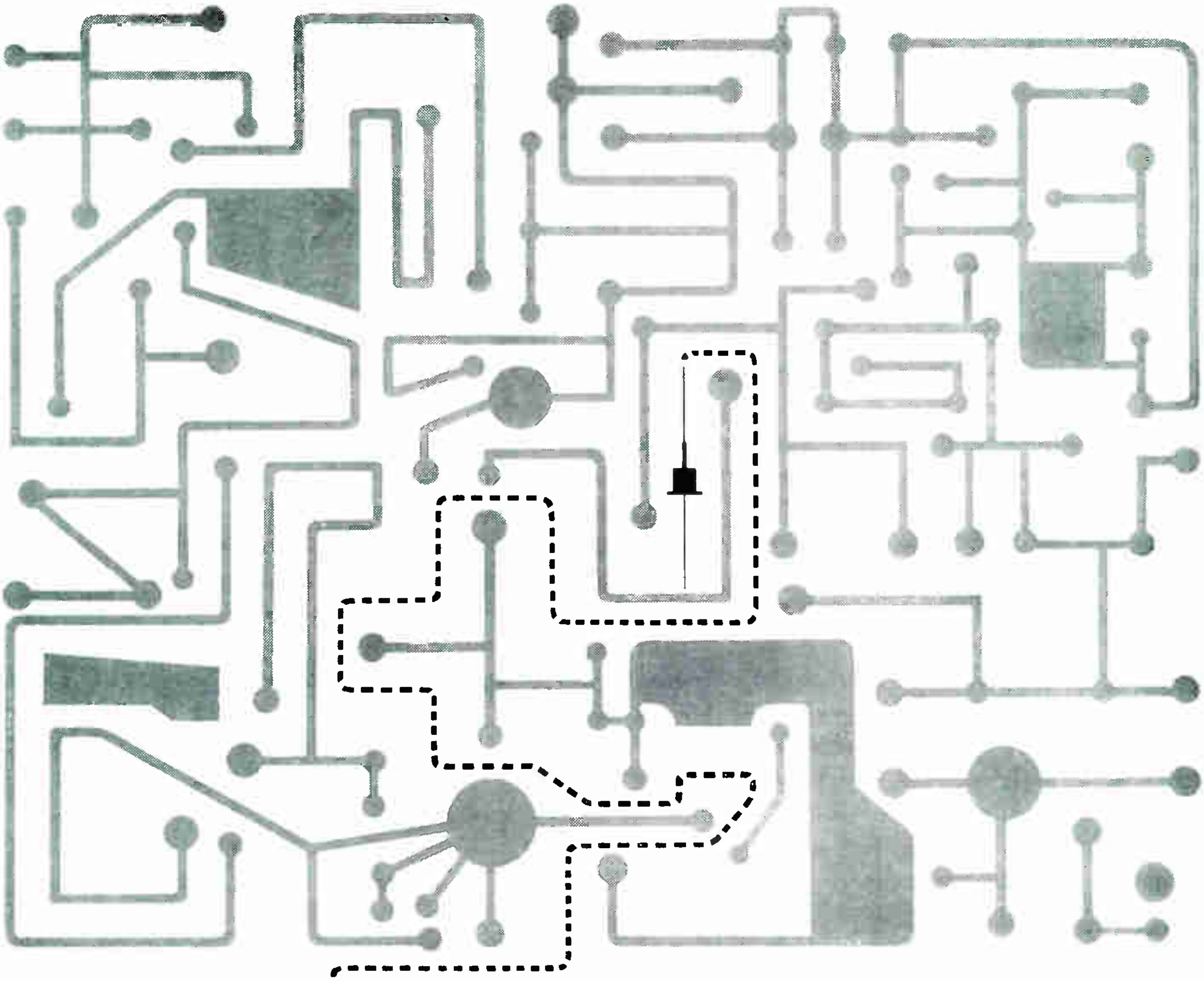
Mullard **Mullard Limited,** Mullard House, Torrington Place, London, W.C.1. Telephone: LANgham 6633

CAM6

World Radio History



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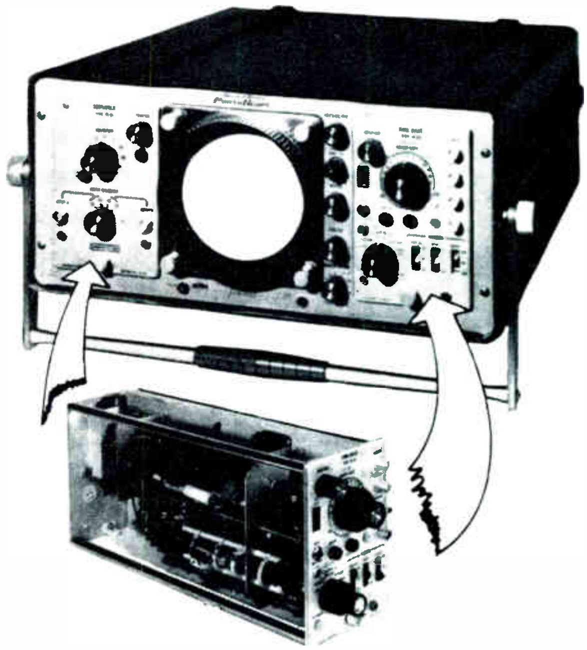
* After sales service is ensured by a well-equipped Technical Services Department, repairing and re-conditioning equipment and producing special modifications and accessories as required.

The 765 "PORTASCOPE"

A high sensitivity lightweight 'scope weighing 27 lbs. only. Designed to accept a constantly expanding range of "plug ins" it has a versatility hitherto unobtainable. 766 Bench & 767 Rack mounting versions are also available.



Ring the changes with the latest range of "plug ins".

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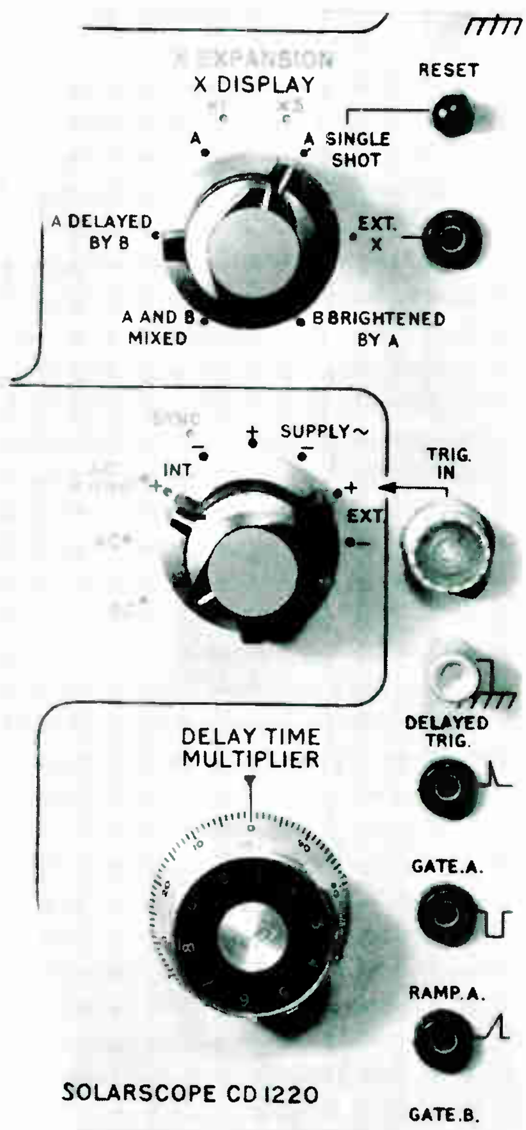
For Further Information Write or Phone

SOLARTRON

OSCILLOSCOPE
TYPE CD 1220



A tool for progress in every Industry

For further information circle 215 on Service Card

SOLARTRON

OSCILLOSCOPE TYPE CD 1220

NEW FEATURES NEW STYLING

OSCILLOSCOPE CD 1220

Delayed and mixed sweeps! Large 6cm x 10cm display! Plug-in Y units! Tunnel diodes for high performance trigger and sync!—Four features from the comprehensive specification which gives the CD 1220 precedence for use on all projects!

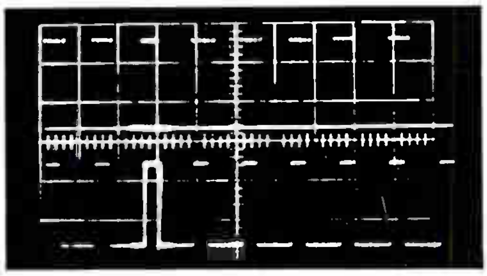
Its wide, basic sweep range, second time-base generator and ability to record fast, single shot transients, contribute toward making the CD 1220 a high quality, general purpose instrument suitable for the examination of the most complex waveforms.

Some of the many fields of application include communication, telemetry, television, automation and power engineering. Time-base delay permits investigation of pulse trains and allows pulse-to-pulse interval, time difference and signal jitter measurements to be accurately made.

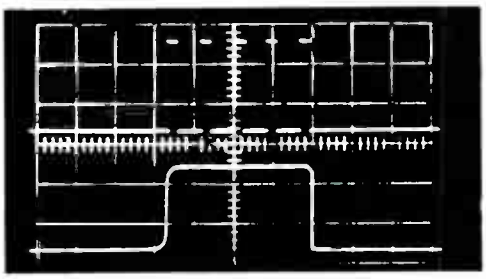
Y UNITS

Two plug-in Y units are currently available:- **Type CX 1256,** a fast rise-time, wide-band amplifier with frequency compensated input attenuator. **Type CX 1257,** a wide-band amplifier with two input channels, either of which can be operated separately. The two channels can, by electronic switching, be either alternately displayed or chopped at approximately 100 kc/s. Both channels can be combined at the output, either adding or subtracting. Trigger signals can be taken from either channel and permit accurate phase displacement measurement.

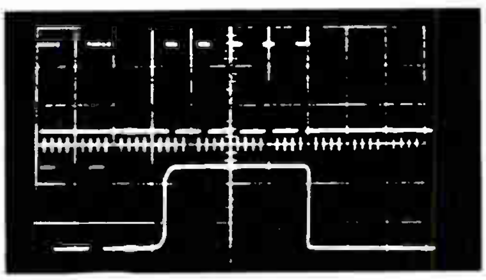
Using the Dual Trace Unit CX 1257 and Solartron Pulse Generator GO 1377 gated to produce pulse trains, the upper trace in each case is displaying the output from the GO 1377 and the lower trace the gating pulse.



1. A and B mixed



2. B brightened by A



3. A delayed by B

MAIN UNIT CD 1220

X Amplifier
Bandwidth : DC - 150kc/s (-3dB)
Sensitivity : 200mV/cm (maximum)

TIME-BASE A

Range : 0.1μsec/cm — 12 sec/cm
Expansion : x5 (20nsec/cm maximum speed)
Measuring Accuracy : 3%
Trigger-Sensitivity : <5mm (internal) 250mV pk-pk (external)
— Level : Time-base triggered from any selected point on waveform over 6 cm (internal) and 6V (external)
— Modes : DC; AC; AC LF Reject; Sync.

TIME-BASE B

Range : 2μsec/cm — 1 sec/cm
Expansion : x5 (maximum speed 0.4μsec/cm)
Measuring Accuracy : 3%
Length Control : 4-10cm (approximately)
Trigger : Facilities as time-base A
May also be used to delay time-base A by 2μsec to 10 sec.

SINGLE TRACE UNIT CX 1256

Bandwidth : DC - 40Mc/s (-3dB ± 1dB)
Sensitivity : 50mV/cm - 50 V/cm
Measuring Accuracy : 3%

DUAL TRACE UNIT CX 1257

Each Channel:
Bandwidth : DC—24 Mc/s (-3dB ± 1dB)
Sensitivity : 50mV/cm — 50V/cm
Measuring Accuracy : 3%

U.K. LIST PRICE

Main Unit CD 1220	- £545
Single Trace Unit CX 1256	- £50
Dual Trace Unit CX 1257	- £100

Please write or telephone requesting further particulars or to arrange for a demonstration.

THE SOLARTRON ELECTRONIC GROUP LTD. (Instrument Division)
Victoria Road · Farnborough · Hants
Tel: Farnborough (Hants) 3000.
Telex : 8545 Solartron Fnbro
Cables : Solartron · Farnborough

M & P S150

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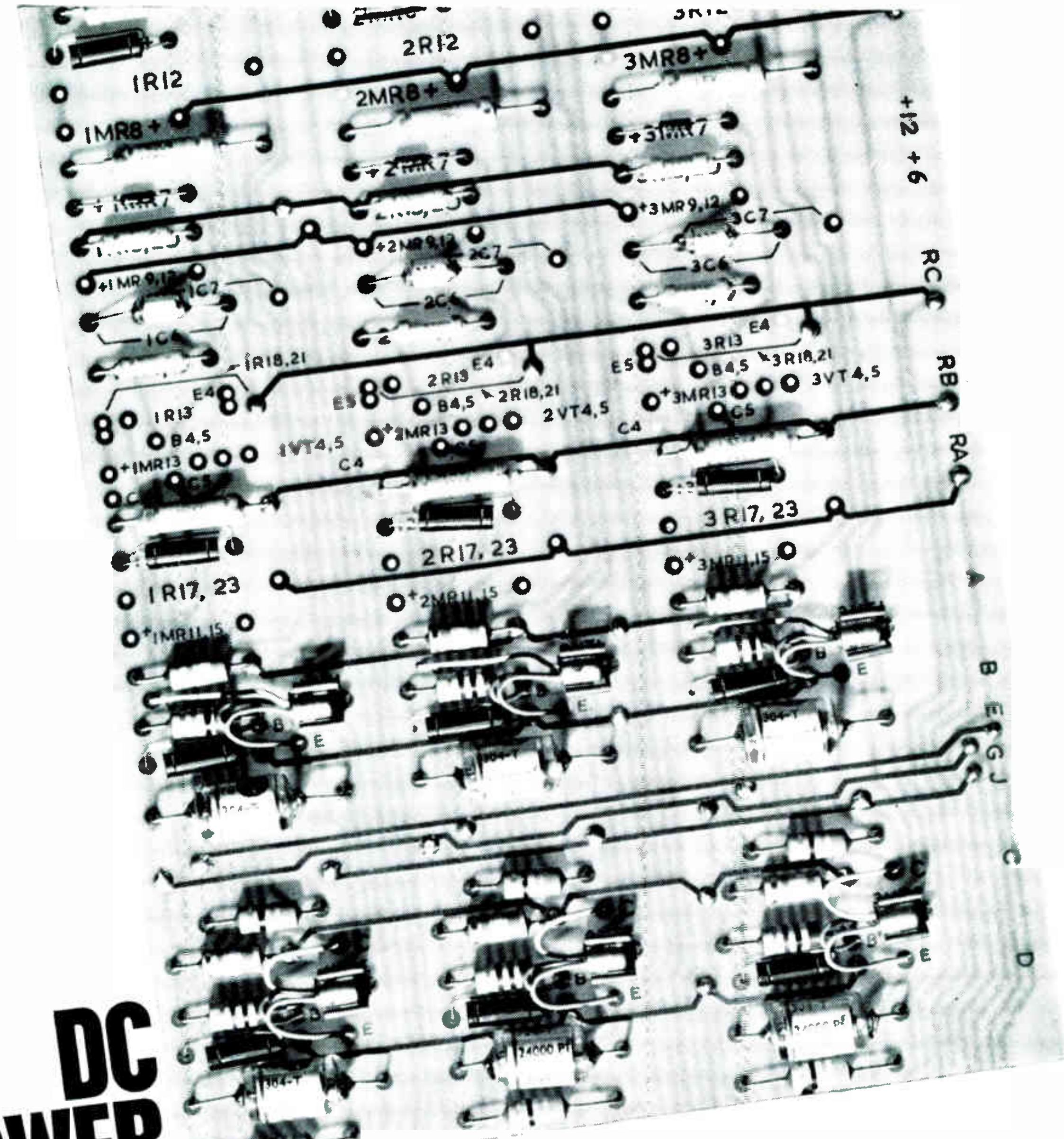

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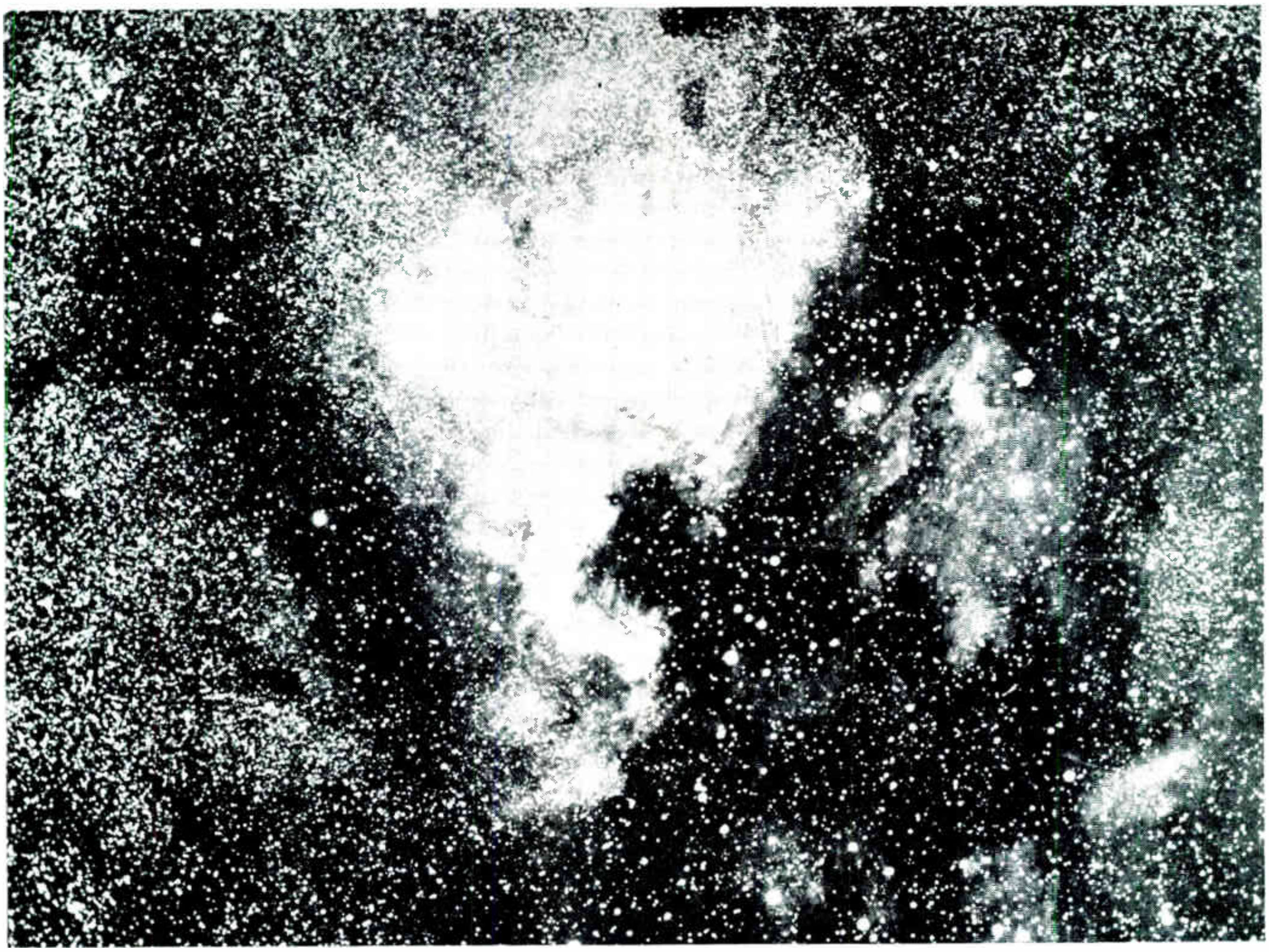

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NOW 100 VOLT RATING

In May this year a range of solid tantalum capacitors rated at 100v was added to the Kemet J-Series.

KEMET J-SERIES Comply with:—

US MIL-C-26655A UK DEF/5134-A/1 EID & ARB release available

OTHER KEMET PRODUCTS

Non-Polar Capacitors · 'C' Series solid tantalum Capacitors (for commercial applications) · Barium Getters · Semiconductor Silicon · Silicon Monoxide · Laser/Maser Crystals · Alumina

We will be happy to send you further information on any of these products.

Production at Aycliffe Industrial Estate, Co. Durham.

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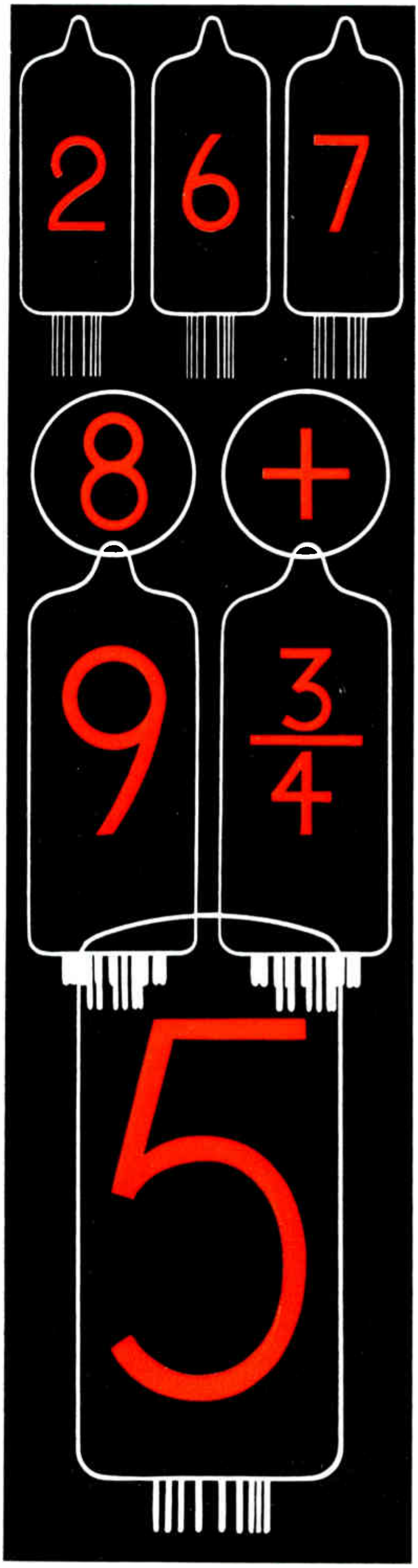
UNION CARBIDE

CRC/K8C



*DIGITRON DISPLAY

FOR INSTANTANEOUS READOUT

Digitron type cold cathode readout is now universally accepted as the most economical and versatile method of presenting numerical and character display.
Their vivid presentation and wide angle viewing facility enable these robust tubes to be viewed quite easily over long distances even in areas of high ambient light. A wide variety of well proportioned character sizes are available in side viewing and end viewing types with wire ended or "pin-base" terminations.
Methods of initiating the readout can be from virtually any switching source ranging from simple mechanical or electro-mechanical devices to cold-cathode counting tube or transistor circuits.
If you are looking for a low-cost, reliable, long life and brilliant method of displaying numerical or character information Digitron tubes are worthy of your consideration.
For data and application information about Digitron Display tubes please write to the address below.

TYPE	Characters	Character Height		Nominal current	Viewing	Base	Equivalents
GR2J	+ and —	18 mm	.709"	1.5 mA	SIDE	B26A	
GR4J	¼ ½ ¾ 1	30 mm	1.181"	3.5 mA	SIDE	B26A	
GR10J	0 — 9	30 mm	1.181"	4.5 mA	SIDE	B26A	Z522M*
GR10K	0 — 9	19 mm	.748"	2 mA	END	B17A	
GR10M	0 — 9	15.5 mm	.610"	2 mA	END	B13B	Z520M B5031*
GR10N	0 — 9	60 mm	2.362"	10 mA	SIDE	B17A	
GR10X	0 — 9	15 mm	.591"	2 mA	SIDE	FLYING LEAD	ZM1080*

*Near Equivalents

*Digitron is an Ericsson Registered Trade Mark.

TUBE DIVISION · TECHNICAL SERVICE DEPT.

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ER67

Potting shed?

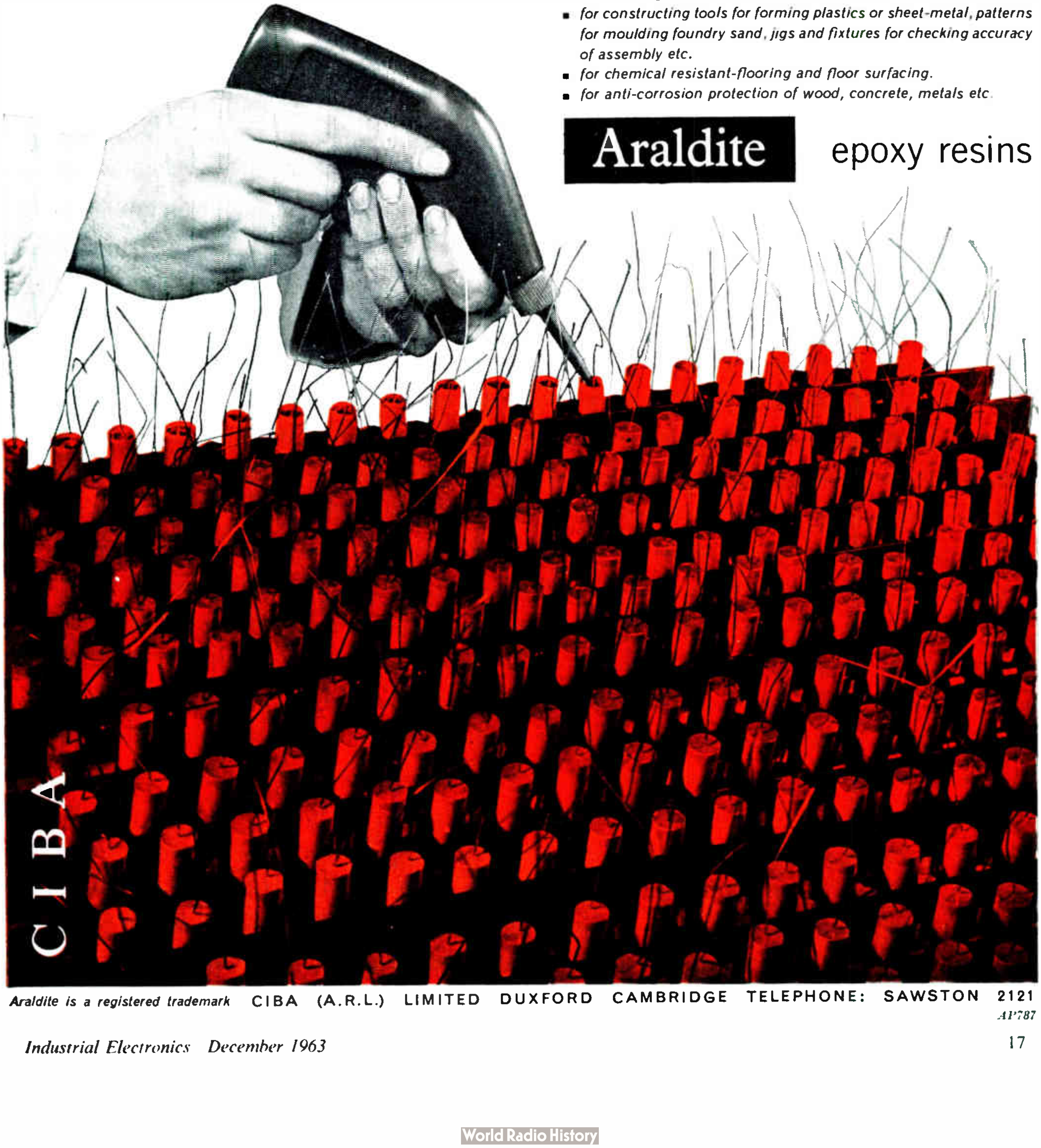
Araldite epoxy resins are ideal for potting—but this is not a potting shed. Here Araldite is being used to seal capacitor windings at Telephone Manufacturing Co. Ltd. The Araldite filler cures, with negligible shrinkage, to form a complete seal. It adheres strongly to metal surfaces —provides perfect insulation and resists tracking. It is impervious to moisture. Araldite sealing formulations pour and cure at room temperature. In many cases curing can be speeded up by heating.

May we send you a copy of our publication 'Araldite epoxy resins in the electrical industry'?

ARALDITE EPOXY RESINS ARE USED:

- *for casting large high-grade electrical insulators and insulation around equipment such as transformers, switchgear components etc.*
- *for impregnating, potting and sealing electrical windings and components.*
- *for constructing glasscloth laminates in electrical, nuclear, mechanical and aircraft engineering.*
- *for bonding metals, ceramics, glass, rubber, plastics, wood etc.*
- *for constructing tools for forming plastics or sheet-metal, patterns for moulding foundry sand, jigs and fixtures for checking accuracy of assembly etc.*
- *for chemical resistant-flooring and floor surfacing.*
- *for anti-corrosion protection of wood, concrete, metals etc.*

Araldite epoxy resins



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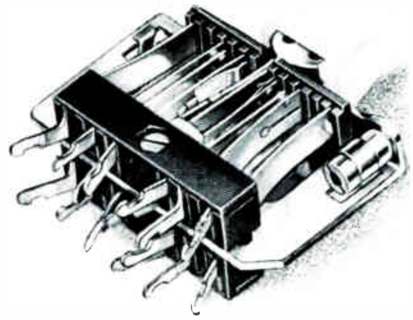

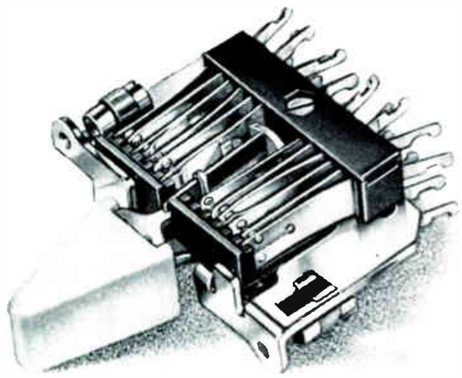

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- LOCK STOP
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TMC Miniature Lever Key

Designed to replace existing telephone keys, the new miniature lever key, now available from TMC, is a compact, space saving switching device of smart modern appearance. The functionally shaped moulded handle is available in several colours. The mechanical action includes a double pivot which ensures positive locking in either the normal or operated positions, and virtually eliminates follow-through of the handle on double-throw keys. A sliding, comb-shaped plate, actuated by the key handle, operates the pre-fabricated spring set. Up to twelve contact springs can be operated by each throw of the key —a total of four changeover actions in either direction.

Twin silver contacts are supplied as standard for switching 300 mA 100 V d.c. non-inductive loads. Several contact arrangements, in all switching actions, are available on excellent delivery.

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STC components review

DECEMBER, 1963

LATEST RANGE OF ZENER REFERENCE DIODES – 1·5 WATTS

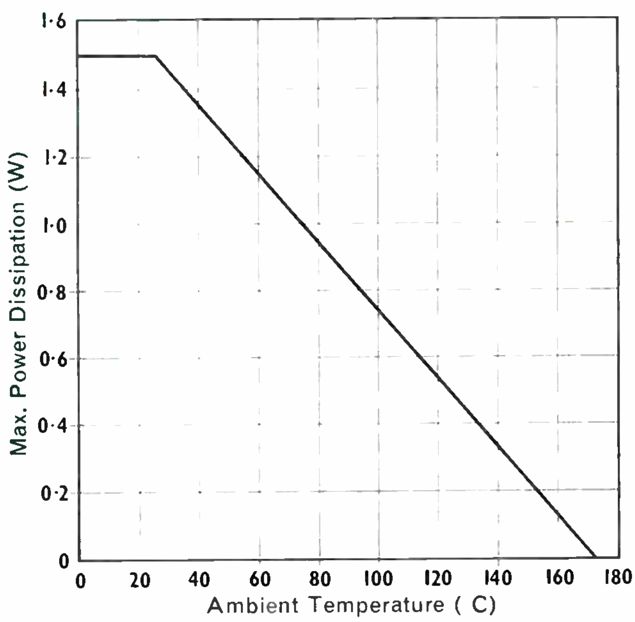
Extensions to the STC ranges of Zener Diodes are wire-ended devices with a maximum rating of 1·5 Watts. Designated Z3 Series, they are available in standard preferred values from 3·3 Volts to 100 Volts inclusive with voltage tolerances of ±5%, ±10% or ±20%.

Z3 SERIES ZENER DIODE (actual size)

ABRIDGED DATA

Nominal voltage range	3·3 – 100 V
Maximum power dissipation	1·5 W
Maximum continuous forward current	1·3 A at 25 °C ambient
Maximum working junction temperature	175 °C
Storage temperature range	–65 °C to +175 °C
Maximum forward volt drop at 1·3 A	1·2 V
Maximum thermal resistance (junction to air)	100 °C/W
Standard outline	VASCA SO-16 JEDEC DO-1 IEC 1 101

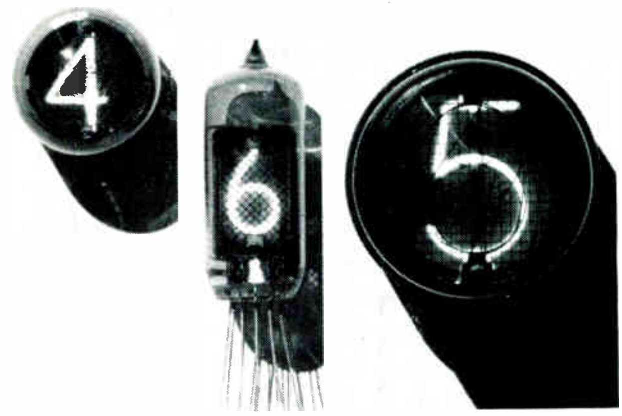
POWER DERATING CURVE



Write, 'phone or Telex for Data Sheets to STC Semiconductor Division (Rectifiers) Edinburgh Way, Harlow, Essex. Telephone Harlow 26811. Telex 81146.

NEW COLD CATHODE INDICATOR TUBES for Displaying Numerals

These new cold cathode indicator tubes have been introduced by STC Valve Division. The GN-4 and GN-5 types, designed for end viewing, are improved quality versions of the earlier types GN-3 and GN-2 respectively. The GN-6 is intended for side viewing. The tube bulbs are coated with an orange filter to enhance the display but if GN-4 or GN-5 type tubes are required for use with an external filter, clear bulb versions can be supplied under codes GN-4A and GN-5A.



ABRIDGED DATA

Type	Numeral Display	Nominal Character Height (mm)	Base	Minimum Supply Voltage (V)	Nominal Cathode Current (mA)
GN-4	0 - 9	15,5	B13B	170	2·0
GN-5	0 - 9	24,4	B12A	200	2·5
GN-6	0 - 9	14,0	Flying Leads	200	2·5

The intended method of operation of these tubes is by selector switches, transistors or other electronic switching devices. An important feature is that the non-conducting cathodes should either be left open-circuited or held at a bias potential of approximately 100 volts (not less than 75 volts or more than 110 volts). Data regarding Transistor switching can be provided, on request, by STC, Semiconductor Division (Transistors) at the address overleaf.

Write, 'phone or Telex for Data Sheets to STV Valve Division, Brixham Road, Paignton, Devon. Telephone Paignton 53685. Telex 4230 or London Sales Office, Footscray, Kent. Telephone FOOtscray 3333. Telex 21836.

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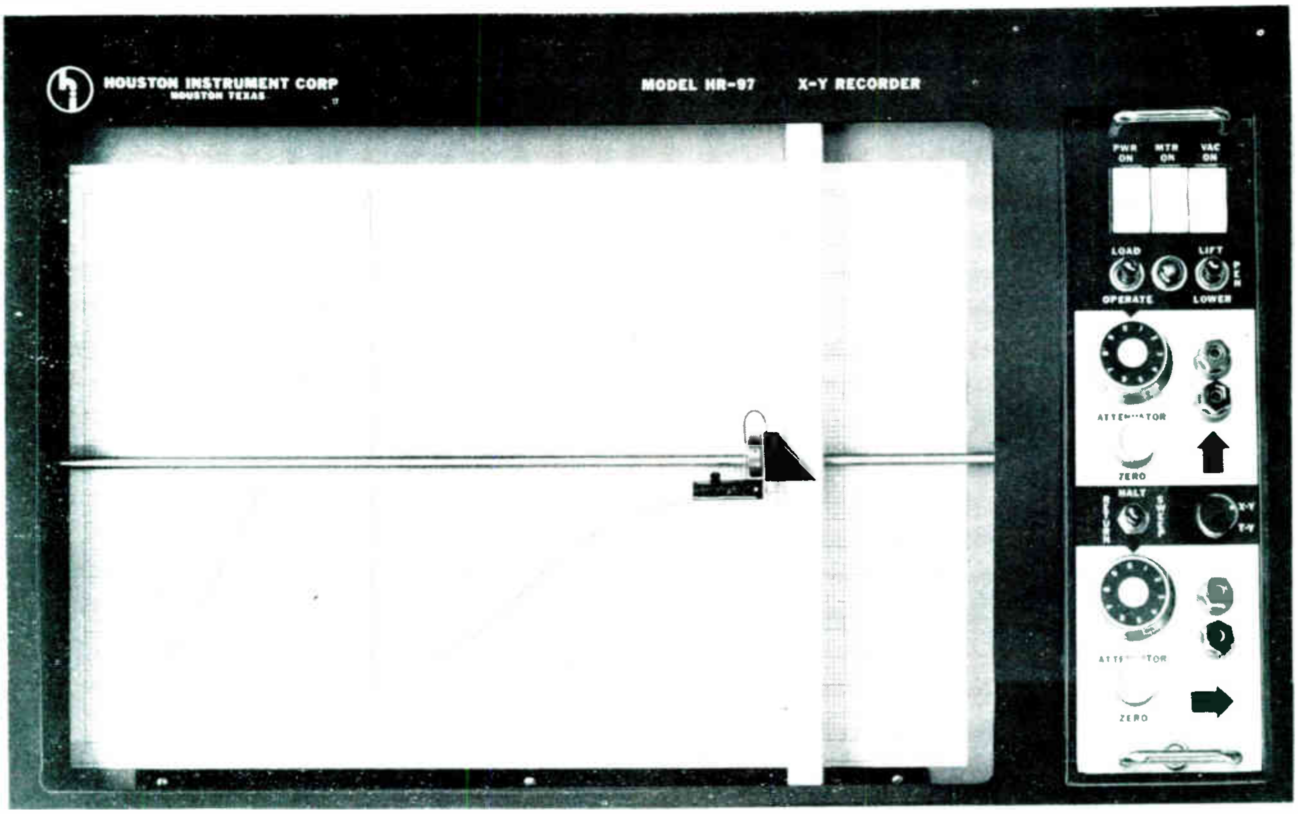
Can you take a chart from your recorder and put it straight into your report – or do you have to re-plot the whole trace on a different time scale? Can you compare multiple test runs on the same chart – or do you have to cut up the roll and start again? You do if you're still using a conventional strip chart or circular chart recorder – you don't if you use an ADVANCE HOUSTON 11 x 17 in. X-Y Recorder.



ADVANCE HOUSTON Model HR-97 X-Y Recorder The Model HR-97 X-Y Recorder is a precise, rugged instrument designed for recording information from two mutually independent variables or from a single variable as a function of time. It features 0.25% overall accuracy, 15 in/sec pen speed, 600 in/sec² peak pen acceleration, vacuum paper hold-down, continuously variable precision attenuators, zener references, interchangeable plug-in control modules, snap-on cartridge pen assemblies and flat bed construction. For further details on the ADVANCE HOUSTON range of precision X-Y Graph Recorders and T-Y Chart Recorders, please write to:

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AH 2

INDUSTRIAL ELECTRONICS

Comment

It is a commonplace to say that research is the basis of technical progress. From a practical point of view, however, research is of little use without subsequent development. Some people indeed think that development is the more important of the two, but this is merely because its results are more quickly apparent. On the basis of existing knowledge an industry could go on developing new and better products for quite a long time before it eventually reached the stagnation which would inevitably occur without continuing research.

Research and development both cost a lot of money, but the results of development can be forecast much better than those of research. Commercially speaking research is always something of a gamble. It is an attempt to gain new knowledge and until one has gained it one cannot know whether it will be of any immediate practical use. It will always be of some use, of course, but the real benefits of new knowledge may not be gained for many years; they may well depend on the results of further research in other fields.

The general long-term welfare of an industry depends on its maintaining a proper balance between research and development. This is true also for some of the larger companies within an industry. Generally, however, the proper amount of research and development for a company will vary enormously from one to another and it may well be impracticable for small ones to carry out research at all.

In view of the importance of research and development we think it is good news that the Department of Scientific and Industrial Research and certain representatives of the electronics industry are undertaking an economic and technical study of the research and development problems of certain sections of the electronics industry. A detailed statement about this appears on p. 796. The study is to cover firms producing apparatus for the civil market, but excluding consumer products, and it is expected to take less than two years to complete.

Equivalent Circuits

In September we referred to equivalent circuits and pointed out that such circuits do not always lead to the same results when calculations of internal power are made. In particular, we referred to a voltage generator with series resistance and compared it to its 'equivalent' of a current generator shunted by a resistance. We pointed out that the two gave the same value for the power dissipated in the internal resistance only when the external load resistance equalled the internal resistance.

In this issue a correspondent points out that even in this condition the calculated 'internal' power is not necessarily the true power of the real circuit. We agree. The reason is, of course, that neither of the two equivalent circuits may be identical with the real circuit.

The real point is that equivalent circuits are equivalent only in their effects on external voltages, currents and powers. B.S. 204 : 1960 defines an equivalent network as 'A network which may replace another network without altering the performance of that portion of the system external to the network'. We have no quarrel with this, but it is worth while to

COMMENT *(Continued)*

point out that if a network and its equivalent are both passive then the total internal power dissipations must be the same. If they were not the performance of that portion of the system external to the network would be affected.

The equivalent circuits which we considered in September were active ones and their non-equivalence as regards internal power dissipation arises because of a change in the internal source of power. An example using Thévenin's theorem makes this clear. Suppose we have a 10-V battery with a 5-kΩ series resistance supplying 1 mA at 5 V to some circuit. The power dissipated in this resistance is 5 mW.

It is well known that alternatively we can use a 100-V battery and feed the circuit with 1 mA at 5 V as before by using a potential divider across the battery. Its two resistances must in parallel be 5 kΩ and the ratio of their values must be such that on open-circuit there is 10 V across the one from which the output is taken. A simple calculation gives one resistance as 50 kΩ and the other as 50/9 kΩ and the total power lost in the resistances of the potential divider is 185 mW.

The high-voltage supply with the potential divider is commonly used in practice but in circuit analysis and design it is also common to imagine it replaced by the low-voltage supply with the series resistor. So far as the rest of the circuit is concerned nothing at all is changed. The two equivalent circuits are not identical and their internal power losses are quite different. There is nothing theoretical or imaginary about the difference. In this case both are eminently practical circuits and the different power losses as calculated are both right for their respective circuits.

In practice we usually adopt the potential-divider circuit in spite of its relatively high power loss because it enables us to use a single battery for supplying many different circuits and so avoids the nuisance of having to use a lot of different batteries.

Valves and Transistors

We did not ourselves refer in September to the equivalent circuits of valves and transistors, but our correspondent does. We do not want to say much about this here but we think it worth while to point out that neither of these devices really includes a voltage or current generator of any kind. At one time this was emphasized by calling the generator of the equivalent circuit a fictitious one. It is perhaps a pity that this custom has fallen into disuse.

Neither valve not transistor have any internal source of energy. The currents are all driven by external e.m.fs. The devices merely use an external voltage or current applied between one pair of electrodes to control the magnitude of a current flowing under the influence of an external e.m.f. between another pair of electrodes. That being so, it would be closer to reality for an equivalent circuit to comprise a resistance the value of which is a function of the controlling voltage or current. Thus the equivalent circuit of a triode valve could be a resistance the value of which depends on the grid voltage.

This is not a very useful equivalent circuit, however, for the relation between the resistance and the controlling quantity is far from a simple one.

It may be argued that there are some internal sources of energy in these devices, because some external current flows with no externally applied e.m.f. In the case of the valve this is due to the energy of electrons emitted from the cathode, but in reality this energy comes from an external source, the cathode-heating supply. In semiconductors any such current is again due to external sources of energy—the ambient temperature and light.

Lasers

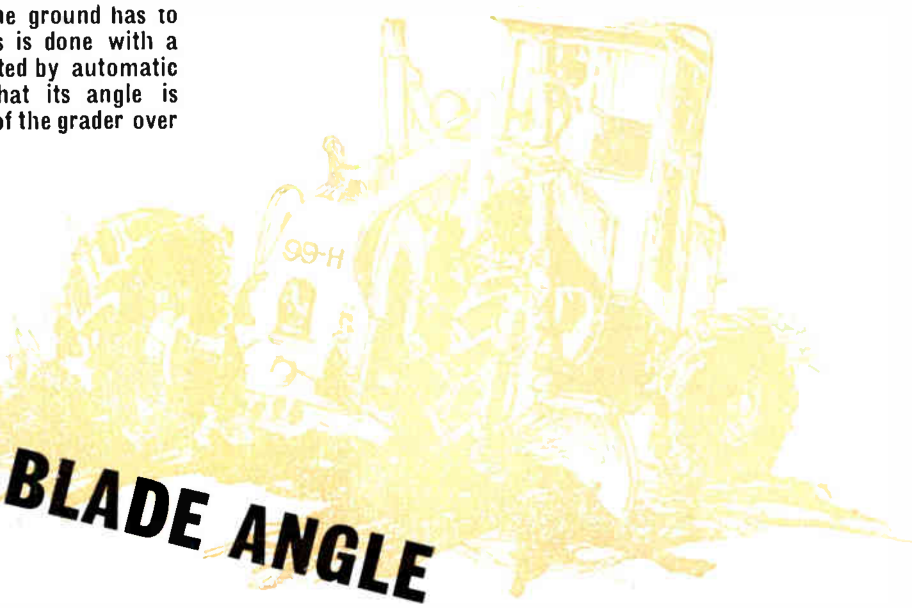
A good deal is now being heard about lasers. Two very different applications have recently come to our notice. One is that light energy produced by a laser has been used to bore holes of under five microns diameter in tin wire which is itself only ·2 thou' diameter. This has been done by Raytheon and it is said that when boring brass molten metal flows back through the opening cone and gives the inner surface of the hole a high polish.

The second use of a laser was at the Crimean Astrophysical Observatory. Installed at the focal point of a 2·6-metre telescope a laser pulse was transmitted to the moon and the reflected pulse received back. A special receiver was used, but no details of this are yet available. The returned light pulses are said to have been greatly attenuated.

Ourselves

With this issue the first volume of *Industrial Electronics* is completed and we therefore include in it an index covering the fifteen issues which comprise the volume. Because the change from *Electronic Technology* to *Industrial Electronics* occurred in October 1962, this first volume comprises the October 1962 to December 1963 issues inclusive in order that subsequent volumes may follow the normal practice of running from January to December.

In the construction of roads and airfields the ground has to be shaped to some prescribed slope. This is done with a motor grader. The operation is greatly assisted by automatic control of the blade in the grader so that its angle is maintained correctly despite the movement of the grader over rough ground.



AUTOMATIC BLADE ANGLE CONTROL FOR MOTOR GRADERS

By A. T. MACDONALD, B.Sc., A.M.I.E.E.*

ROADS and airfields today are constructed for high-speed, high-performance vehicles and aircraft. As such, particular attention must be paid to their cambers, gradients, surfaces and foundations. The cost of construction work is high; the business is highly competitive. Any automation or efficient mechanization which can reduce costs is, therefore, welcomed. Use of the Sperry Grademaster on motor graders (vehicles used in road or airfield construction to shape a formation to some prescribed slope) results in the achievement of the desired plane with fewer passes of the grader and with a consistency of performance which is virtually independent of the operator's skill. Time and money are therefore saved.

The grader has a curved-section blade mounted between the front and rear wheels and positioned by hydraulic rams to give variable depths of cut and slope angles. In conventional grader operations the operator controls the blade's height and slope with two of the blade rams and will, while the vehicle is in motion, have continually to correct the blade slope angle due to the movement of the road grader over uneven ground. The equipment described in this article maintains the blade slope angle to a preset value automatically in a range of ±6° from the horizontal to an accuracy of 0·1°.

The equipment consists of four units: pendulum, hydraulic valve, control console and levelling switch which are shown in position on a grader in Fig. 1. The basic reference is the pendulum which is mounted on the frame carrying the blade, known as the goose neck, in such a manner that the plane of the pendulum remains at right angles to the fore and aft axis of the machine. Thus even when the blade is rotated at an angle to this axis, the vehicle's accelerations do not disturb the pendulum. The pendulum is fitted with a synchro resolver for signalling purposes.

* Sperry Gyroscope Co. Ltd.

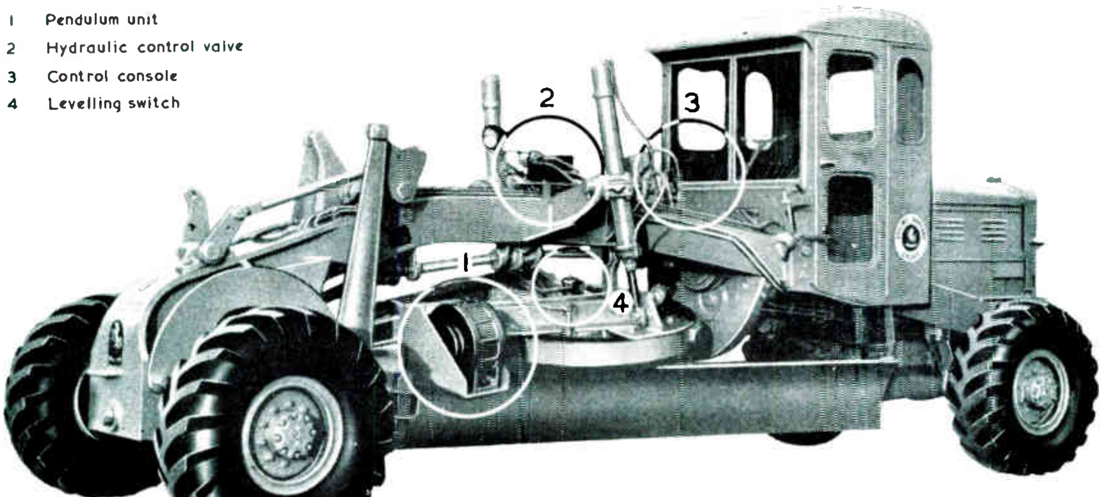


Fig. 1. Aveling-Barford motor grader 99H fitted with Sperry Grademaster apparatus

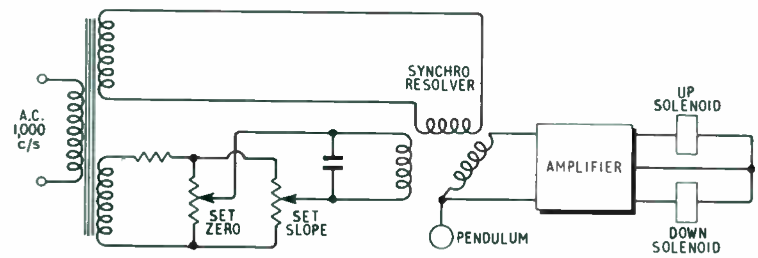


Fig. 2

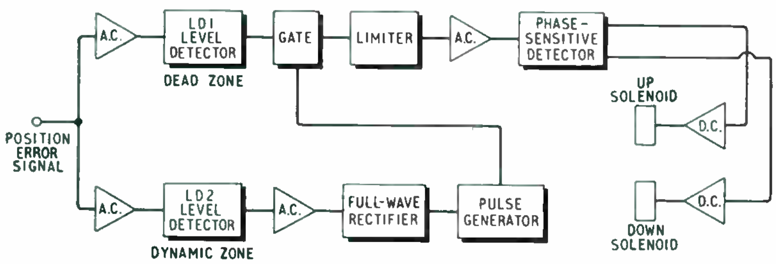


Fig. 3

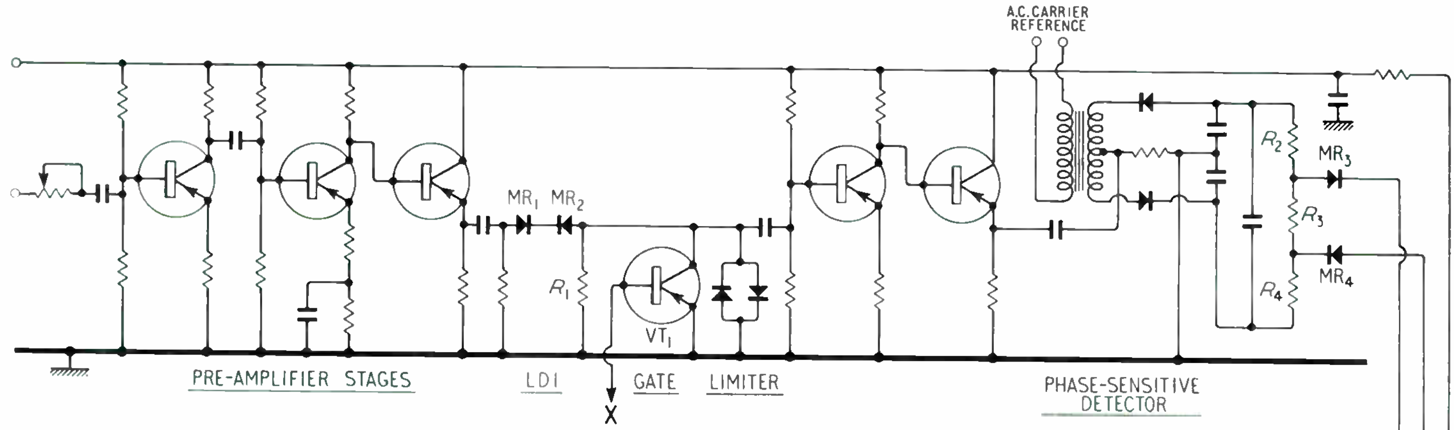
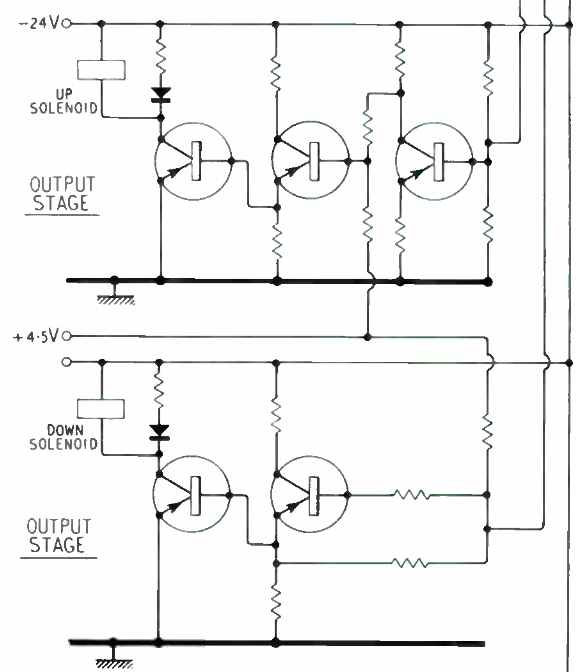
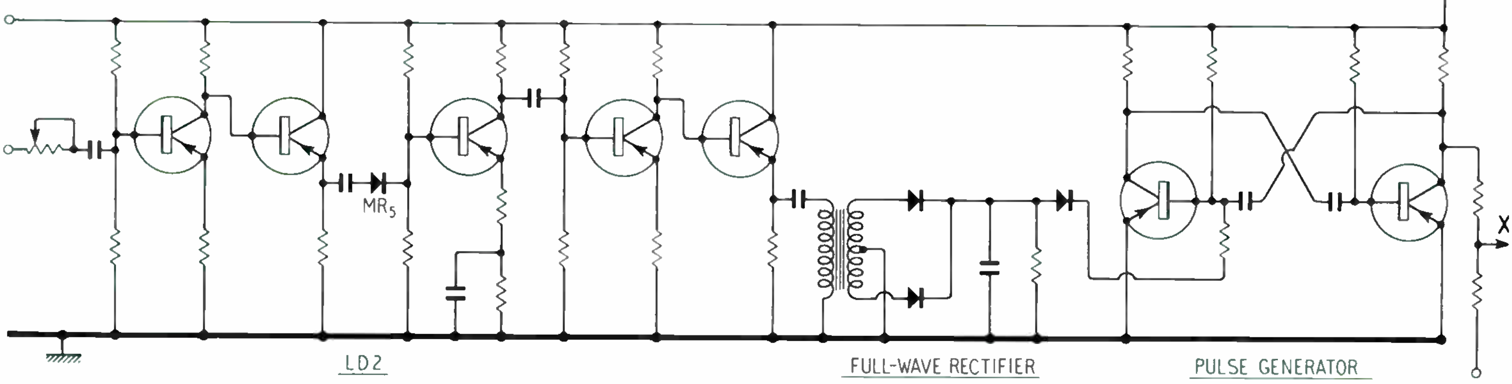




Fig. 4

The slope angle of the blade is controlled from the right-hand ram by the operation of a specially-designed, high-speed, two-stage solenoid valve. Two solenoids are fitted, the operation of one solenoid raising and of the other lowering the blade.

The control console is mounted in the driver's cab and contains the operating controls as well as the system electronics. When the blade is not at right angles to the fore and aft line of the grader and the goose neck is not horizontal a compound angle effect is introduced which produces a 'zero error' between the actual and set blade slopes. A control is provided on the console which, in conjunction with a mercury level switch directly mounted on the blade, allows the datum to be reset at the blade operating height; i.e., the 'zero error' to be eliminated.

A functional diagram of the electrical system is shown in Fig. 2. One winding of the stator of the pendulum resolver is fed with a constant-amplitude 1,000-c/s voltage. The other winding is fed from a potentiometer bridge. By this means the voltage on the second winding can be varied both in amplitude and phase. One potentiometer of the bridge is used to 'set in' the required slope angle, the other is used for zero setting. The rotor of the pendulum resolver will have zero volts induced in its winding when it is at right angles to the field set up by the stator voltages. This will occur when the blade is at the required slope angle. The output voltage from the synchro rotor will indicate, in amplitude and phase, the departure of the blade from the required slope angle. The rotor signal is amplified before being applied either to the 'up' solenoid or to the 'down' solenoid to bring the blade to the correct slope angle.

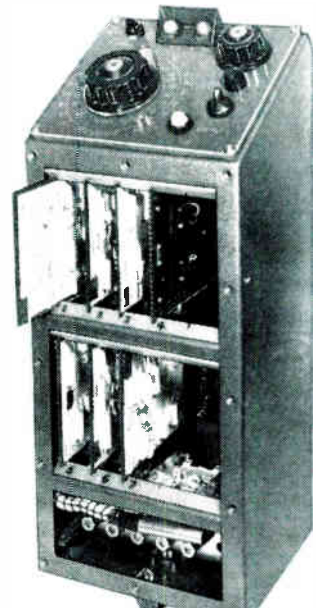
Solenoid valves are used, since this allows the normal grader hydraulic system to remain unchanged. However, for stable operation a dead zone is required which ideally should be no wider than the required accuracy, here $\pm 0{\cdot}1^\circ$. Due to the machine dynamics, instability can occur when the dead zone is as small as this. To prevent instability the solenoid valves are pulsed as the blade approaches the required angle, thereby effectively reducing the approach speed so that overshoots are reduced and a stable system results. The zone in which the solenoid valves are pulsed is approximately $\pm 1^\circ$ about the desired angle and has been termed the dynamic zone.

The amplifier therefore performs a number of functions. A block diagram is shown in Fig. 3. The position error signal from the pendulum resolver is passed to two separate level detectors, LD_1 and LD_2, one for the dead zone and one for the dynamic zone. Should the position error signal exceed $\pm 1^\circ$ then the dynamic zone reference level is exceeded and signals will be produced at the output of LD_2. These signals are amplified, full-wave rectified and fed to a pulse generator. The pulse generator produces pulses if no signals are received from LD_2. If, however, the signals have broken through LD_2, then the pulse generator is inhibited and its output stays at a fixed positive voltage. Should the error signal be less than $\pm 1^\circ$ no signals are produced from LD_2. The pulse generator therefore operates to produce negative pulses at a frequency of two pulses per second.

The dead-zone level detector LD_1 is set at $\pm 0{\cdot}1^\circ$. An output will be obtained from LD_1 only if the error signal is greater than $0{\cdot}1^\circ$. The output of LD_1 is passed to a gate which will conduct, and pass the error signal, when the output of the pulse generator is positive. The negative pulses from the pulse generator make the gate non-conducting and therefore prevent the error signal from passing to the next stages for the duration of the pulse.

Any signals passing the gate go through a limiting stage before they are fed to the amplifier and phase-sensitive detector. The phase-sensitive detector is arranged to operate the solenoid valves in such a manner that the resultant motion

The Sperry Grademaster control console

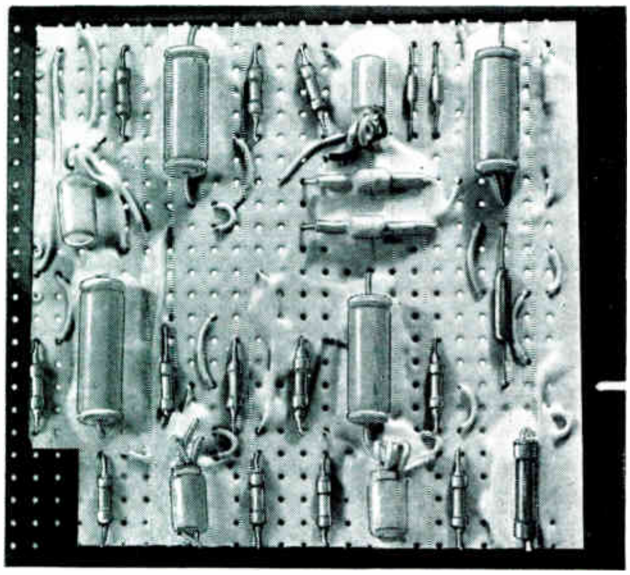


The console with its cover removed showing the plug-in printed-circuit boards

Close-up of the control panel

detector is a peak detector with a quick response. In the absence of any error signal a d.c. voltage is developed across the resistor chain R_2, R_3, R_1. The mid-point of the chain is at approximately earth potential. If a signal is received in one phase, both ends of the resistor chain move in a positive direction; if a signal is received in the other phase, both ends of the chain move in a negative direction. The driver stages for the output solenoids are fed from intermediate points on the resistor chain to match the bias potentials. Diodes MR_3 and MR_4 decouple the driver stage bias potentials from each other.

The dynamic zone level detector is the Zener diode MR_5. The pulse generator is a free-running multivibrator which is biased off by the full-wave rectified signal voltage.



A printed-circuit board

of the blade reduces the error signal. The limiter after the gate is provided to prevent asymmetrical saturation of the output stages when the error signal is large.

A circuit diagram of the amplifier is shown in Fig. 4. The level detector LD_1 is formed by the Zener diodes MR_1 and MR_2. The transistor VT_1 acts as the gate. If the base is held positive the transistor is cut off and does not effect the signal voltage across R_1. The pulses from the pulse generator apply a negative voltage to the base, the transistor goes fully on and shorts out the signal voltage, thus preventing it passing on to the succeeding stages. The phase-sensitive

Construction of Electronic Unit

Since the electronic unit is to be mounted on a road vehicle, considerable thought was given to making it as rugged as possible. The circuits are produced on printed-circuit plug-in boards. All heavy components have been mounted on a slide in a horizontal metal tray, which also acts as a heat sink. The boards are kept in position by a foam-rubber pad on the back of the front panel. Various photographs show the complete unit, the unit with the front panel removed to expose the plug-in boards and a view of the control panel. All control knobs, lamp covers, etc., have sealing gaskets fitted so that the console is splash proof. The console is mounted in the grader cab on anti-vibration mountings. The printed-circuit boards are sprayed with 'Selastic' compound, thus affording an extra measure of protection. Prototype units of the system have been extensively tested, not only on motor graders, but also on vibration tables and under extreme environmental conditions, thus ensuring that mechanical and other deficiencies have been discovered at an early stage.

Spectrometer Increases Foundry Productivity

As a part of a development programme, Lancefield Foundry at Glasgow has installed an automatic X-ray spectrometer for the rapid analysis of bronzes and other non-ferrous metals before they are poured.

With this instrument, samples may be taken from the melt and within minutes an analysis is available on which corrections can be based or the decision to pour be made. A typical check on leaded gunmetal sample for lead, tin, zinc, nickel and copper takes 4 minutes. Previously, wet chemical methods of analysis took from 4 to 24 hours.

Metals used by Lancefield include brasses, gunmetals, phosphor bronzes, nickel bronzes and aluminium bronze. As many as eight furnaces may be operating at once and individual samples may have to be checked for up to ten elements. This easily handled by the spectrometer which, in one cycle, can analyse sequentially four specimens for up to 15 elements. Different types of specimen are catered for by a small plug-in patch board which can be changed in a few seconds. The results of the analysis are printed out with an identification number on paper tape.

For further information circle 41 on Service Card

Inserting a specimen in the automatic X-ray spectrometer

TEST RIGS FOR TORQUE CONVERTERS

By H. J. BUNKER,
Grad.I.E.E., A.C.T.(Birm.)*

The testing of motor-car gearboxes and differentials, as well as other forms of torque converter, can be carried out automatically according to a pre-arranged programme. This article describes equipment in which electric motors provide the drive power and simulate the load. The apparatus can be manually-controlled for research or automatically for routine testing.

The term 'torque converter' used in this context covers the conventional and automatic types of gearbox as used in the automobile industry today, various types of differential units which may or may not incorporate an ntegral gearbox with variable ratios, and the hydraulic torque converter which provides an infinitely variable ratio instead of fixed ratios of torque conversion.

In this age of speed, M1 and other motorways, manufacturers of torque converters are becoming increasingly conscious of noise and vibration, as are the people who buy the vehicles these components are fitted into. The motorways now enable cars to be run at maximum speeds for long periods which prior to the advent of the M1 were not possible for every-day motorists in this country. It is thus natural that the companies in the highly-competitive automobile industry should be concerned in eliminating as many undesirable facets in their products as possible.

Thus there is a requirement for electronically-controlled test rigs incorporating accurate measuring equipment from which data may be obtained for development work during the prototype stage. Often it is desirable to monitor and record speed, torque, efficiency, noise and vibration during an endurance test, the recorded data being rationalized after the test.

Obviously it is desirable to test the torque converters after unit assembly, but prior to fitting into the vehicle in order to avoid the expensive procedure of having to replace faulty units once they have been fitted into the vehicle.

The test rigs are required to provide facilities for testing the torque converter from minimum to maximum speed

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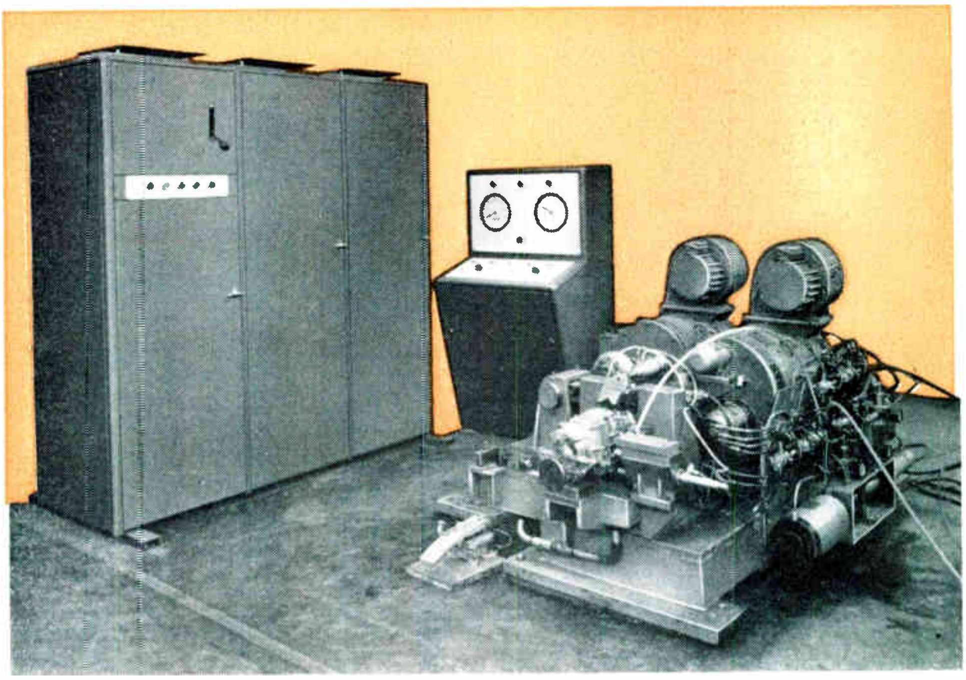


Gearbox test rig for rear engine drive vehicle

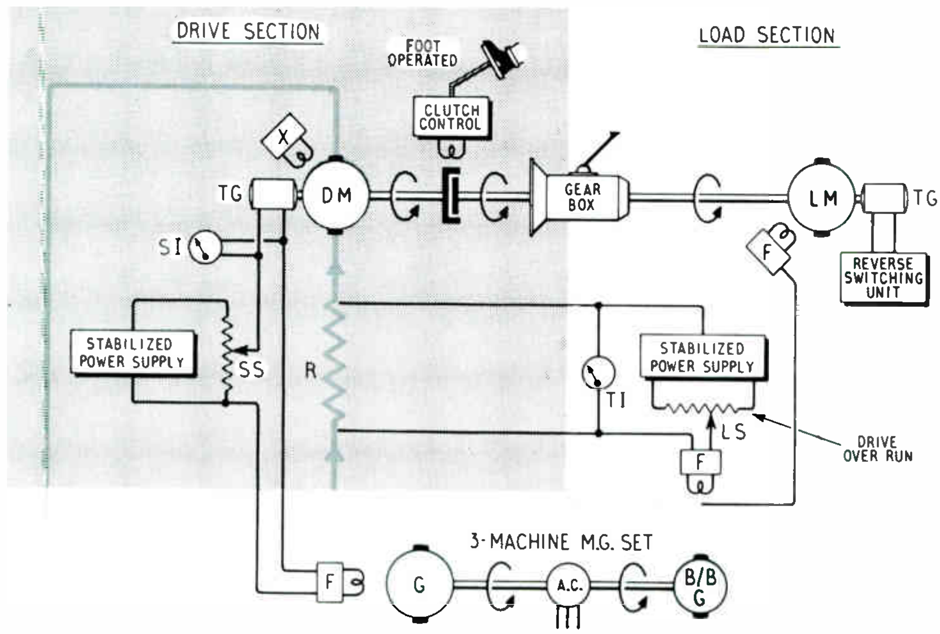


Fig. 1. Gearbox test electrical schematic

under various load conditions as near to actual road-running conditions as possible, together with accurate control of speed and loads. At the same time the equipment must be simple to operate while the time taken to adjust the speed or load from one level to another must be kept to a minimum so that the overall test time may be kept as low as possible and a high rate of throughput maintained.

Twin-Arm System

The equipment for testing gearboxes, automatic gearboxes and hydraulic torque converters is the same from the control point of view and comprises two main sections, the drive section and a load section.

Fig. 1 shows the basic control system which is divided into two sections.

Drive Section

A foot-mounted variable speed d.c. motor (drive motor DM) simulates the car engine and drives the gearbox. In order that the gearbox may be tested under conditions experienced on the road the drive motor is designed to have a maximum speed equivalent to the maximum engine speed and a minimum speed equivalent to the slow-running speed of the engine. Maximum speeds of 6,000 r.p.m. and higher, with an infinitely variable speed range of down to 100 r.p.m. can be obtained. The drive motor is rated so that it is capable of delivering a torque equivalent to the maximum torque developed by the car engine, which is usually developed at about 60% maximum engine speed. In fact, because the speed of the d.c. driving motor is controlled by adjusting the armature voltage it is capable of delivering the maximum engine torque throughout its speed range. This is useful because, providing the motor is rated for the maximum engine torque condition, it is adequately rated at all speeds throughout the speed range.

Fig. 2(a) shows the typical torque characteristic of an internal combustion engine and the constant torque characteristic of the d.c. driving motor, while Fig. 2(b) shows the

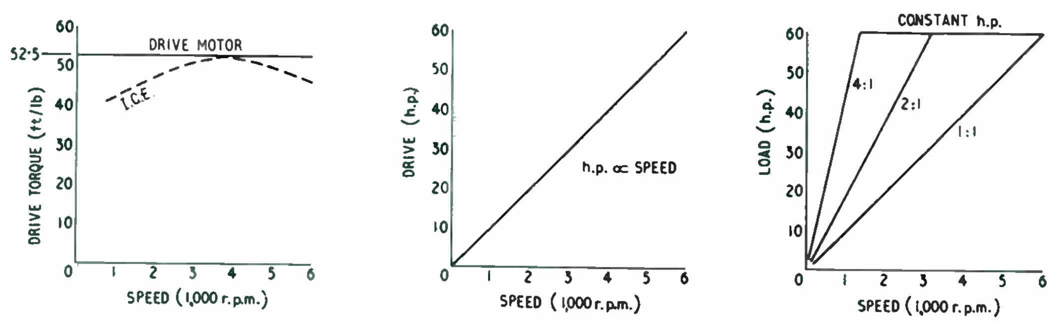


Fig. 2. Drive and load-motor characteristic curves; (a) shows the maximum torque/speed characteristics of a typical i.c. engine and of a drive motor simulating it; (b) shows the horse-power/speed characteristics of the drive motor; and (c) indicates the load-motor h.p./speed characteristics for various gearbox ratios

equivalent horsepower characteristic for the drive motor; i.e., horsepower proportional to speed.

The armature of the drive motor is supplied from a common generator G, Fig. 1, forming part of a 3-machine Ward-Leonard M.G. set. By exciting the field of the generator from thyratrons or silicon controlled rectifiers the excitation of the generator, and hence its output, is controlled.

A tachometer generator TG, mounted on the non-drive end of the driving motor, provides an electrical signal proportional to the speed of the motor. This signal is compared with that obtained from a speed-setting potentiometer SS fed from a stable reference voltage, and the difference or error signal is used to adjust the field excitation F of the common generator and hence the armature supply to the driving motor so that the speed of the driving motor is restored to the level set by the speed-setting potentiometer. Thus by this closed-loop system the speed of the driving motor is accurately controlled to maintain the level set by the speed-setting potentiometer to within close limits irrespective of the load on the motor and gearbox.

Under steady-state conditions for loads ranging from no-load to full-load a regulation of better than $\pm 0{\cdot}25\%$ of maximum speed is obtained. For certain applications where the noise or vibration from the gearbox is being monitored by a frequency analyser it is desirable that the set speed be maintained as accurately as possible. By using a very accurate tachometer generator, and a stable reference voltage to feed the speed setting potentiometer, a speed regulation of better than $\pm 0{\cdot}1\%$ for a driving motor speed of 6,000 r.p.m. maximum can be provided.

The speed of the driving motor is indicated by measuring the signal from the tachometer generator with a voltmeter calibrated in r.p.m. (SI in Fig. 1).

In order to change gear during running an electrically-operated clutch is shown in Fig. 1. This could in fact be the same type of clutch as used in the vehicle.

Load Section

The output shaft of the gearbox is coupled to a foot mounted d.c. motor (load motor LM) which simulates the load imposed on the gearbox by the road wheels via the transmission.

So that the gearbox may be loaded under conditions experienced in practice, the load motor has to be capable of operating over a speed range equivalent to that of the drive motor together with a further range due to the range of gearbox ratios.

For example, if we have a gearbox whose ratios are 1 : 1, 2 : 1, and 4 : 1 driven from a motor with a speed range of 6,000 r.p.m. to 100 r.p.m., when the gearbox is in 1 : 1 the speed range of the load motor will be 6,000 r.p.m. to 100 r.p.m., but when the gearbox is in bottom gear 4 : 1 the speed range of the load motor will be 1,500 r.p.m. to 25 r.p.m. Hence the total speed range of the load motor will be 6,000 r.p.m. down to 25 r.p.m.

Furthermore, the rating of the load motor must be such that it is capable of loading the gearbox and driving motor for all gear ratios. For example if we assume a gearbox approaching an efficiency of 100% driven by a driving motor capable of developing 60 h.p. at 6,000 r.p.m., when the gearbox is in top gear (1 : 1) the load motor must absorb 60 h.p. at 6,000 r.p.m. to load the gearbox and drive motor fully. If the gear ratio is then changed to bottom gear (4 : 1) the load motor must absorb 60 h.p. at 1,500 r.p.m. to load the gearbox and drive motor fully. Hence the load motor must be capable of absorbing 60 h.p. over a speed range of 6,000 r.p.m. down to 1,500 r.p.m. and must have a constant horsepower characteristic over this range. See Fig. 2(c). Because of this constant-horsepower range the load motor is physically larger than the driving motor.

In order to control the load motor over a constant horsepower range the field excitation F of the motor, which is supplied from silicon controlled rectifiers, is varied.

The armature of the load motor is supplied from the common generator via a buck/booster generator (B/BG, Fig. 1), which forms part of the 3-machine M.G. set. This buck/booster generator has two fields (F), the one excited in a positive sense and the other in opposition or in a negative sense. This enables the buck/booster generator to provide an output, the polarity of which may be reversed. The polarity of output depends upon which field is the greater and the amplitude of output depends upon the difference in excitation of the two fields. The excitation of the field of the buck/booster generator is supplied from silicon controlled rectifiers.

By controlling the output from the buck/booster generator the amount of current flowing through the load motor is controlled and hence the torque developed, while by controlling the polarity output from the buck/booster generator the direction of current flow through the load motor armature is controlled. It is possible therefore to make the load motor act as a generator and try to resist the turning of the output shaft of the gearbox hence simulating loading under normal running conditions or alternatively, by reversing the current, the load motor acts as a motor and tries to drive the output shaft of the gearbox round, hence simulating loading under over-run conditions.

Upon adjustment of load, the buck/booster generator initially controls the current flowing round the loop comprising the driving motor, loading motor and a buck/booster generator. The field of the loading motor is then controlled to reduce the output from the buck/booster generator to a level equivalent to the IR drop in the loop while still maintaining the same amount of armature current flowing in the armature circuit. This ensures that the buck/booster generator has capacity available for further control and at the same time that the load motor field is excited at the correct level for the particular gear ratio.

Drive Load Control

The control system is arranged so that the load is measured in terms of torque developed by the drive motor. A voltage obtained from a resistor R in series with the armature of the drive motor provides a signal proportional to drive motor torque. This signal is compared with a signal obtained from a load setting potentiometer (LS, Fig. 1) and any error voltage is used to control the excitation of the buck/booster generator in such a manner that the load imposed by the load motor *via the gearbox* on the drive motor is maintained at the level set by the load-setting potentiometer.

Hence by this closed-loop load control system the load is accurately controlled to maintain the level set by the load control potentiometer irrespective of the speed of the drive motor. A load regulation of better than $\pm 1\%$ of maximum load can be attained. By measuring the armature current and indicating it on a meter, calibrated in terms of torque (TI, Fig. 1) drive torque indication is provided.

In cases where a more accurate means of torque measurement and control are required a torque transducer coupling is interposed between gearbox and drive motor. This coupling provides an electrical signal proportional to the torque exerted which when amplified may be used, instead of the signal from the armature circuit of the drive motor, for control purposes. A load regulation and torque indication to within $0{\cdot}5\%$ of maximum may be obtained by this method.

Overrun Load Control

By reversing the current flowing in the loop comprising drive motor, load motor and buck/booster generator, the load motor tries to drive the output shaft of the gearbox round at a torque determined by the amount of current flowing round the loop dictated by the setting of the load control (LS). The speed of the gearbox is still, however, determined by the driving motor-speed control potentiometer, as the drive motor speed is maintained at the set level, irrespective of the load motor trying to drive the drive motor, via the gearbox, faster.

This provides facilities to test the gearbox under overrun conditions, as experienced when the vehicle is coasting, or travelling down hill using the engine as a brake.

The control system is similar to that for drive load control and the same load setting potentiometer is used to adjust for drive or overrun conditions. By feeding the potentiometer from a centre-tapped reference the polarity of the load-setting signal is reversed over the second half of its travel, this causes the buck-booster generator to reverse in polarity and hence the current round the loop. Over the first half of its travel the potentiometer adjusts for drive torque conditions from maximum down to zero torque, and over the second part for overrun torque conditions from zero to maximum overrun torque; there is therefore no discontinuity in adjustment of torque setting.

Because the load motor feeds current back to the drive motor and helps to provide the power to supply the drive motor, the system is a minimum-loss system. The a.c. motor (AC) driving the M.G. set (a.c. motor—common generator—buck/booster generator) is rated to supply the losses in the system, the losses comprise those in the gearbox together with the other rotating machines. Normally, the a.c. motor will have a rating of the order of 50% of the drive motor, this depends to a certain extent upon the minimum efficiency of the gearboxes to be tested.

This minimum-loss system avoids having to dissipate large amounts of power in the form of hot air or hot water on the load side, which of course saves a considerable amount of power over a period of time and keeps running costs to a minimum.

Although a large proportion of the power to supply the driving motor is obtained from the load motor, the common generator itself is normally rated to supply the drive motor in order to provide a fast rate of acceleration and deceleration. The buck/booster generator rating is of the order of 20% of the rating of the common generator.

Reverse Gear

Under conditions where reverse gear on a gearbox is to be tested it is important that the armature supply from the load motor be reversed. This supply could be switched manually by the operator switching the armature contactors over. It is, however, preferable that this be done automatically as failure to reverse the armature contactors could cause a fault condition to occur which may not be detected by the operator. A d.c. tachometer generator, driven by the load motor, is fed into a polarity-sensitive relay which switches the armature contactor. Under reverse conditions the polarity of the output from the tachometer generator changes and the relay it feeds operates and switches the reverse armature contactor.

Maximum Speed Limit (First and Reverse Gears)

Sometimes there is a requirement for limiting the maximum speed of the drive to, say, 3,000 r.p.m. when first or reverse gear is selected. This is achieved by taking the outputs from the drive-motor and load-motor tachometers and feeding them into a circuit which senses the ratio of the two signals. If the signals are at a ratio equivalent to first gear or reverse gear a clamp is switched on to the drive speed setting reference so that it cannot be adjusted by the operator to exceed a predetermined maximum speed, in this case 3,000 r.p.m.

One of the photographs shows the gearbox test rig used by Rootes (Scotland) Ltd. for a rear-engine drive vehicle, the Imp.

Three-Arm System

The equipment for testing differentials of fixed ratio, as in the case of the rear axle, and also differentials with a variable gear ratio, as used on some of the smaller cars today, comprises three sections.

Fig. 3 shows the sections which are the drive section, the master-load section and the slave-load section.

The drive motor drives the differential, thus simulating the internal combustion engine driving through a gearbox, while the load machines simulate the load imposed by the half-shaft and differential by the road wheels.

Drive Section

The control of the driving motor is similar to that already described for the gearbox test equipment and provides the same facilities in the form of accurate speed control and close speed regulation for all load conditions.

Load Section

As shown in Fig. 3 the load section of the test equipment is divided into two parts, the master section and the slave section.

Each half-shaft is loaded by a load motor (LM) which is normally rated to absorb half the power exerted by the drive motor.

The speed range of each load motor is determined by three factors:

(a) The speed range of the drive motor which has to cater for maximum engine speeds down to tick-over speeds plus a further speed range due to a range of intermediate gearbox ratios, if any.
(b) The range of differential ratios to be catered for.
(c) An increase in speed above the nominal maximum which would be required if facilities for setting a speed differential between load shafts is required.

The maximum speed of the load motors is usually much lower than that of the drive motor because of the step-down ratio of the differential itself, while the minimum speed of the load motors is usually very low. It is of the order of a few r.p.m. only, due to the stepdown ratio of the differential together with that of any intermediate variable-ratio gearbox.

Thus each load motor has to have an extremely wide variable-speed range and although each motor only has to absorb half the power exerted by the driving motor (because the maximum speed of each load motor is much lower than that of the drive motor), size for size, the load machines are physically larger than the drive machine.

Furthermore, the load machines have to incorporate a constant horsepower characteristic over part of their speed range in order to cater for a range of differential ratios or provide facilities to set a speed differential between each load motor.

The armatures of both load motors are connected in parallel and supplied from the common generator G via a buck-booster generator B/BG. The buck/booster generator has two fields which may be excited in a similar manner to that already described for the gearbox test equipment so that the output and polarity from the buck/booster generator is controlled.

Drive Load Control

The load control system is such that the two d.c. load motors are controlled to maintain the load imposed via the differential on the driving motor to a level set by the load setting potentiometer LS. As in the case of the gearbox

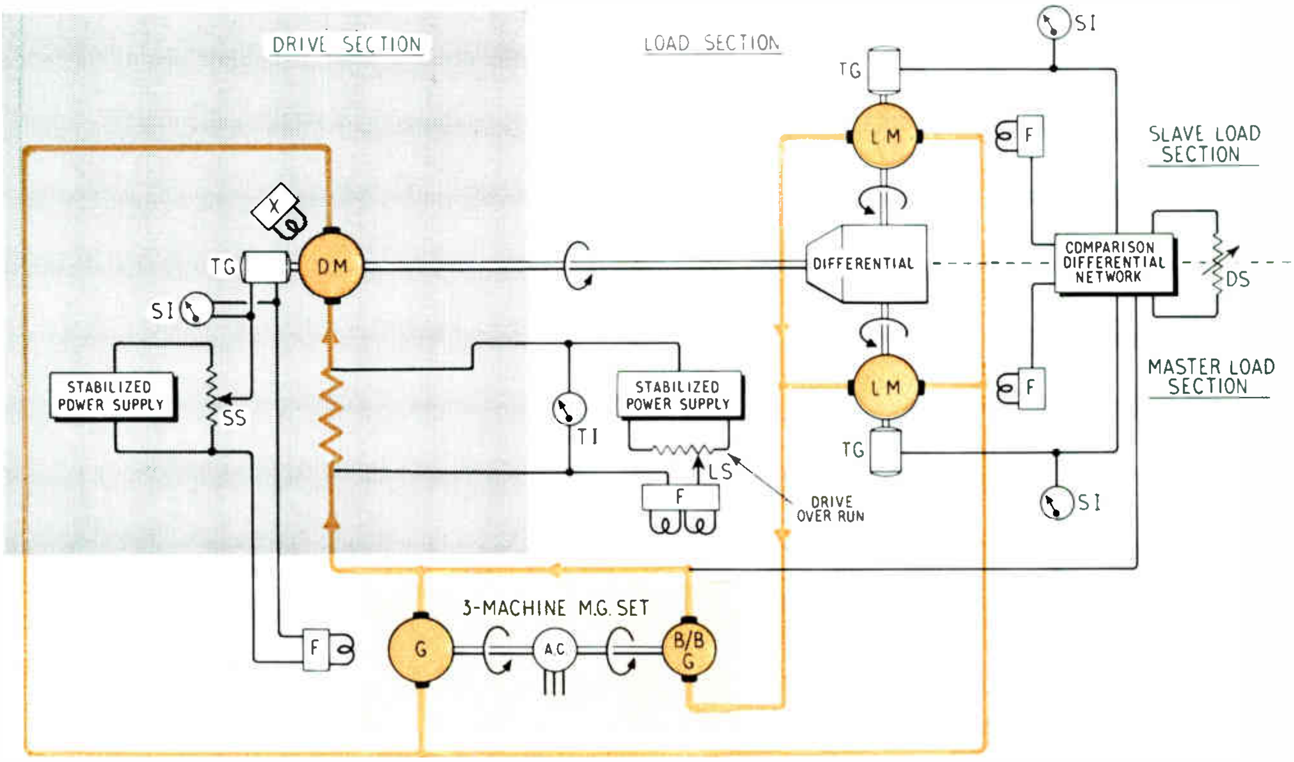


Fig. 3. Differential test electrical schematic

test equipment, the load is controlled in terms of torque exerted by the drive motor.

Under load conditions the loading motors regenerate and act as generators, thus helping to provide power for the driving motor. In this manner minimum power is used from the mains supply and the a.c. motor on the M.G. set purely serves to make up the losses in the system.

The control of the drive load is achieved in a similar manner to that already described for the gearbox equipment by taking a signal proportional to the armature current of the drive motor, and hence drive torque, and comparing it against a signal obtained from the load setting potentiometer. Any difference is used to control the buck/booster generator and hence armature current of the load machine. In this manner the load imposed by both load machines via the differential on the drive motor is controlled and maintained at the level set by the load setting potentiometer LS.

To cater for any range of differential ratio, or ratios of gearbox incorporated in the differential, the fields of the load machines are also controlled to maintain the output from the buck/booster generator equivalent to the *IR* drop in the loop while at the same time maintaining the load

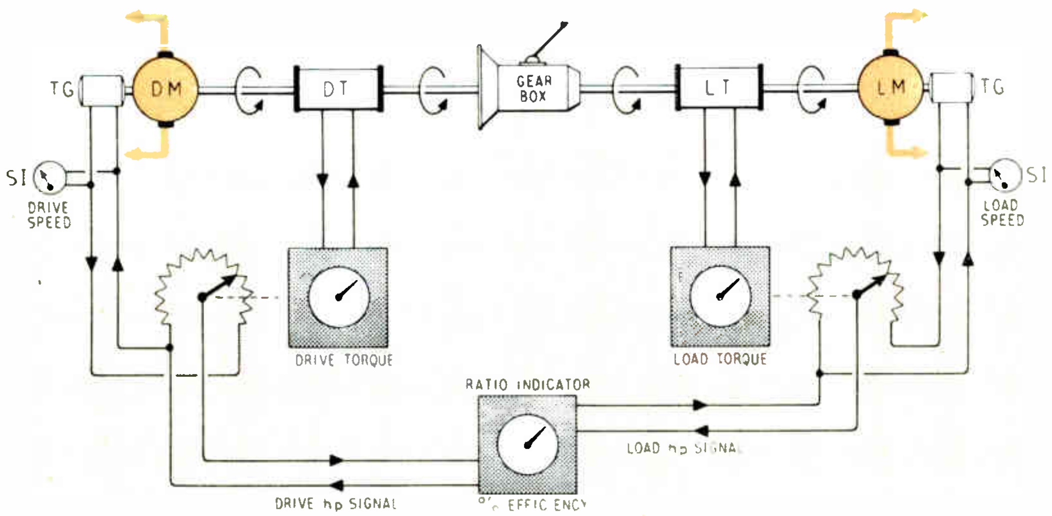
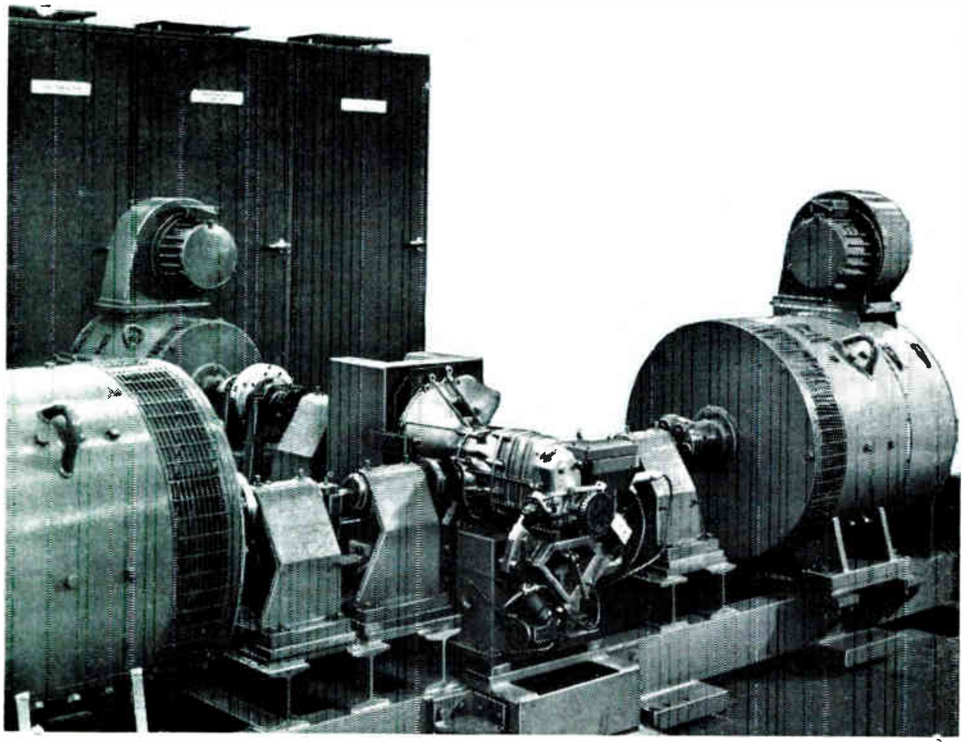


Fig. 4. Efficiency computer electrical schematic



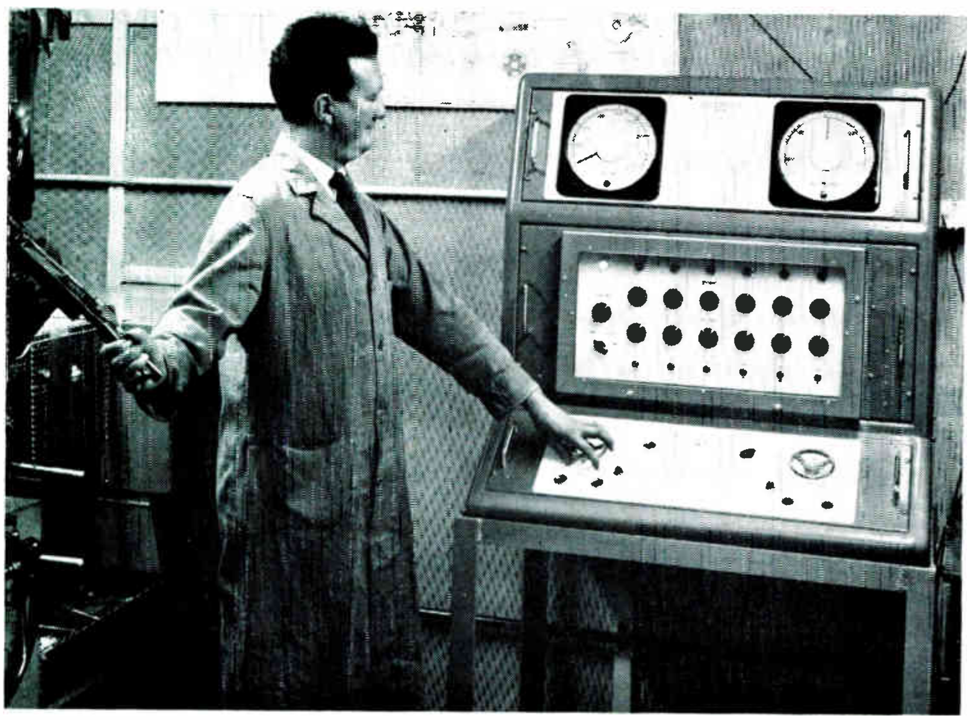
Combined gearbox and differential test rig

imposed on the drive motor. This is achieved in a similar manner to that already described for the gearbox test equipment.

In order to obtain speed matching between the two load machines, a signal is obtained from a tachometer generator TG, mounted on the non-drive end of the master-load machine, and compared with a signal obtained from a tachometer generator mounted on the non-drive end of the slave-load machine. Any deviation between the two tachometer generator signals is used to adjust the field excitation of the slave-load machine so that its speed is maintained at the same level as that of the master load machine.

Overrun Load Control

Overrun load control facilities can also be incorporated, the control system being similar to that already described for a gearbox test equipment whereby the buck/booster generator is controlled to reverse the current flowing round the loop so that a reverse torque condition is simulated.



Programme control desk

The maximum amount of overrun torque is not normally as high as the maximum amount of drive torque, as under overrun conditions the degree of torque is mainly determined by the engine friction torque and frictional losses in the gearbox and transmission shaft. Normally, the test equipment is rated to provide a maximum amount of overrun torque of the order of 25% of the maximum drive torque available.

A single control is used to set either drive load or overrun load, the circuit being arranged so that over the first part of rotation the control sets drive load, while over the latter part of rotation the control sets overrun load, as in the case of the gearbox test equipment.

The torque is indicated on a circular-scale meter TI which monitors the armature current of the driving motor and is calibrated over the first part of its scale in terms of drive torque and over the second part of its scale in overrun torque.

Differential Speed Setting

Sometimes it is necessary to test the action of the differential and simulate the effect of the vehicle turning round a corner and this is achieved by controlling the field of the load machines so that one machine rotates at a speed faster than the nominal speed and the other machine at a speed slower than the nominal speed level.

This is achieved by taking the output voltages from the two load-motor tachometer generators and feeding them into a differential network which trims each signal. Under conditions where the speed of the two load motors is the same, and with zero differential setting, the output from the differential network is zero. If, however, the differential setting is adjusted, the differential network is designed to trim the signals controlling the field excitation of each load motor so that one load motor speed is increased and the other decreased by a percentage determined by the setting of the differential speed potentiometer DS.

Additional Features

In cases where the equipment is used to test a combined gearbox and differential system, as in the case of the gearbox test equipment, automatic reversal of armature contactors for the two load motors when reverse gear is selected can be incorporated, and also facilities to limit the maximum speed setting of the drive motor when the gearbox is selected to a particular gear such as first, or reverse gear.

A typical test equipment for a differential incorporating a variable-ratio gearbox as well is shown in a photograph.

Thus the system described above provides accurate drive speed control, the speed of the drive being controlled to the set level irrespective of the load; accurate control of the load on the drive motor and hence load on the component being tested, the load being controlled to the set level irrespective of the speed; facilities to simulate reverse torque conditions; provision for maintaining a set differential percentage irrespective of speed and load; and a minimum-loss system where the maximum amount of power is recirculated and used to contribute to the power required by the driving motor.

Programme Control

Often, a desirable feature of test rigs testing on production is that each gearbox or differential has the same type of test.

Because speed and load parameters are adjusted by a potentiometer it is simple to programme a series of speed and torque settings, by using a uniselector. The uniselector is driven round from pulses derived from a timer, and at each step selects two of a number of preset potentiometers which set the desired speed and torque.

Thus a complete programme of speed and load torque may be preset and once initiated the programme controller will reproduce the preset test cycle ensuring that each item being tested has the same type of test.

By adjusting the timer setting, the overall cycle time may be varied.

This type of programme controller not only ensures that each unit is tested to the same conditions but also dictates the test time taken for a particular item. Thus a gearbox or differential can be tested to its optimum in the minimum amount of time.

Alternatively, the manual speed and load control potentiometers can be adjusted by means of a lever and cam arrangement. The profile of the cam determines the level of speed or torque and also the rate at which it is adjusted. Normally, the cam itself is driven round by a constant-speed a.c. geared motor unit, but by using a small variable-speed d.c. geared motor unit the cycle time of cam control can be adjusted to suit the particular test requirements.

An alternative to the operator adjusting the speed-control potentiometer manually is the electronic integrator. This provides a speed setting reference voltage of increasing amplitude; the rate of increase and hence rate of acceleration of the drive is determined by the time constant of the integrator, which can be preset. The initial and final amplitudes of the integrator signal can also be preset and hence the speed at which the drive starts to accelerate and the final speed of the drive. By reversing the procedure the integrator can also control deceleration as well as acceleration. It is also possible to interpose a dwell period, the duration of which is controlled by a timer, so that after an acceleration the drive is maintained at the maximum speed for a set period before decelerating.

If the preset potentiometers controlling the characteristics of this sequence are selected by means of the uniselector system, a number of sequences can be preset and run through in succession. Normally, during acceleration and deceleration sequence the load on the gearbox is maintained at a preset level during acceleration, with facilities to change the load to another preset level during deceleration, so for each sequence of acceleration and deceleration two preset load settings are available.

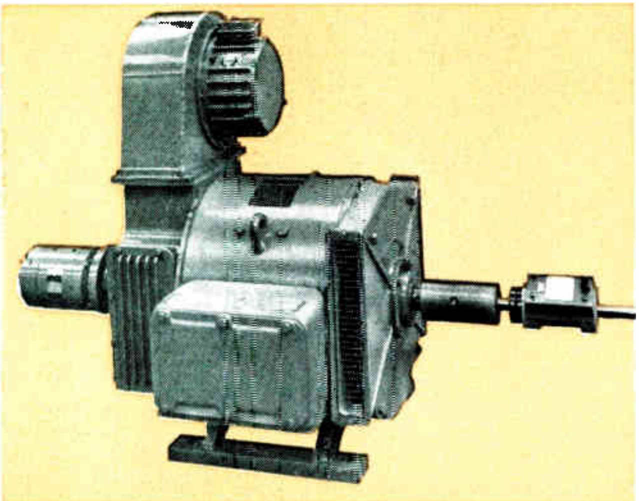
Once the various preset levels have been set up the operator, having fitted the gearbox on the test rig, selects a gear and presses the programme start push-button. The drive then accelerates from the set minimum to maximum speed at a rate determined by the acceleration rate control potentiometer and upon reaching maximum speed dwells for a period of time determined by the dwell timer. On timing out, another load setting is selected and the drive decelerates from the maximum to the minimum preset speed and dwells at the preset minimum speed level. During this dwell time the operator selects the next gear and the sequence continues. This type of programme control can be adapted to control equipment for testing automatic type gearboxes. On all the above types of programme control equipment a push-button is incorporated to arrest the programme in the event of the operator wishing to stop the programme and maintain the drive speed and torque at any particular instance.

The above simple types of programme control are normally used for production tests.

For research and endurance tests more complex types of programme control equipment, for use with the previously described gearbox and differential test equipment, can be incorporated in the form of a punched-tape programme, magnetic-tape programme or line-follower programme.

The punched-tape programme control uses a tape which is punched from available data. The tape is fed into a tape reader which provides signals to control the speed, load and, where applicable, percentage differential in speed of half-shafts.

Magnetic-tape programme control may be used to control



Load motor with torque transducer coupling

the speed of the test equipment so that it reproduces an actual road test run. This is achieved by recording the contact breaker pulses during the road test run, the frequency of the pulses being proportional to engine speed, and then playing back the recording on a tape recorder on the test equipment. The tape recorder provides a pulse output proportional to the required drive speed; the digital train of pulses is then converted to an analogue signal which is used to control the speed of the drive.

A more sophisticated type of programme control is the line-follower programme controller. Each programme is drawn as a curve on a roll of paper strip 6 in. wide. The paper is passed across the face of a cathode-ray tube the other side of the paper being viewed by a photo-electric multiplier which senses the position of the ink line on the paper. This is achieved by monitoring the position of the spot on the c.r.t. at the instant when the photo-multiplier detects absence of light due to the line on the curve obscuring the spot. An output proportional to the position of the curve at any instance is obtained and used to control speed, load, or differential.

A small variable-speed d.c. drive is used to move the paper strip across the face of the c.r.t. Hence, by varying the speed of the strip, the programme time can be varied.

Control desk incorporating efficiency computer

Instrumentation

Apart from the instrumentation already mentioned in the form of speed indicators and load indicators, the equipment lends itself to incorporating strip-chart or disc-chart type recorders. These instruments can be used to produce a permanent record of the control parameters during a test so that an assessment may be made on a quantitative basis during the research and design stage of a component.

Equipment is available to monitor and record the noises and vibration from a gearbox or rear axle. The information obtained when used in conjunction with a recording of load and speed conditions can be used to an advantage when considering modification of geared teeth in order to produce a quieter unit.

On the differential type of test equipment, for design or research purposes, it is often desirable to monitor individually the torque on each half shaft. This is possible by using the torque transducer type of coupling, which provides an output signal proportional to the torque on a particular shaft. The signal is fed into a servo-rebalance type of instrument which indicates the torque on a large circular scale. With very little additional equipment a permanent recording of torque can be provided on a disc chart.

By using the torque indicator also to drive a potentiometer, a system to compute continuously the efficiency of a gearbox being tested can be incorporated.

Fig. 4 shows the electrical schematic arrangement for an efficiency computer. A drive motor DM drives via a drive torque coupling DT the gearbox which is loaded by the load machine LM coupled to the gearbox via a load transducer LT. Each transducer feeds a torque indicator and each torque indicator drives a potentiometer, so that the angular position of the potentiometer bears a direct relationship to the torque transmitted through the torque coupling. By feeding a signal from a tachometer generator TG on the drive side, across the potentiometer, and taking the output from one side of the potentiometer and the slider a signal is obtained proportional to the product of drive speed and torque and, hence, proportional to the drive horsepower. A similar signal is obtained proportional to the load horsepower.

These two signals are fed into a circular-scale indicator which produces an indication proportional to the ratio of the two signals, the indicator being calibrated directly in percentage efficiency. The torque indicators and efficiency indicator are driven by servo mechanisms operating on the rebalance principle and provide a highly accurate means of measurement plus adequate force to drive any associated potentiometers. Normally, the efficiency indicator also incorporates disc-chart recording facilities so that a permanent record of the efficiency of the gearbox during the test procedure can be obtained.

A photograph shows a control desk which incorporates instrumentation for monitoring drive and load speed, drive and load torque, together with instrumentation for directly computing and recording the efficiency of a torque converter during the test procedure. It may be noted that an additional indicator and recorder has also been incorporated for monitoring the oil temperature of the converter during the test.

Controls for the television system, X-ray source and specimen traversing mechanism are all grouped so that they can be adjusted while the operator views the monitor screen

New X-Ray Microscope

RADIOGRAPHIC examination of objects in minute detail, from the detection of latent faults in transistors to the observation of the movements of the internal organs of insects, is made possible by the Norelco 'Searchray', a new X-ray equipment now available in Britain.

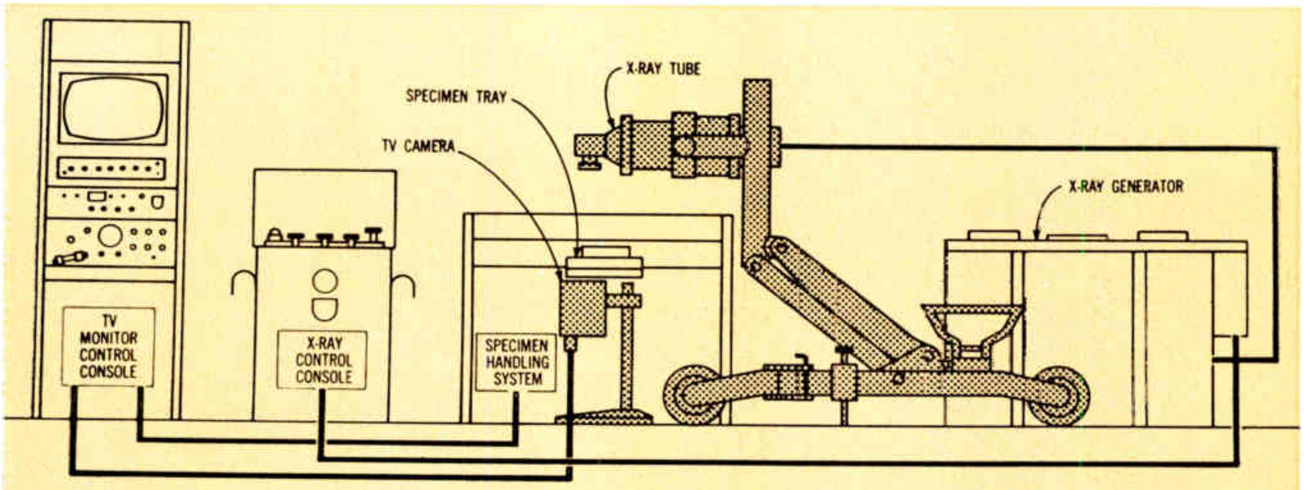
The equipment utilizes an X-ray sensitive vidicon television camera tube working in conjunction with a high-quality closed-circuit television system. The X-ray image is received on the vidicon target and is converted directly into a video signal. There is no intermediate conversion of the X-ray image into an optical one as is the case with image converters and ordinary television camera systems. The resolution of the electronically-magnified image on the television monitor screen of the equipment is consequently very high, and good sensitivity and contrast are obtained.

The results with both stationary and moving specimens are claimed to be equal to or better than those obtained with other radiographic techniques, and can be produced with materials of different densities such as plastics, ceramics, steel, rubber and aluminium.

The specimen is carried on a tray that can be automatically traversed in both X and Y directions under the X-ray tube at speeds from 1 to 12 in./min. At these speeds a copper-mesh sample of 100 wires to the inch can be seen clearly without blurring. An indication of the resolution with a stationary specimen is that a single 0·0005-in. diameter tungsten wire at the vidicon face plate can be detected without additional absorbers in the X-ray beam. The radiographic sensitivity is 1·4% through $\frac{1}{4}$-in. aluminium or $\frac{1}{8}$-in. steel. Image magnification with a 17-in. monitor tube is 27 times.

All the controls for the television equipment, traverse mechanism and X-ray unit are grouped together so that the operator may control all parts of the system while viewing the display. This arrangement also enables the operator to be located remote from the X-ray tube and so simplifies radiation screening requirements.

The equipment is well suited for the inspection of very small instrument assemblies and thin welds in space vehicles and nuclear plant. It may also be used for the detailed inspection of precision castings of light alloys and thin sections of dense materials such as jet engine turbine



Schematic outline of the 'Searchray' radiography equipment. In practice the television monitor control is located immediately at the side of the X-ray control console, and both may be several yards from the X-ray tube and specimen blades. In instrument movements, valves and similar mechanisms, the spacings between internal parts or their motions can be observed and measured to 0·001-in. accuracy.

In hydraulic and pneumatic systems, internal passages, orifices and fluids can be examined for particle contamination of the order of 10 microns. With dense fluids such as mercury, bubbles or voids can be detected through metallic walls of ⅛-in. thickness. With low density wall materials, it is sometimes possible to see motions of water or hydrocarbon fluids as well as contaminants of greater densities. Extreme examples of applications of the equipment have included the study of the motions of body fluids in insects and the birth of larvae from a fly.

The Norelco 'Searchray' is manufactured by Philips Electronic Instruments, U.S.A., under licence from the Research Foundation of Ohio State University. It is supplied and serviced in Britain by Research & Control Instruments Ltd.

For further information circle 42 on Service Card

Eddy-Current Coupling

As a result of a recent licensing agreement between Lancashire Dynamo Electronic Products and Elco S.A. of Paris, eddy-current couplings, known as LDEP Elcotron units, are available in the U.K.

This coupling is a variable-torque transmission device in which the input torque is equal to that imposed by the load on the output shaft.

It is an air or liquid cooled cylindrical unit comprising a stator and two independent concentric rotors separated by a small air gap. The inner rotor is driven at a constant speed by an external prime mover and the outer rotor is connected by a shaft to the load.

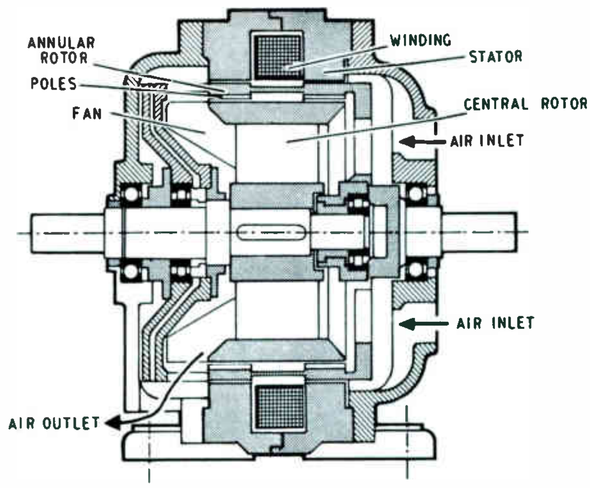
The coupling depends upon electromagnetic induction for its mechanical and electrical characteristics. A stator coil is wound concentric with the two rotors and, when excited, magnetic lines of force emanate from the coil passing through the two air gaps into the two rotors and from the rotors back to the stator.

With the stator coil excited by d.c., any relative movement between the two rotors will generate eddy currents and a motor torque is produced. The magnitude of the torque is related to the difference in speed of the two rotors and to the intensity of the stator coil magnetic field.

This device can therefore be used simply as a torque transmission device. Alternatively by varying the energizing field current, and therefore the torque-handling capacity, it can be used as a step-down speed control.

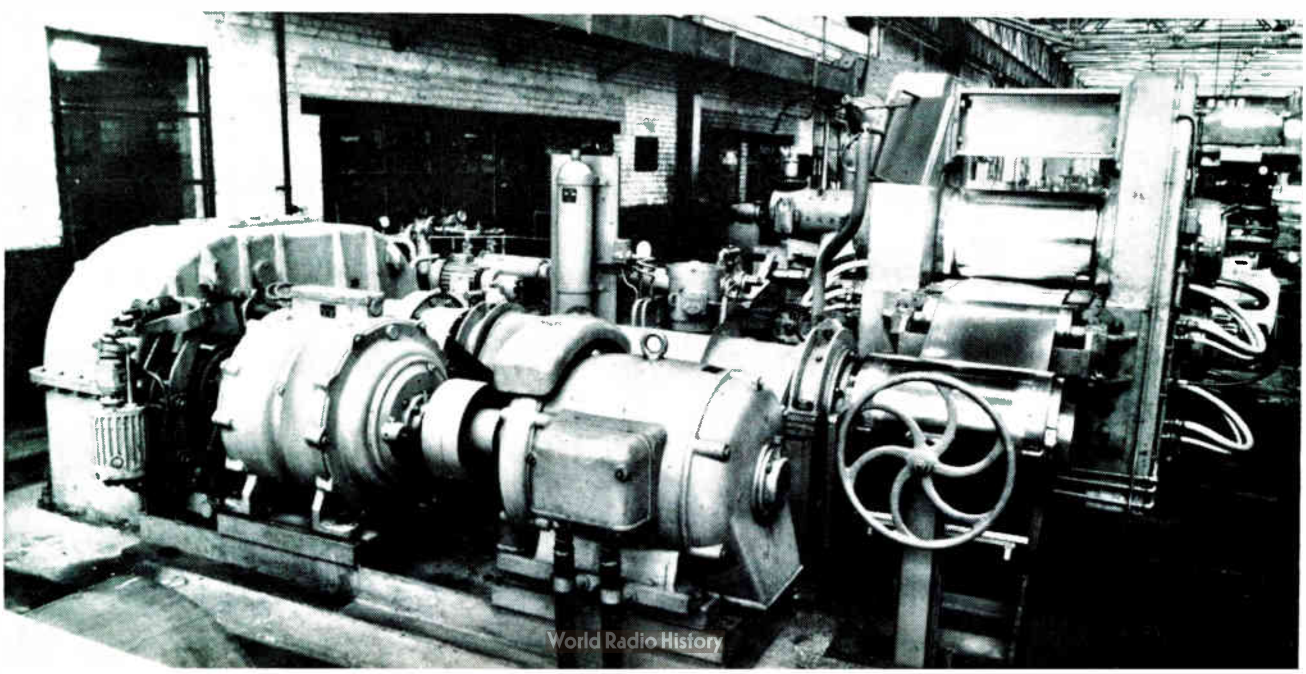
Models are available covering a range of 1 to 1,000 h.p.

For further information circle 43 on Service Card



▲ *This simplified cross-sectional drawing shows the basic components of an LDEP Elcotron unit*

Illustrated here is a 200 h.p. liquid cooled coupling being used in a strip steel application ▼



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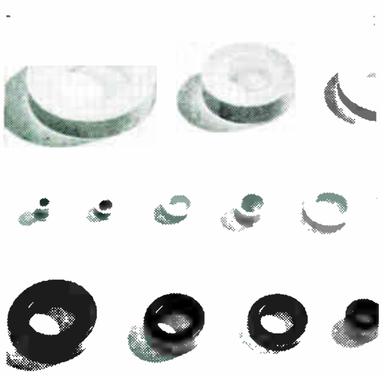

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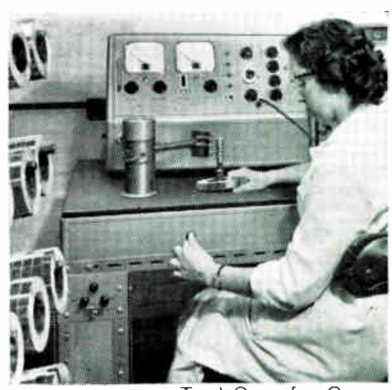
Cores are available in a wide variety of sizes and strip thicknesses down to 0.000125″ (3 microns) and full technical information will gladly be sent on request. Core finishes can be made to suit customer requirements which include epoxy resin and other coatings, metal casings and sealed boxes of various plastic combinations.



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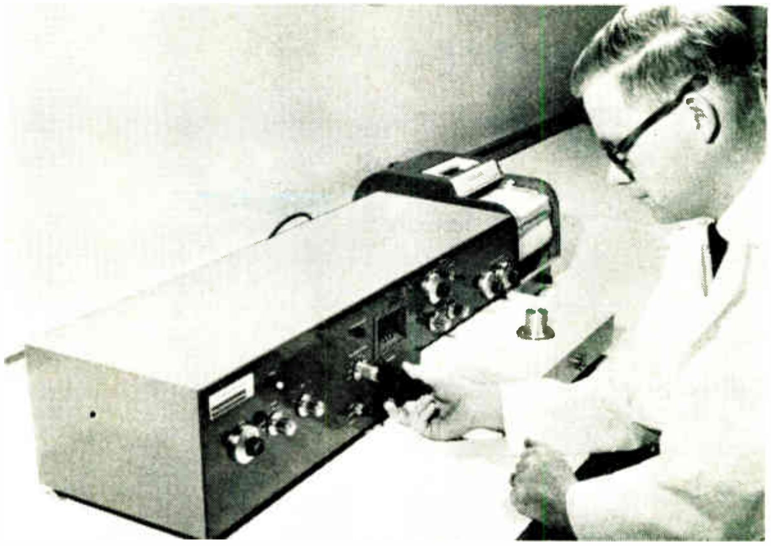
Electronics In Thermal Analysis



The differential scanning calorimeter in operation

The application of electronics to thermal analysis is well illustrated by the Perkin-Elmer DSC-1 'Differential Scanning Calorimeter'. Performance advantages over manual calorimetric techniques include higher resolution, higher scanning speeds, smaller sample requirements and good reproducibility of qualitative and quantitative data. The instrument is also noteworthy in that it may include within the system a thermal conductivity gas monitoring system for analysis of sample decomposition products.

Conventional thermal analysis subjects equal quantities of sample and inert reference material to gradually increasing temperature while measuring the difference in temperature between them. In the DSC-1, sample and reference material are subjected to either an increasing or decreasing temperature; a separate control system detects any difference between sample and reference temperature and simultaneously changes the heat applied to either in order to maintain them both at the temperature called for by the rate of change set into the overall control system. The instrument's actual measurement is the difference in electrical power required in maintaining sample and reference at the desired temperature. Because this power is directly proportional to the quantity of energy involved in any change undergone by the sample, it can be directly correlated with the physical or chemical mechanism involved in the change.

Thermal lags associated with conventional equipment are avoided through the use of very small samples. These samples, which are sealed in inert-metal foil packets before analysis, can be in either powder, disc or sheet form, and as small as 0·1 mg.

The operating range of the DSC-1 extends from −100 °C to +500 °C. The instrument, which has a digital temperature readout facility, will scan temperatures automatically at fixed, reproducible rates up to 80°/min. A typical analysis can be carried out in 10 min, with the analytical output presented on a strip-chart recorder and taking the form of peaks superimposed on a reference line. The area of peaks corresponds to the quantity of energy absorbed or liberated by the sample. Because the rate of temperature change is linear, the position of the peaks on the record indicates the temperature at which the energy transition occurs.

Provision is made for conducting analyses in atmospheres on inert gas which may then be sampled by other techniques, such as gas chromatography, to provide additional information on products of sample breakdown or chemical change. Differential scanning calorimetry thus has direct application to such fields as polymer studies, structural analysis of fatty acids in glycerides, investigating the breakdown of lubricants and additives at high temperatures, and measuring the melting range, curing rate and crystallinity of plastic materials such as polyethylenes.

For further information circle 44 on Service Card

NEW V.H.F. AERIAL

Broadcast v.h.f. receivers usually embody some form of folded dipole as an internal aerial or have a telescopic rod. Both are apt to be inefficient and the latter is often inconvenient since it should be more or less horizontal. Such aerials are also directional which is again an inconvenience.

Development is taking place on a ferrite-rod aerial which is non-directional and which is small enough to be included in even a portable receiver. It depends on the use of a grade of Ferroxcube which has low losses and a reasonable permeability at 100 Mc/s. The resonator of the aerial comprises a copper tube of 2 cm internal diameter and 14 cm long. The tube is slit longitudinally and six capacitors are connected at equally spaced intervals across the slit. The resonator is, in effect, a single turn coil with the capacitors for tuning.

Two lengths of ferrite rod of total length 16 cm are inserted in the tube with an air-gap at the centre between the two. In this air gap there is a single-turn coupling coil with its leads brought out through holes in the tube. Tuning is carried out by sliding one of the ferrite rods in and out of the tube and the rod can be ganged to the main receiver tuning control.

The coupling coil connects to an earthed-base transistor amplifier which is, of course, of low input impedance.

The aerial is mounted vertically for the reception of horizontally-polarized waves. It is described in *Philips Technical Review*, Vol. 24, No. 10, p. 332, and it is still experimental. The present performance is about 13 dB below that of a half-wave dipole of 130 cm total length.

EQUIPMENT review

1. Paper Tape Reader

Ohr-Tronics, Inc. has announced a new paper tape reader, model 119, which reads up to 8-channel paper tape bi-directionally, at a speed of 30 c/s (tape readers for more than 8 channels are available on special order). Sensing of the holes is accomplished by the use of star wheels. When a star wheel enters the hole, an arm carrying the star wheel closes a switch. Bounce time of the sensing switch is well under one millisecond. Two electromagnets are used for stepping the tape in either direction.

Available voltages are 24, 48 and 90 V d.c. Coils are conservatively designed for continuous duty and are arc-suppressed with zener diodes. An interrupter switch is provided to protect the star wheel sensing switches and also for self-stepping of the tape. The reader is available with extension plates for mounting on to a standard 19 in. rack. Height of the unit, which is wired to a 24-pin connector, is 3½ in. A mating connector is supplied.—*Ohr-Tronics, Inc., 516 Fifth Avenue, New York, N.Y., U.S.A.*

For further information circle 1 on Service Card

2. Insulating Laminates

Three types of electrical insulating laminates formed from glass fibre and synthetic resins have recently been marketed by Attwater & Sons. These are (a) glass fibre Bakelaque Phenolic Bond which is suitable for operating temperatures up to 155 °C; (b) glass fibre Bakelaque Melamine Bond for operating temperatures up to 240 °C; and (c) glass fibre Bakelaque Silicone Bond for operating temperatures up to 250 °C. The range thus provides electrical insulating laminates for class B, class F, and class H insulation requirements.

The materials which have good dielectric and mechanical properties are available in sheets 36 by 24, 48 by 24, and 36 by 18 in., and from 0·15 in. thick. Where required Attwaters can machine, punch, drill and assemble these laminates against any given requirements. The melamine and silicone-based laminates are available in white, phenolic laminate being available in brown and black.

The photograph shows (above) a part for a constant voltage generator in glass fibre Bakelaque Silicone Bond, and (below) shapes punched from Bakelaque Phenolic Bond.—*Attwater & Sons Ltd., G.P.O. Box 39, Preston, Lancs.*

For further information circle 2 on Service Card

3. Sound Level Indicator

To meet the rapidly increasing demand for equipment for general noise surveys, Dawe Instruments have designed the type 1408E sound level indicator. This is a fully-transistorized pocket-size unit intended for rapid noise checks calling for a simple, robust yet accurate instrument without the input and output facilities provided by a sound level meter.

The instrument comprises a moving-coil microphone (housed within the plastic casing), a high-gain amplifier, standard weighting networks, attenuators and an indicating meter. The use of end-mounted components in a printed circuit results in an extremely compact design, the overall dimensions being 6 by 3 by 2¼ in. The weight, complete with battery, is 14 oz.

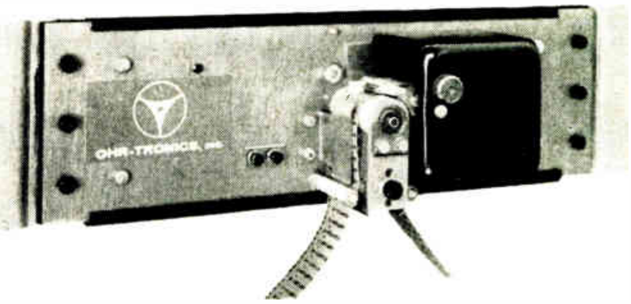
The attenuator enables sound levels from 40 to 120 dB (referred to a standard sound pressure level of 0·0002 dyne/cm²) to be measured in six overlapping ranges. The amplifier provides a stable gain over the temperature range from 0 to 45 °C and is virtually unaffected by variations in transistor parameters and supply voltage. Power is provided by a single 9-V dry cell, adequate for about 70 hr operation.—*Dawe Instruments Ltd., Western Avenue, Acton, London, W.3.*

For further information circle 3 on Service Card

4. Power Triodes

English Electric Valve Co. are now producing two new power triodes, types B1152 (illustrated) and B1153, developed primarily for use in dielectric and induction radio-frequency heating equipments. They are also suitable for application in communications equipments.

The maximum anode dissipation for continuous operation with forced-air cooling is 500 W for the B1152 and 800



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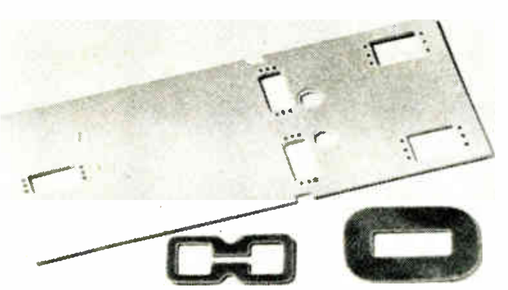

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W for the B1153. For certain low duty cycle operations the anode dissipations may be increased to 1,000 W and 1,500 W respectively. Both valves can be operated to full ratings at frequencies up to 50 Mc/s.

For each type the variation of electrical parameters from valve to valve is much less than that previously attainable, thus reducing the necessity for circuit adjustments when valves are changed.—*The English Electric Valve Co. Ltd., Chelmsford, Essex.*

For further information circle 4 on Service Card

5. Power Divider for Coaxial Cables

A power divider for coaxial cables available from Cannon Electric is designed to provide an equal power division through each arm at 240 Mc/s. The mating ends are type 'N' female and will mate with any type 'N' 50-Ω plug, either brass or aluminium. The divider itself is aluminium, finished with clear Alodine 1200.

The v.s.w.r. is less than 1·5 : 1 at 240 Mc/s and the maximum insertion loss is 0·5 dB.—*Cannon Electric (G.B.) Ltd., 168/172 Old Street, London, E.C.1.*

For further information circle 5 on Service Card

6. Optical Thickness Gauge

H. G. Stevens are marketing the Schneider optical thickness gauge which will measure the wall thickness of transparent and translucent materials which are only accessible from one side.

Thicknesses from 0·2 to 10 mm can be read directly off the scale calibrated in steps of 0·1 mm (accuracy: ±0·01 mm). A second model is available for the range 0·02 to 1·2 mm, calibrated in steps of 0·01 mm, with an accuracy of ± 0·005 mm.

The gauge can be made to slide over a surface, to measure variations in thickness or its distribution. This is important for check measurements of irregularly shaped objects such as light bulbs, valves, bottles, jars, etc., and it is also of value for measuring the thickness of flat glass.

The instrument is light, easy to handle, and equally suited to individual or continuous (batch) measurements. It can be supplied with a small carrying case which also incorporates a small transformer for the low-voltage light source.—*The H. G. Stevens Co. Ltd., 16 Coverdale Road, Cricklewood, London, N.W.2.*

For further information circle 6 on Service Card

7. Rear Release Connector

The latest Cannon plug to incorporate the 'Little Caesar' rear release system is a subminiature rack/panel connector, called 'Royal-D'. The crimp-type contacts are inserted, released and removed from the rear.

When inserted, the contacts are retained by metal clips inside the monobloc-type insulator. The contacts are removed with a simple plastic tool which is slipped over the wire and into the rear of the insulator. The tool releases tangs on the clips and enables the contact to be withdrawn.

Other features of the Royal-D include simplified contact design which resists bending and provides strong contact stability. Also, the socket insulator has a hard dielectric closed-entry design with lead-in chamfers to assure positive pin and socket engagement. The Royal-D is available in five 'D' shell sizes with arrangements ranging from 9 to 50 contacts.—*Cannon Electric (G.B.) Ltd., 168/172 Old Street, London, E.C.2.*

For further information circle 7 on Service Card

8. Automatic Transistor Curve Tracer

The Elliott transistor curve tracer will generate the data required to display the characteristic curves of transistors, diodes and tunnel diodes on a general-purpose oscilloscope.

The instrument provides information in a convenient form for circuit designers and for instructional purposes. It is also ideal for on-line testing applications in the production of semiconductor components and in the manufacture of equipment incorporating these devices. For example, it enables totally unskilled operators to select matched pairs of components easily and quickly.

This transistor curve tracer contains the necessary supplies and waveform generators to apply equal steps of voltage or current to the input of the device under test and to sweep the selected collector voltage on each step of input signal. Small and easily portable, it

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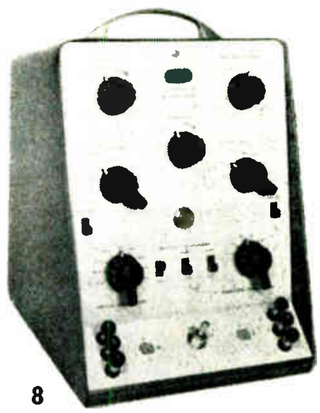

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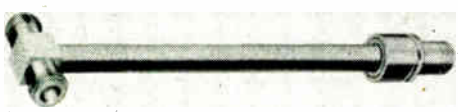

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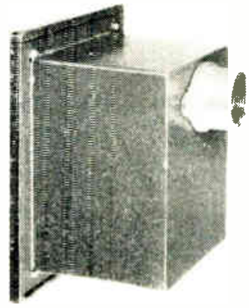
EQUIPMENT review



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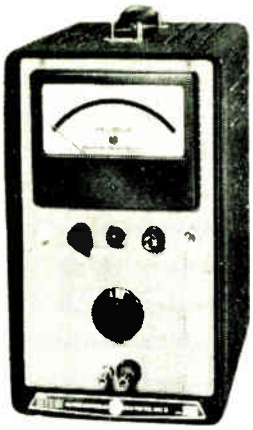

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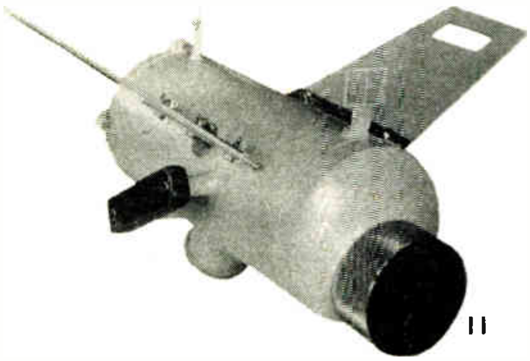

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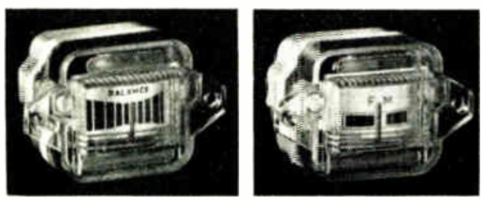

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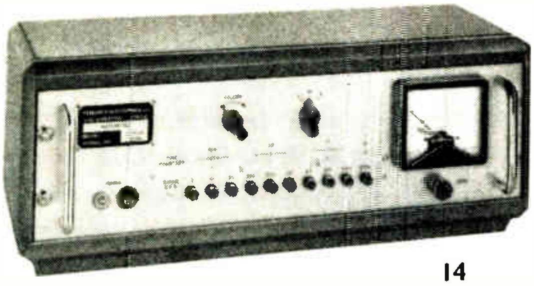

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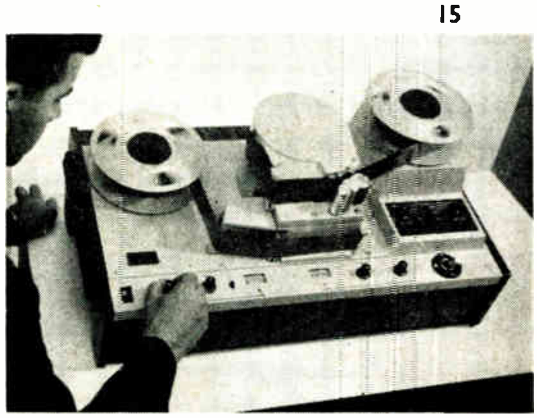

measures 10 by 9 by 7 in. and weighs 15 lb. The price of the instrument is £97 and the size and cost of the display required can be chosen to suit the particular application.—*Microwave and Electronic Instruments Division, Elliott Brothers (London) Ltd., Elstree Way, Borehamwood, Herts.*

For further information circle 8 on Service Card

9. Ultra-Violet Flame Detector

Photronic Controls have introduced a flame detector which utilizes a photoelectric cell with a high response in the ultra-violet region of the spectrum (1,900 to 2,900 Å), radiation found in all types of flames including oil, gas, solid and pulverized fuel. This flame failure control unit is completely insensitive to incandescent or fluorescent illumination and sunlight.

When used as a flame-failure detector on a boiler the control type UV2 is mounted on the front plate so that it can view the flame continuously. As long as the cell can see the flame the relay will be energized providing a supply to the oil or gas solenoid valve. Should flame failure occur, or should any fault develop with the unit or mains supply, then the relay will shut off the fuel supply.

The whole unit is contained in a cast aluminium housing 6 by 5 by 4 in. and is suitable for ambient temperature operating conditions from −30 to +165 °F. The supply voltage is 200/250 V a.c., 50 c/s and relay contact capacity is 5 A at 200 V a.c. non-inductive. The sight tube is fitted with a heat resisting filter and is suitable for mounting direct on to standard 1¼ in. screwed conduit fitted on the boiler front plate.

This unit can operate in conjunction with the Photronic synchronous motor sequencing control type OB/UV to provide fully automatic control of the lighting-up sequence together with flame failure safeguard. A further application is for visual fire detection in a building (type UV4). With a suitable optical system the unit has a cone of vision of 90° and may be installed in any position. It will respond to a petrol fire in a 1 sq ft dish at a distance of 15 ft in less than one second.—*Photronic Controls Ltd., The Lodge, Randalls Road, Leatherhead, Surrey.*

For further information circle 9 on Service Card

10. Voltmeters

Ballantine Laboratories have announced the model 340 v.h.f. voltmeter designed for true r.m.s. measurements with high resolution from 300 μV to 3 V over a frequency range of 0·1 Mc/s to 1 Gc/s. It has a 5-in. logarithmic voltage scale.

Its ability to measure true r.m.s. means that it can be calibrated using a signal source that may be far from sinusoidal. D.C. output is available for application to a recorder.

Also announced by Ballantine is the model 311 video voltmeter (illustrated). This is a linear scale instrument designed for measurements from 100 μV to 300 V or up to 10 kV with optional accessories, over a range of frequencies from 10 c/s to 6 Mc/s. Signals as low as 30 μV may be measured in the null detector mode.

The indicating meter has two linear voltage scales and one decibel scale. Signal input may be made to a coaxial connector or to binding posts. The conservative design results in expected life between calibrations in excess of 3,000 hr.—*Livingston Laboratories Ltd., 31 Camden Road, London, N.W.*1.

For further information circle 10 on Service Card

11. Underwater Television Camera

Nippon Electric Company of Tokyo recently announced the development of an underwater television camera, type NWV-193-16, designed to provide greater convenience to frogmen while conducting underwater investigation and research. It is linked with an industrial television receiver on land (c.c.t.v.), the cameraman receiving his instructions from the surface by telephone.

Balancing wings are provided to eliminate pitching and rolling, and the streamlined, compact and lightweight design (9·5 kg) affords easy operation by minimizing underwater resistance. The camera lens is remotely controlled for focus and aperture and the picture angle is 53·52° for horizontal and 41·43° for vertical.

The NEC underwater television system, which operates either on d.c. or a.c., is comprised of an underwater camera, camera operating handle, power supply unit, 8-in. monitor set, and 100 m of cable.—*Nippon Electric Company Ltd., Tokyo, Japan.*

For further information circle 11 on Service Card

12. Edgewise Indicators

Measuring Instruments (Pullin) are now in production with a subminiature edgewise indication meter, designed to meet the demands of the radio and electronics industries. Typical applications will be for tuning centre indication, tape recorder audio level, battery residual capacity for transistor radios, and simple position indication.

The movement for the Series 1 Edgewise Indicator is moving-coil d.c. with an accuracy of ±10% at 20 °C, and basic ranges from 50 mA to 1 mA £.s.d. The instrument is housed in an all-plastic case, sealed against moisture and dust, weighs ½ oz. and measures 0·84 in. across by 0·89 in. high, discounting fixing flanges; depth overall is under 1 in.

The pointers, which can be obtained in either red or black, are supplied in standard zero position, bottom left, non-adjustable. Centre zero and right-hand zero types are available on bulk orders if required. The scale plate is a nominal 0·5 in., these being preprinted dials, though alternative scale presentations are available.—*Measuring Instruments (Pullin) Ltd., Electrin Works, Winchester Street, Acton, London, W.3.*

For further information circle 12 on Service Card

13. Pencil-Type Galvanometers

Two pencil-type recording galvanometers are now being manufactured by S.E. Laboratories.

Type A.35 (illustrated) is a high-sensitivity, low-resistance galvanometer ideally suited for direct application to low signal levels, such as from strain gauges, thermocouples, etc. Sensitivity is 0·8 μA/cm deflection with a 35-cm optical arm. Internal resistance is 25 Ω, and a 250-Ω damping resistor gives a flat response within ±3% up to 25 c/s. Undamped natural frequency is approximately 38 c/s.

Type C.300 is directly interchangeable with the complete range of S.E.L. galvanometers, but has been designed specifically for the new, low-priced galvanometer recorder type S.E. 2005. The galvanometer has a trace deflection sensitivity of 120 μA/cm. Internal resistance is 38 Ω and with a damping resistor of 230 Ω, the unit gives a flat frequency response within ±3% up to 200 c/s.—*S.E. Laboratories (Engineering) Ltd., North Feltham Trading Estate, Feltham, Middlesex.*

For further information circle 13 on Service Card

14. Counting Ratemeter

A versatile wide-range counting ratemeter for use in industrial and nucleonic applications is announced by Research Electronics. Designated the model 9031, the instrument has applications as complementary equipment to scaling units where the instantaneous rate of count is required to be indicated directly on a meter. It is suitable for use with all forms of radiation detector including Geiger, scintillation and proportional counters, as well as electromechanical and photoelectric transducers and pickups for engineering applications such as speed of revolution measurement.

The instrument has nine switched ranges (selected by pushbuttons) from 3 to 30,000 counts per second f.s.d., with a correspondingly adequate range of integrating time constants from 125 to 0·2 sec.

Power supplies for subsidiary units and a high-voltage supply for the polarization of Geiger tubes and certain types of photoelectric cell are incorporated. The instrument may thus be used as a self-contained nucleonic counting unit and the internal loudspeaker makes it suitable for use as a contamination monitor for continuous audible monitoring of laboratory 'background'. —*Research Electronics Ltd., Bradford Road, Cleckheaton, Yorkshire.*

For further information circle 14 on Service Card

15. Television Tape Recorder

The Ampex VR-660 'Videotape' recorder weighs just under 100 lb and is designed for mobile and studio use by network, commercial and educational broadcasters throughout the world. Its price is well below that of any other television recorder of broadcast quality. It is reported to be the only recorder of comparable size which may be used on the air with no additional equipment other than that available in most television stations.

The all-transistorized VR-660 has the same basic design as the Ampex VR-1500 closed-circuit television recorder but incorporates electronic advances which enable it to produce television pictures which meet broadcast standards.

The VR-660 is available in both a 60-c/s version for operation in the U.S., Canada and certain other nations and a 50-c/s version compatible with power standards elsewhere in the world. Both offer substantial operating and maintenance economies. The 60-c/s version offers the lowest tape consumption of any broadcast recorder on the market. It operates at a tape speed of 3·7 in./sec and can record up to five hours of continuous programme material on a single 12½ in. reel of standard 2-in. broadcasting tape.—*Ampex Great Britain Ltd., 72 Berkeley Avenue, Reading, Berks.*

For further information circle 15 on Service Card

16. Printed Circuit Manipulator

McKettrick-Agnew & Co. have recently developed a printed circuit manipulator. This unit is designed to hold a p.c. board up to a maximum size of 10 by 10 in. An adjustable friction arrangement allows the board to be held in any position and consequently enables components to be inserted and soldered with ease.

One arm is designed with a spring arrangement to facilitate loading and

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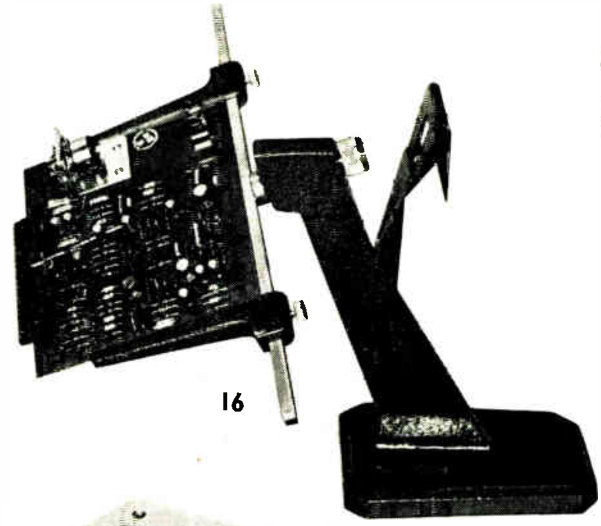

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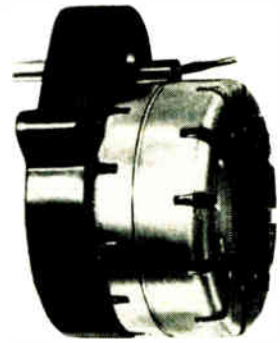

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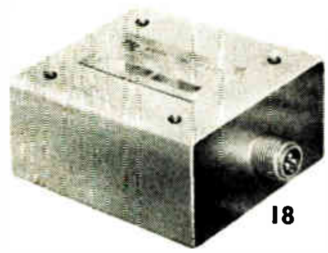

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unloading. These arms are normally provided to accept a board thickness of $\frac{1}{16}$ in., but arms can be provided to accept alternative sizes. The arms are adjustable from a minimum width of $\frac{1}{4}$ in. to a maximum of 10 in., but in certain circumstances a modification can be made to accommodate boards of greater width.

Also provided on the holder is a spring clip located in a convenient position for attaching a drawing or sample printed circuit. The manipulator markets under the name Printed Circuit Unit type 1 and at a price of £5 8s. 6d.—*McKettrick-Agnew & Co. Ltd., Great North Road, Macmerry, East Lothian.*

For further information circle 16 on Service Card

17. Swiss Synchronous Motor

The Swiss company of S.A.I.A. have now introduced an improved design of synchronous motor (known as the S.A. type) for applications such as chart drives, process timers, integrators, programme controllers, etc.

Compared with the earlier design the S.A. type offers twice the torque with lower power consumption and therefore lower temperature for continuous running. The many design improvements include an encapsulated coil which will withstand 8 kV peak potential. The bearings are nylon as are some of the gears in the reduction box, leading to quiet trouble-free running.

There is a large range of gear boxes available with this motor to vary the speed between 1 rev per sec to 1 rev in 48 hr and the gear boxes can be changed in the field without jigs or special tools.—*Ferraris Development and Engineering Co. Ltd.*, 26 *Angel Factory Colony, Angel Road, Edmonton, London, N.*18.

For further information circle 17 on Service Card

18. Time Delay

A medium-tolerance time delay unit is being introduced by M. L. Aviation for use over a temperature range of −65 °C to +70 °C. The initial range will cover input supplies of 18 to 29 V d.c. with a current rating of 3 A.

The units incorporate a semiconductor circuit which operates an electromechanical switching relay, all housed within a hermetically-sealed container. Power consumption, with the relay energized, is 7 W and the unit automatically re-sets when the supply voltage is broken. Maximum pulse frequency is dependent on the ambient conditions: 1·5 sec 'on' and 10 msec 'off' at −65 °C and 1·15 sec 'on' and 10 msec 'off' at +70 °C, for a 29 V d.c. unit.

Alternative types are also offered for a.c. operation up to 50 V r.m.s. and delays of up to 10 sec. All delays can be supplied fully tested to climatic and vibration specifications D.T.D. 1085B and Av.P.24 (engine bay) for aircraft use.—*M. L. Aviation Co. Ltd., White Waltham Aerodrome, Maidenhead, Berks.*

For further information circle 18 on Service Card

19. Torque Spanners

A range of torque spanners suitable for BA and unified thread plain nuts and special self-locking nuts is being offered by Ward, Brooke & Co. The BA sockets cover 10 BA to 2 BA and the unified 4 UN to 10 UN while special 6- and 12-point sockets for Kaylock type nuts range from 4 UN to $\frac{1}{4}$ UN. Loadings vary from 3½ to 24 lb/in. Each spanner is preset by the manufacturers to the customer loading requirement and sealed.

The standard spanner is 6¾ in. overall in length, but can be reduced to 4½ in. for special applications. It is also available with a screwdriver head, Philips type head and special heads to customer requirement.—*Ward Brooke & Co. Ltd., Westbourne Street, High Wycombe, Bucks.*

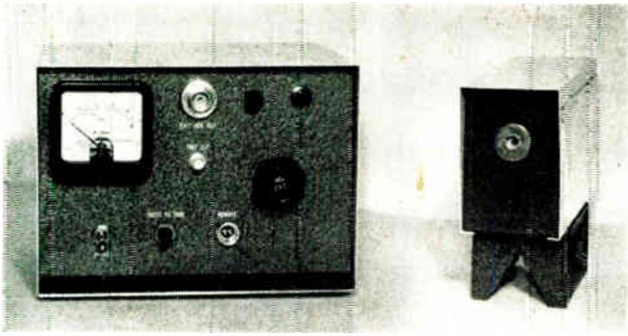
For further information circle 19 on Service Card

20. Point Spark Light Source

Lunarton Electronics have announced a spark light source which incorporates an end-fire spark gap embodying a constricting insulator to increase the brilliance of the discharge. The light source is separate from the power supply and trigger source, and is suitable for optical-bench mounting. The source size is approximately 1·5 mm and is suitable for operation in shadow and Schlieren systems.

The power supply and trigger unit incorporates all the necessary electronics to operate the spark source. The e.h.t. output is variable over a range so that expensive mains and high-voltage stabilization are not required. Power input to the spark gap is 9 joules.

The light duration is 1 μsec with a



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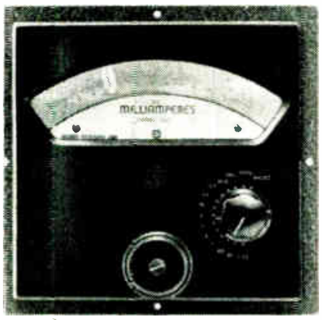

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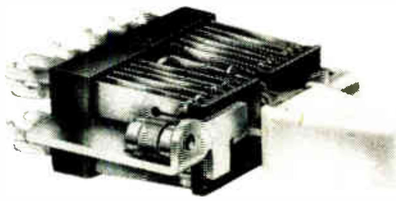

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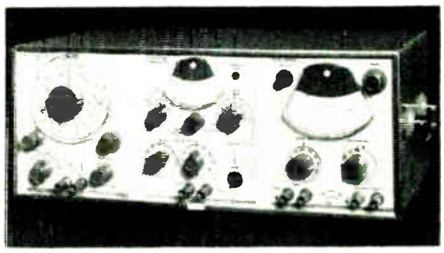

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rise time of 0·1 μsec. Triggering is by pushbutton or remote socket on a positive pulse of 30 V.—*Lunarton Electronics Ltd., 40-42 Langley Street, Luton, Beds.*

For further information circle 20 on Service Card

21. Transistor Solder Pack

Adding to their range of pre-packed solder lines, Multicore announce the introduction of a new transistor solder pack which will be known as size 10.

The size 10 contains 250 ft of 60/40 alloy 22 gauge Ersin Multicore 5-core solder wound on a plastic reusable reel, and individually packed.

The size 10 transistor solder pack retails at 15s.—*Multicore Solders Ltd., Maylands Avenue, Hemel Hempstead, Herts.*

For further information circle 21 on Service Card

22. True R.M.S. Meters

A line of precision true r.m.s. current and volt meters has been announced by the Greibach Instrument Corporation. Designed for extremely accurate measurements of complex waveforms, from d.c. to 500 kc/s, these precision meters achieve measurements with an accuracy of 0·5% full-scale for square waves and irregular waveforms with crest factors in excess of 4.

The voltmeters are available with f.s.d. from 30 mV up to 1 kV. These multirange instruments can be supplied with 100, 500, or 1,000 Ω/V as required. The current meters feature full scale ranges from 100 μA up to 30 A. Higher currents are possible with the use of auxiliary external elements.

The Greibach meters incorporate the 'Transquare' solid-state transducer network to provide true square-law response. Unlike thermocouples, transducers may be interchanged without recalibrating the scale.—*Greibach Instruments Corporation, 315 North Avenue, New Rochelle, N.Y., U.S.A.*

For further information circle 22 on Service Card

23. Miniature Lever Key

A miniature lever key (Post Office 1000 type) is available on short delivery from T.M.C. This neat compact component is now replacing earlier P.O. lever keys, and has already proved its reliability in G.P.O. equipment.

The miniature lever key combines the advantages of an extremely positive switching action, simplicity of mounting, and attractive appearance. The moulded plastic handle is available in six colours and the keys are supplied complete with mounting screws.—*Telephone Manufacturing Co. Ltd., Martell Road, West Dulwich, London, S.E.21.*

For further information circle 23 on Service Card

24. M.F. Transmission Measuring Set

Marconi Instruments have announced the M.F. Transmission Measuring Set, Type TF 2333, the latest equipment in their modular range. This is a triple unit instrument developed primarily for testing transmission lines and multi-channel radio link systems, but which is equally suitable for any measurements of gain, attenuation or frequency response.

The three units comprising the instrument are an oscillator with a frequency range of 30 c/s to 560 kc/s in five bands, a monitored attenuator giving up to 70 dB loss in 1 dB steps and a level meter with a measurement range of +25 to −70 dBm. The combination of oscillator and attenuator constitutes a signal source with an output up to +3 dBm which can be used with balanced 600- and 150-Ω systems or unbalanced 600- and 75-Ω systems.

Monitoring is effected by a meter with an 0 dBm centre scale. Additional ranges of the meter facilitate a.c. and d.c. voltage measurements on the equipment under test. Level measurements can be made, over the frequency range of the oscillator, with the level meter either acting as a matching termination or bridging an externally terminated circuit.

Transistors are used throughout and the stabilized power supply will accept

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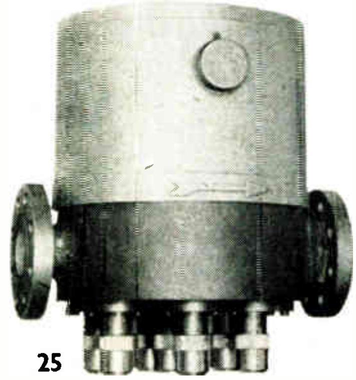

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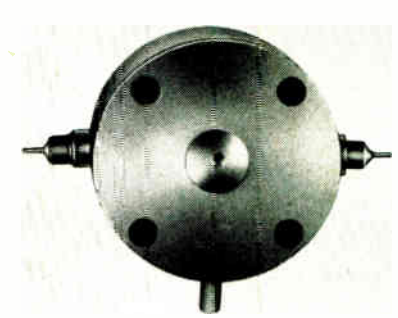

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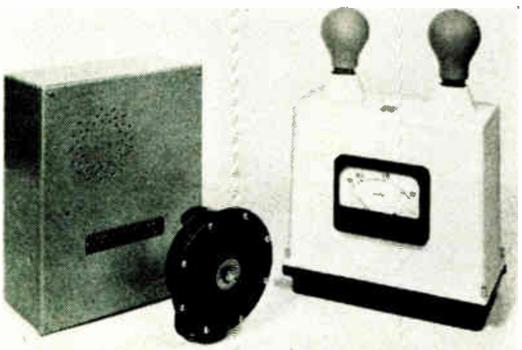

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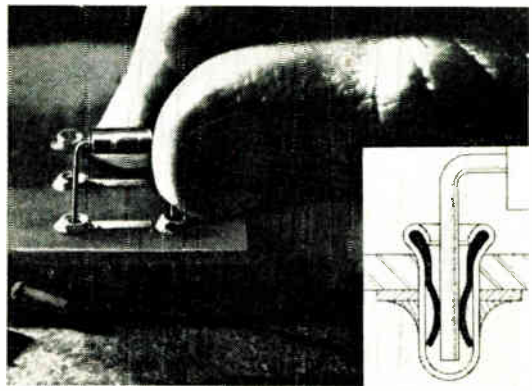

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a wide range of mains inputs; batteries may also be used. A complete selection of leads is supplied with the instrument, and these stow neatly in a special compartment in the lid of the case. The weight of the instrument, including leads, is 28 lb. A rack-mounting version is available. — *Marconi Instruments Ltd., St. Albans, Herts.*

For further information circle 24 on Service Card

25. Electrical Digital Valve

Lignes Telegraphiques et Telephoniques have announced a regulation and control valve which is entirely electric with no rotating parts, such as motors, pumps, etc., nor stuffing boxes. It can be produced in any of the standard valve sizes.

This valve represents a digital-analogue converter. The binary digital control signal is sent to 7 solenoid coils corresponding to 7 individual electromagnetic valves. The presence or lack of a magnetic field through the cylindrical walls of each individual valve determines the open or closed positions which make up the given flow value of the valve. The open position of each individual valve has a cross-section which corresponds to its place in the digital control number. The liquids being controlled pass through these different valves to arrive in parallel at the output flange of the digital valve. Therefore the sum of the output can vary from 0 (valve closed) to 100% (valve open).

The 2-in. version can be used for liquids and gases up to a temperature of 400 °C and a pressure of 700 p.s.i. The flow factor is equal to that of the best equivalent pneumatic valves and the response time is 0·5 sec.—*Lignes Telegraphiques et Telephoniques, Boite Postale No. 5, Conflans Ste. Honorine (Seine-et-Oise), France.*

For further information circle 25 on Service Card

26. Infra-Red Detector

Claimed to be the smallest long-wavelength photo-conductive detector available, the QKN1227 has been introduced by Raytheon Company. Sensitive in the 2 to 15 μ region of the infra-red spectrum, its time constant of less than 1 μsec permits fast scan rates and high resolution.

The modular package has an overall diameter of 1·19 in. and a thickness of 0·39 in. Its vacuum-sealed and electrically-isolated sensitive element is mercury-activated germanium and the window is barium fluoride. Average detectivity D is $8{\cdot}0 \times 10^9$ (cm c/s)$^{1/2}$/watt. (D is expressed as the square root of the product of the detector area and the detector circuitry bandwidth, divided by the noise equivalent power.)

Designed for maintenance-free use in currently available, closed-cycle cooling systems, this infra-red detector operates at 35 °K.—*Raytheon-Elsi, S.p.A., Villagrazia, Palermo, Italy.*

For further information circle 26 on Service Card

27. Radiography Alarm System

An alarm system from Research & Control Instruments provides industrial radiographers with an additional safeguard from radiation hazards, particularly in gamma radiography.

The system utilizes the customary safety interlocks on X-ray generators, isotope containers and X-ray room doors, but in addition incorporates a Philips radiation monitor. This is a G.M. count-rate type of instrument and when radiation exceeds a pre-set level it trips a klaxon alarm which sounds for a period of up to five seconds. Red warning lights are also illuminated and remain lit as long as there is any danger.

The basic system comprises a transistorized radiation alarm monitor, a relay switch unit, a 12-V battery with trickle charger, and a klaxon alarm. Operation is from the mains, but any mains failure is immediately and continuously signalled by the klaxon. Provision is made for the connection of additional warning lights and alarms. —*Research and Control Instruments Ltd., Instrument House, 207 King's Cross Road, London, W.C.1.*

For further information circle 27 on Service Card

28. Re-Usable Test Jack

A re-usable test jack which enables the testing of components without the need for soldering and permits repeated use of the same printed circuit board, has been introduced by A-MP.

Designed to fit into a hole of 0·089 in. diameter, the A-MP test jack consists of a drawn brass cup with a built-in spring receptacle that will accommodate component leads ranging from 0·018 to 0·040 in. diameter. The components can be inserted and removed by hand and are held rigidly in place during testing, thus ensuring maximum performance.

Because soldering is not required, this re-usable jack eliminates damage to boards and components.—*Aircraft-Marine Products (Great Britain) Ltd., Amplo House, 87-89 Saffron Hill, London, E.C.1.*

For further information circle 28 on Service Card

29. Subminiature Feed-Through

A subminiature Sealectro 'press-fit' feed-through designated as FT-SM-900 TUR offers an unusual method of making an electrical connection. The brass lug extends through the minor diameter of the Teflon body for the normal soldered connection on one end, while at the other end, the lug remains inset within the body. Electrical contact to this end of the terminal is made by a round spring riding inside the Teflon body and pressing against the brass lug. Overall height of the terminal is only 0·481 in. which makes it ideal for dense electronic packages. For installation ease, a B-22X insertion tool is available. —*Sealectro Corporation, Hersham Trading Estate, Walton-on-Thames, Surrey.*

For further information circle 29 on Service Card

30. Bulk Tape Eraser

Amos of Exeter have introduced the Weircliffe bulk tape eraser designed for professional and semi-professional users of magnetic tapes who require a fast and foolproof method of erasing all matter from complete reels of tape.

Tapes are 'cleaned' instantly by insertion of the reel or cassette into the receiving slot of the eraser. Spring loaded guides and a reject mechanism enable tapes to be cleaned at the rate of 10 seconds per tape. A combined switch gate ensures that the instrument is only operational during the cleaning of each tape.

Two standard models are available, model 6 being suitable for reels having a diameter of 8¼, 7, 5¾ and 5 in., while model 7 accepts commercial 6¾ by 8 in. continuous tape cassettes. Both models are housed in attractive yet rugged mahogany cases impregnated with clear Melamine to withstand hard wear.

The dimensions are 11½ by 12¼ by 7½ in.; weight: 33 lb. The current consumption (intermittent) is approximately 14 A.—*Amos of Exeter Ltd., Weircliffe Court, Exwick, Exeter, Devon.*

For further information circle 30 on Service Card

31. Miniature Timer

Electrical Remote Control have introduced a simple and inexpensive timer which operates one set of changeover contacts at the end of an adjustable delay period, resetting automatically on disconnection of the voltage supply to the timer motor.

The timer has a self-clutching miniature synchronous motor which, on energization, drives one timing cam against its resetting spring and a changeover microswitch is operated. The motor should be then de-energized, when the resetting spring returns the timing cam to its pre-set position adjustable on a calibrated dial.

Time ranges available are: 0 to 10, 0 to 30 and 0 to 60 sec; and 0 to 10 min. Switching capacity: 5 A at 240 V a.c. inductive, 10 A at 240 V non-inductive, and 3 A at 415 V a.c. non-inductive.

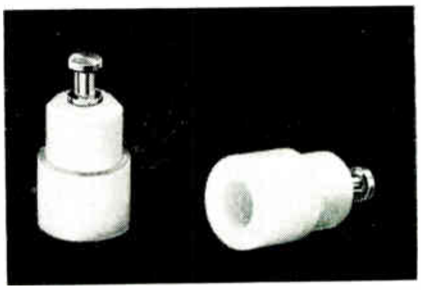
The timer is supplied as standard with a Perspex cover. For applications where the smallest possible dimensions are required, the timer can be supplied without a cover: the overall dimensions are then 2 by 2½ by 2⅝ in. The price is £5 12s. 0d. each.—*Electrical Remote Control Co. Ltd., Elremco Works, Bush Fair, Harlow, Essex.*

For further information circle 31 on Service Card

32. Portable Off-Air Standard

Advance Components have introduced a portable off-air frequency standard, the model OFS 1, which can be either mains or battery operated, and sells for £60.

Providing an accuracy as good as a quartz crystal standard, the OFS 1 has two square-wave outputs of 100 kc/s and 1 Mc/s, 6 V peak-to-peak into 1 kΩ. It can be phase locked to the 200-kc/s carrier-wave signal from the B.B.C. Light Programme transmitter at Droit-



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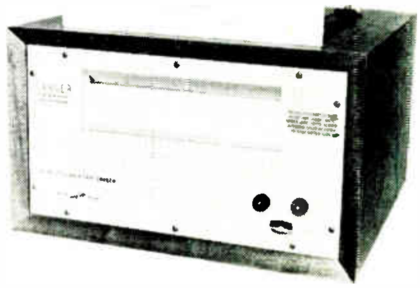

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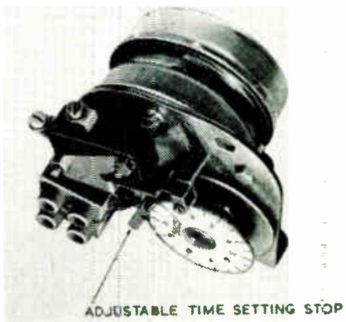

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wich, and then has a long-term accuracy better than 5 parts in 10^9. Stability per day is 1 part in 10^{10}.

The short-term frequency accuracy is better than 3 parts in 10^8 for any period up to 5 sec and better than 1 part in 10^8 in any period of 5 to 50 sec.

Use of an external aerial gives full U.K. coverage, but for most of England the internal aerial will give adequate reception.—*Advance Components Ltd., Roebuck Road, Hainault, Ilford, Essex.*

For further information circle 32 on Service Card

33. Glass Dimmer Caps

A new range of glass dimmer caps, offering improved performance and higher operating temperatures, has been developed by Plessey for use with existing pattern LH.23 lamp bodies. Six closely controlled colours (red, green, blue, yellow, orange and clear to B.S. 1376) are available and the light transmitted can be varied by means of a mechanical iris from maximum to zero by rotating the lens and bezel by hand through 60°.

The new dimmer caps, which are ¾ in. in diameter, are designed to satisfy the requirements of DEF. 5201 with humidity classification H.1 and temperature category −40 to +85 °C. Construction is dull nickel-plated brass, and the glass lens has the ability to withstand elevated temperatures and remain colour-fast. Synthetic rubber seals give a smooth action requiring only a low operating torque (not more than 10 oz in.) and are also unaffected by heat and damp.—*The Plessey Company (U.K.) Ltd., Abbey Works, Titchfield, Fareham, Hants.*

For further information circle 33 on Service Card

34. Improved Optical Shaft Encoder

Digital Measurements Limited, in conjunction with Winston Electronics, are producing an improved version of their optical shaft encoder. This version, designed to meet rigorous military requirements, has the ability to maintain reliable operation in extreme environments. The changes include an increased maximum readout rate of 6,100 bits per second, higher signal outputs, and optional hermetic sealing.

The output of the standard encoder is in Gray binary code, but other codes can be supplied to special order. For each revolution of the shaft, the encoder makes 2^{13} counts, giving the high angular resolution of 2 min 38 sec; full readout resolution can be maintained up to speeds of 45 rev/min.

The Winston-DM encoder has only one moving part and uses no gears, brushes or contacts for its operation. Backlash is eliminated, whilst moment of inertia, torque, friction and wear are reduced to a minimum. The only two bearings employed have precision ball races, sealed and permanently lubricated with a silicone oil. The encoder is housed in a small case with a NATO size 23 mounting flange and its weight is 1 lb 5 oz.—*Digital Measurements Ltd., 25 Salisbury Grove, Mytchett, Aldershot, Hants.*

For further information circle 34 on Service Card

35. V.H.F. Transmitter

Radio Communications have announced the 'Telecomm' v.h.f. transmitter type TT20. This instrument is designed for single-channel operation in the frequency range 40 to 140 Mc/s with amplitude modulation.

By the use of transistors throughout, the power consumption has been reduced to a very low figure in comparison with valve transmitters. A small internal mercury battery permits approximately 40 hours' continuous use. A moving-coil lapel microphone and flexible aerial are normally provided.

The transmitter is crystal controlled and suitable for use in the most modern 25-kc/s channel-spaced systems. A typical peak power output of approximately ¼ W is attained depending on frequency.—*Radio Communications Co., 16 Abbey Street, Crewkerne, Somerset.*

For further information circle 35 on Service Card

36. Transistor Voltmeter

As part of a range of solid-state equipment, Furzehill Laboratories are introducing a voltmeter covering a range of 10 μV to 300 V over a frequency range of 10 c/s to 10 Mc/s.

A printed circuit is used, employing semiconductor techniques throughout. The basic instrument draws its power from the mains supply but provision is made for a rechargeable battery to be incorporated as an optional extra. This is a useful facility for field or laboratory work, ensuring complete absence of hum and earth-loop problems.

A linear meter is used scaled 0 to 3·5, 0 to 10, reading 1 mV full-scale on the most sensitive range and 300 V on the highest range. Substantial negative feedback ensures an accuracy better than 2% over the majority of the frequency range. The meter is also

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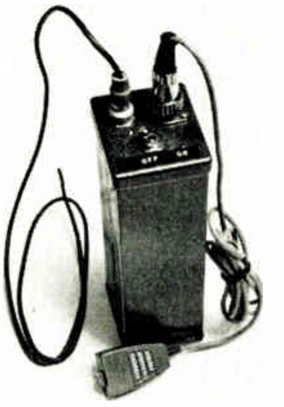

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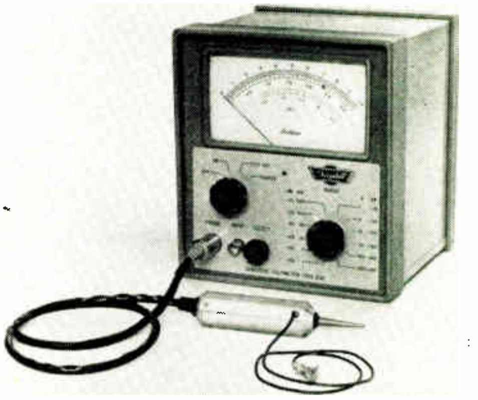

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scaled in dB relative to 1 mW in 600 Ω. The input impedance is 3 MΩ with 25 pF shunt capacitance. A low-capacitance probe (3 MΩ, 5 pF) having a gain of unity is available as an optional extra. The dimensions of the instrument are 6¼ by 7¾ by 8½ in., and the weight is 10 lb.—*Furzehill Laboratories Ltd., Theobald Street, Borehamwood, Herts.*

For further information circle 36 on Service Card

37. High Rate Strain Testers

For some time it has been recognized that most materials are sensitive to the rate at which they are strained. Equipment capable of faithful operation at strain rates in excess of 20,000 in./min has been virtually unavailable and hence, data on the performance of materials at impact-simulating strain rates has been marginal.

Dimensional Research is now producing a line of high strain rate testing machines based on what is claimed to be a radically different approach to the problem of accurate testing of materials in the strain rate region of 10,000 to 100,000 in./min.

These machines, now in production, cost 20 to 25% of the price of conventional equipment.—*Technical Marketing Division, Dimensional Research Inc., 7920 Empire Avenue, Orlando, Florida, U.S.A.*

For further information circle 37 on Service Card

38. Dual Pulse Generator

The Orba type 01 492 dual pulse generator provides accurate pulse trains for applications such as fault location, impedance and uniformity tests on coaxial cables, e.g. to P.O. Engineering Department Specification LW 543.

Alternative trains of +40 V pulses at 15 kc/s into 75 Ω resistance are provided with nominal half-height widths (*W*) of 100 and 200 nsec respectively. A ±15% tolerance applies to actual widths at quarter, half and three-quarter heights—namely 1·33 *W* (actual half-height width), *W* and 0·66 *W*. Overshoot is negligible. The generator will deliver synchronizing trigger pulses of 10 V amplitude into 2 kΩ.—*Alexander Orba Ltd., 109 Obelisk Road, Woolston, Southampton.*

For further information circle 38 on Service Card

39. Miniature Potentiometer

The WL18 potentiometer has been added to the range available from Reliance Controls. This 18-turn, wire-wound unit has been designed for use when an economically-priced, high-quality component is required, but where sealing is not of paramount importance. Both standard and printed-circuit versions are available, the latter having tags on the 0·1 in. grid. The unit is stackable, and has slipping clutch action at both ends of travel.

Important features are the resistance range, 1 Ω to 40 kΩ, and the operational temperature range from −40 to +105 °C. The power rating is 0·5 W at 20 °C and the maximum working voltage is 500 V d.c. The weight of the unit is 1·8 gm and the dimensions are: length 1 in., width 0·28 in., height 0·36 in. — *Reliance Controls Ltd., Relcon Works, Sutherland Road, Walthamstow, London, E.17.*

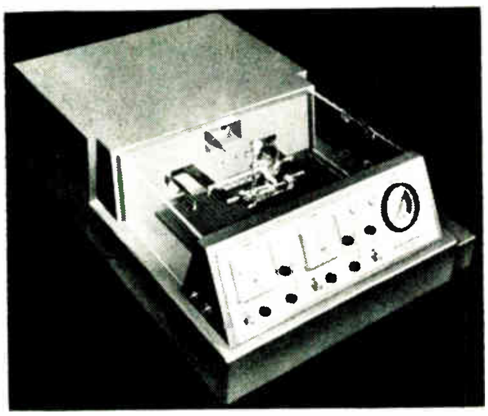
For further information circle 39 on Service Card

40. Spectrum Analyser

A spectrum analyser introduced by Raytheon permits analysis of acoustic and random noise from 3 c/s to 13 kc/s. Parallel filter channels make possible high analysis rates while the close spacing of filter channels reduces ripple in amplitude response. Fine and coarse resolving ranges are incorporated for complete frequency analysis.

The MRFR 150-2 uses 50 channels spaced 2 c/s apart to provide resolution of 5 c/s in a 100-c/s range; another 100 parallel filter channels spaced 10 c/s apart offer 25-c/s resolution over a 1-kc/s range. Each channel consists of a two-section filter, a solid-state amplifier, detector, and RC integrator (RC time constants from 0·1 to 100 sec). Channel outputs are sampled by a low noise switch at one or more rates from 1 to 3,000 per sec.—*Raytheon-Elsi, S.p.A., Villagrazia, Palermo, Italy.*

For further information circle 40 on Service Card



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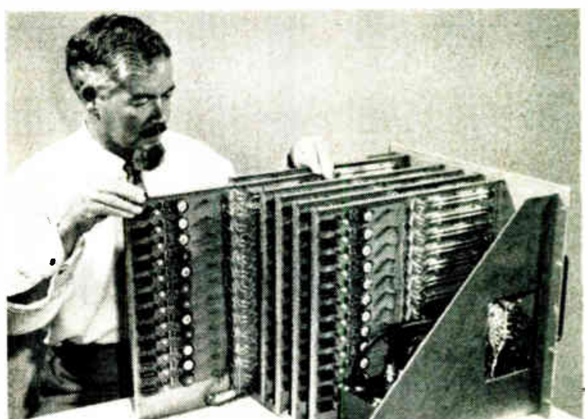

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The article describes a linear delay circuit using a constant-current diode as part of the timing circuit of a monostable multivibrator. The 'pulse width-control voltage' characteristic is linear over quite a wide range. An application of the constant-current diode to a linear pulse stretcher is also described.

LINEAR DELAY CIRCUITS

using constant-current diode

By S. S. HAKIM, Ph.D., B.Sc., A.M.I.E.E.*

THE constant-current diode operates on the same principles as the field effect transistor[1, 2] shown illustrated in Fig. 1. The gate is biased negatively with respect to the drain electrode. If the applied bias voltage is large enough, then the depletion layer of the p-n junction can become wide enough to 'pinch off' the channel at the drain end.

The 'voltage-current' characteristic of the constant-current diode is as shown in Fig. 2. Between the voltages V_P and V_B the current flowing across the diode remains practically constant. The voltage V_P is called the 'pinch-off voltage' and V_B is the 'breakdown voltage'. When the applied voltage exceeds V_B, avalanche breakdown occurs causing the current to increase.

Linear Delay Circuit

The constant-current diode described above can be used in the timing circuit of a monostable multivibrator as shown in Fig. 3. This differs from a conventional monostable multivibrator in two respects:

(i) The constant-current diode is used in the base circuit of transistor TR_3 instead of a resistor.
(ii) The collector of transistor TR_2 is returned to a variable voltage supply via the common-collector stage TR_1.

In the quiescent condition TR_3 is in saturation while TR_2 is cut off. Therefore, the timing capacitor C is charged up to a voltage closely equal to the base voltage $-V_{B1}$ (with respect to earth) of transistor TR_1 as determined by the potential divider. When at time $t=0$ the monostable multivibrator is triggered by a negative pulse applied to the base of TR_2, this transistor is made to conduct and TR_3 is cut off. Since the voltage across the capacitor C cannot change instantaneously it follows that at $t=0_+$ the base voltage of transistor TR_3 rises to V_{B1}. The timing capacitor then begins to charge up, via the constant-current diode, towards the negative supply voltage. Assuming that I is the current supplied by this diode, the base voltage V_{B3} of transistor TR_3 varies linearly with time and is given by

$$V_{B3} = V_{B1} - \frac{It}{C} \qquad (1)$$

* Lanchester College of Technology, Coventry.

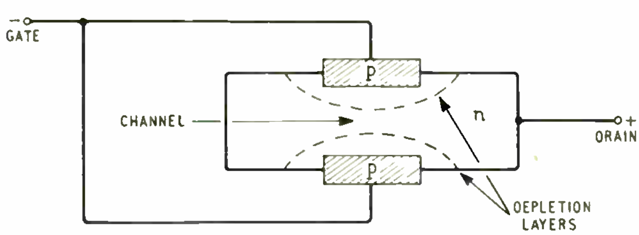

Fig. 1. Constant-current diode

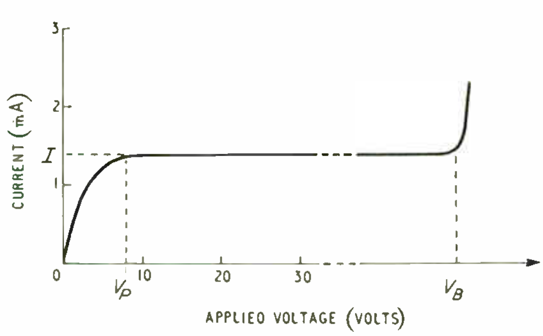

Fig. 2. 'V-I' characteristic for constant-current diode

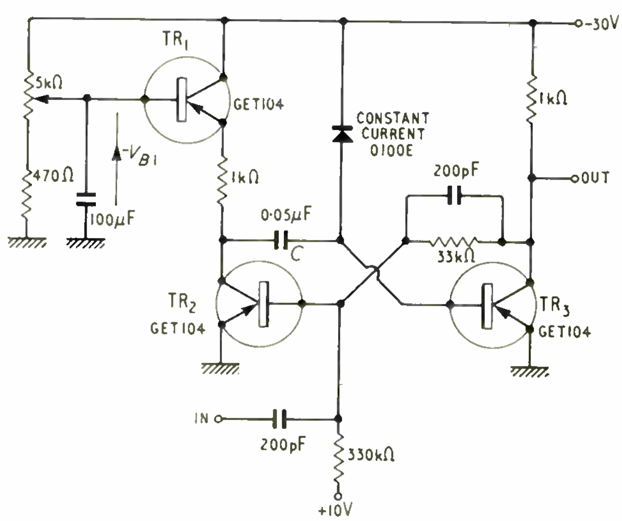

Fig. 3. Linear delay circuit

Suppose that $V_{B_3}=0$ at $t=\tau$. At this instance transistor TR_3 begins to conduct again and so the monostable multivibrator returns to its quiescent condition. Therefore, the pulse duration τ is

$$\tau = \frac{CV_{B1}}{I} \qquad (2)$$

Here we see that τ is directly related to the control voltage V_{B1} at the base of transistor TR_1. Fig. 4 shows τ plotted against V_{B1} for the circuit of Fig. 3. The measured values agree closely with Equ. (1). For the diode used in Fig. 3 the current I is 1·4 mA (see Fig. 2).

Fig. 5 shows the waveforms associated with the circuit of Fig. 3. It is of interest to observe the linear variation of the base voltage of TR_3 with time. By returning the collector of TR_3 to a constant d.c. supply and by arranging it to be in saturation in the quiescent condition it is possible to main-

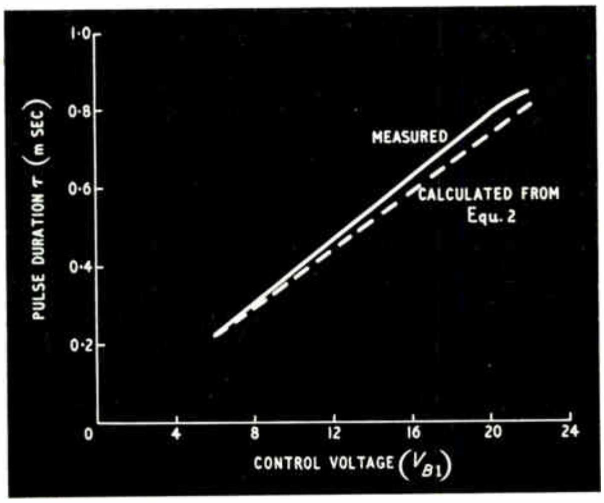

Fig. 4. 'Pulse width-control voltage' characteristic

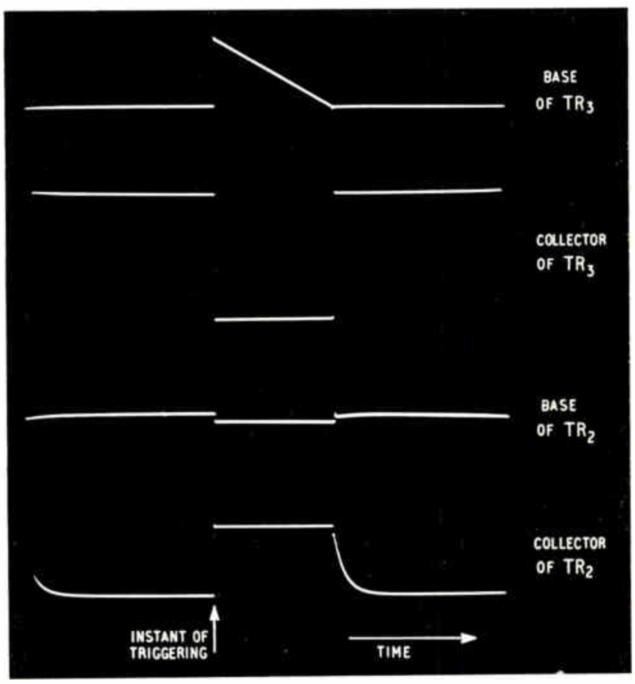

Fig. 5. Waveforms for circuit of Fig. 3

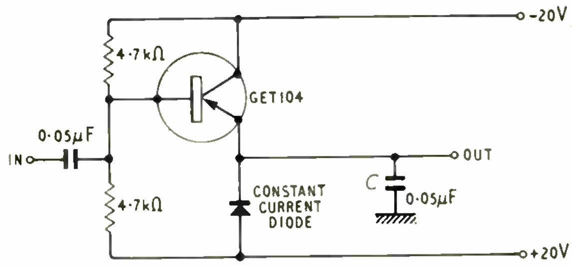

Fig. 6. Linear pulse stretcher

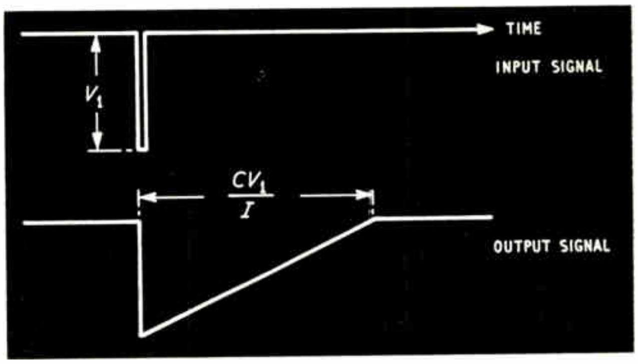

Fig. 7. Waveforms for circuit of Fig. 6

tain the amplitude of output pulse at the collector of TR_3 practically constant irrespective of variations in control voltage V_{B1}.

On differentiating the output of TR_3 and clipping the negative pulse it is possible to generate a delayed positive pulse, the delay being controlled by the potentiometer setting.

Linear Pulse Stretcher

Another useful application of the constant-current diode is in linear pulse-stretching circuits. One such circuit is shown in Fig. 6. When a negative pulse of amplitude V_1 is applied to the input base terminal, the capacitor C charges up rapidly to the voltage V_1 via the low output impedance of the common-collector stage TR_1. When the input pulse ceases the emitter is left at a negative potential with respect to the base. Therefore, transistor TR_1 cuts off and the capacitor C discharges via the constant-current diode. The discharge process will thus be a linear one terminating at time τ equal to CV_1/I where I is the current flowing through the constant-current diode. The width of the resulting output pulse is therefore proportional to V_1 and the circuit acts as a linear pulse stretcher.

The waveforms of Fig. 7 illustrate the output of the circuit of Fig. 6.

On amplifying the output signal, differentiating and then clipping, it is possible to generate a delayed pulse with the delay being controlled by the amplitude V_1 of the applied input pulse.

Acknowledgments

The author is grateful to Mr. J. S. Lamming of the Hirst Research Centre (G.E.C. Ltd.) for kindly supplying two samples of the constant-current diode.

References

[1] J. S. Lamming, 'The design of a new type of germanium constant current diode', Proceedings of International Conference on Semiconductor Devices, Paris, 1961.

[2] L. P. Hunter, 'Handbook of Semiconductor Electronics'. Second edition, New York, 1962.

EXCESS DEMAND WARNING SYSTEM FOR STEELMAKING PLANT

A Ferranti excess demand warning system has been installed and commissioned at the Steel, Peech and Tozer (Rotherham) branch of the United Steel Companies Ltd., to provide two-stage control of their maximum electrical power demand.

Power for six 40-MVA electric arc furnaces to be installed in what is claimed to be the world's largest electric steel-making plant is supplied from a 275/33 kV substation at Templeborough. Three of the six furnaces are already in use.

The warning system provides a much closer degree of control over the consumption of electrical energy than the conventional maximum demand warning devices. It was developed primarily for use in plants of the continuously-operated type designed for maximum production, as shut-downs based upon too frequent warnings of approaching maximum demand can seriously affect the quality of the product and the plant's efficiency, quite apart from the loss in production.

For first stage control the E.D.W.S. ensures that half-hour demands do not exceed a pre-determined level during normal operations and, to achieve this, impulses representing the actual load consumed are obtained from the C.E.G.B. tariff metering equipment and compared with impulses representing the 'target' load.

Any discrepancy between the two pulse rates is indicated in the substation and furnace control room on instruments which display the number of kWh by which the integrated actual load differs from the target load.

Because the demands of the steel making process vary considerably, the furnace controller may exceed this target load during the early part of the demand integration period, provided that subsequent reduction brings the integrated value for the half-hour within the target setting.

The controllers are provided with two instruments as aids to meeting these conditions. One indicates continually the value to which load must be shed in order to come within target by the end of the period and the other consists of an illuminated band, behind the discrepancy indicator scale, which contracts towards the centre zero mark as the period progresses. The controller must keep the discrepancy pointer within the illuminated band and, as a further aid, a pre-set dial indicates the amount of load to be shed when the pointer and the edge of the band coincide.

Should manual control prove ineffective, two safety circuits take over. They consist of 30-minute integrators pre-set at slightly different levels to make contact just before the target number of kWh has been consumed. The circuit with the lower setting sounds an alarm, while the other automatically trips the furnace air circuit breakers.

The terms of the electricity supply tariff to Steel, Peech & Tozer include a provision that, within five minutes of receiving a request from the C.E.G.B. Grid Control Centre, the company must be able to shed at least 25 MW of load.

As part of the second-stage control, during this restricted period, the demand is integrated over five minute periods. The impulses corresponding to actual load are derived from a high-speed contactor on the tariff metering equipment, while the target load impulses are from a generator running at a frequency corresponding to the nominated load. All facilities are otherwise provided as for first-stage control.

For further information circle 45 on Service Card

Standard Frequency Receiver

Hewlett-Packard, of Bedford, the British subsidiary of the American instrument company, established about one year ago their own research and development laboratory.

This shows John Hearn, designer of the new instrument, setting up the receiver during field trials in Geneva

Now announced is the first all-British H.-P. instrument which is called the 5090A Standard Frequency Receiver (Droitwich). This is intended to provide reference frequency signals of 100 kc/s and 1 Mc/s for setting up highly stable secondary frequency standards, counters, etc.

In February 1963, the B.B.C. improved the frequency stability of the Droitwich transmitter to better than 5 parts in 10^{10} per day. The 5090A receiver uses the signal from this transmitter to synchronize the frequency of an internal oscillator which provides output signal frequencies at 100 kc/s and 1 Mc/s with the same frequency stability as that of the original transmission.

The sensitivity of the receiver is better than 1 μV and its stability is such that it will not contribute phase delay changes of more than 1 μsec over the operating temperature range 0 to 50 °C.

A further facility is provided by the circuit associated with the 'external standard socket'. This makes it possible to compare either 100 kc/s or 1 Mc/s signals with that provided by the receiver; a resulting d.c. difference signal can be used to drive a chart recorder.

For further information circle 46 on Service Card

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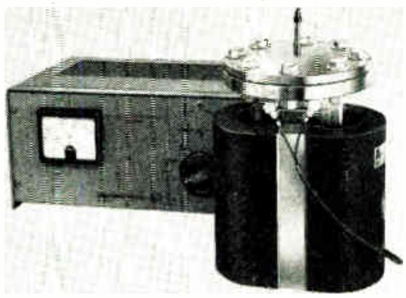

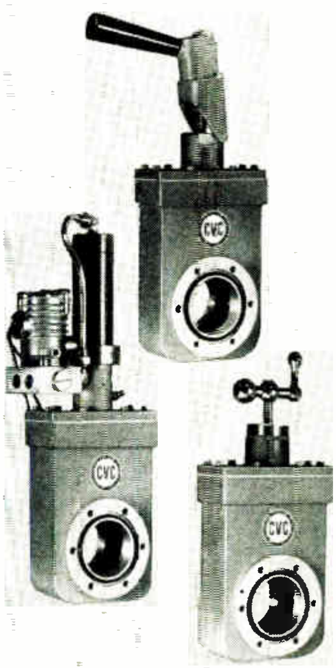

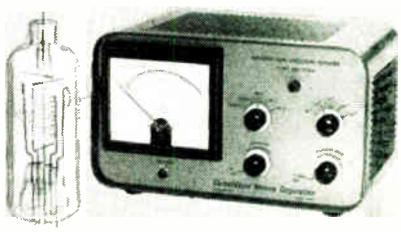

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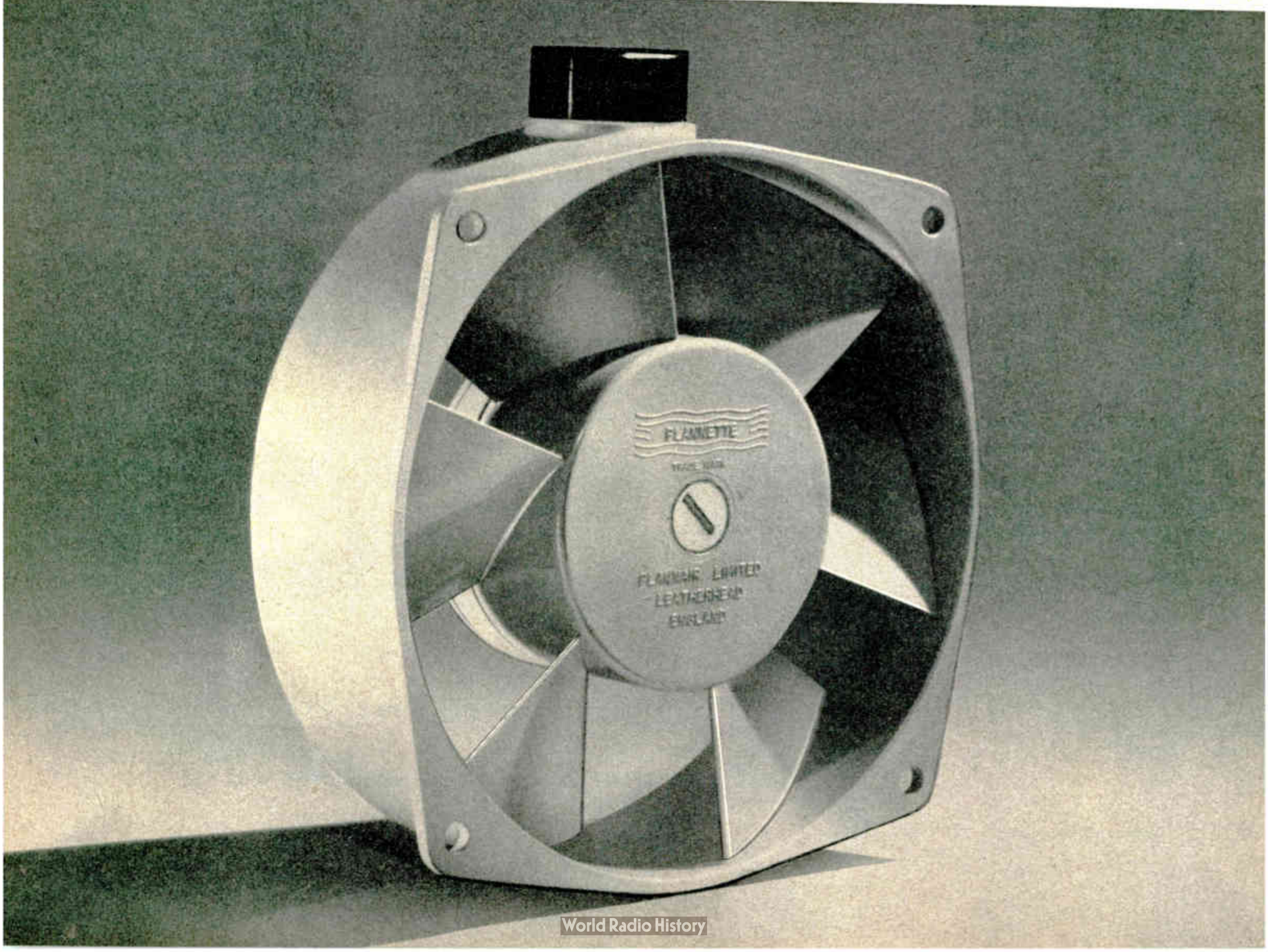

According to the generalized classification the Owen bridge is what is termed an 'adjacent balancing-arm' type of bridge. This configuration is prone to shielding difficulties which are shown to be removed by inserting a balancing arm in series with the unknown. The aims of this paper are firstly to pay attention in general to the resulting configuration and secondly to investigate in this regard the specific case of the Owen bridge when component residuals are taken into account. Experimental evidence in support of the derived theory is provided.

THE OWEN BRIDGE

By K. POSEL, Ph.D., A.M.I.E.E.*

THE author has recently[1] proposed a simplified treatmen of Ferguson's[2] generalized classification of four-terminal bridge networks, the simplification having arisen by the use of the convergence-to-balance expression as the basis of all derivation as opposed to that of the balance equations themselves. According to this classification the Owen[3] configuration emerges as what is termed 'an adjacent balancing-arm type of bridge with no resistance in arm 3' and is eminently suitable for the measurement of an inductive impedance. The resulting bridge is shown in Fig. 1 and the variable elements to achieve the balanced state are R_4 and X_4. The Owen bridge is often used in this form.[4] However as first proposed,[3] and as used even more often, a variable resistance is inserted into arm 1 in series with the unknown, as shown in Fig. 2, and this takes over, from the reactance X_4, the role of a balancing variable.

The implications of having a balancing element in the same arm as the unknown itself are many and important, and is a feature which has not, in the author's opinion, been paid its merited attention in the relevant published literature to date. The aim of this paper is firstly to discuss briefly the general effects of such a balancing-variable connection and secondly to consider the implications involved in such a situation with specific reference to the Owen bridge. In the latter instance an analysis is presented which takes into account the second-order effects of the component residuals of the self-inductance of, and stray capacitance across, each resistor of the bridge and the dissipation factor of each capacitor. Previous analyses of the Owen bridge[3, 5, 6] have taken regard of the first and third of these residuals, but there has not, as far as the author is aware, appeared in the relevant published literature one taking cognizance of the stray capacitance effect. It is shown in this paper that of all residuals the latter causes the most harm in accurate Owen bridge measurement.

The procedure with the Owen bridge configuration of Fig. 2 is firstly to short-circuit the unknown and to balance by suitable adjustment of the arms R_4 and R_1. Thereafter the short-circuit is removed and the bridge re-balanced. It can be shown that the unknown inductance is determined in terms of an expression involving the difference in values of the resistor R_1 under these two conditions and as such the use of the short-circuit test is regarded as a convenient means of obtaining an evaluation of the part played by the component residuals in the operation of the bridge. When the stray capacitance effect is taken into account, however, it is shown in this paper that the value required of the resistor R_1 to permit of a balanced state under the short-circuit condition can actually become *negative*; the use of the short-circuit test results under these circumstances is then shown to decrease, as opposed to enhancing, the accuracy with which the determination of the unknown inductance is achieved.

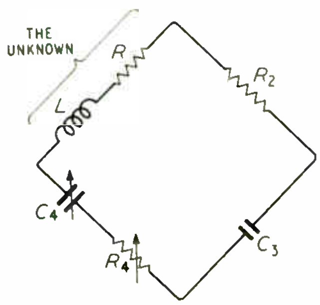

Fig. 1. The Owen bridge, according to the generalized classification

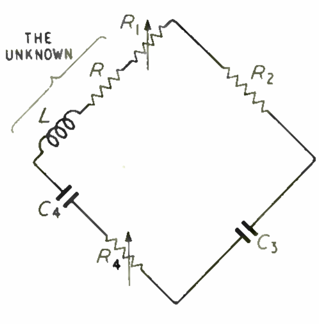

Fig. 2. The Owen bridge, with the balancing variable changed from C_4 to R_1 in series with the unknown itself

Balancing Variable in Series with Unknown

Preliminary Considerations

As mentioned in an earlier paper,[1] the one difficulty experienced with the 'adjacent balancing-arm' type of bridge is that, as both bridge variable-elements occur in series in the same arm, it is impossible for both of the latter to have direct connections to earth. If the operating frequency is sufficiently high it is found that such an earth connection is an invaluable asset in eliminating the undesirable feature of the operator's body-capacitance to earth affecting the balanced state, and as such some other approach must be adopted in order to realize this property in the adjacent balancing-arm bridge.

The numerator in the expression for the output voltage from the bridge has been termed[1] the 'characteristic equation'; the manner in which the convergence-to-balance is achieved is then the manner in which this characteristic equation approaches zero. This latter equation in the case of the

* Electrical Engineering Department, University of the Witwatersrand.

adjacent balancing-arm bridge has been shown[1] to consist of a real component in which there feature terms involving the product of like components of opposite bridge arms and a j-component containing products of unlike components of the same opposite arms. Any one of the two components of the unknown being measured can then be made a suitable bridge balancing arm by the inclusion in series with the unknown and in the same arm of a variable element of type the same as that component of the unknown which is to be used.

Having one balancing variable in the arm containing the unknown, and the second in an adjacent arm means that each of the latter can be connected to one terminal of the output isolating transformer; if one variable is then directly earthed the second is earthed under balance conditions since there is then no potential difference between the two terminals of the latter transformer.

Therefore to summarize, the earthing problem concerning the balancing-variables, which arises in the adjacent balancing-arm bridge, can be virtually cured by having one such variable in series with, and in the same arm as, the unknown itself.

Additional Benefits

Placing a variable in series with the unknown in this manner gives rise to an important additional benefit, as follows. It becomes possible under these circumstances *completely to short-circuit the unknown* and still to achieve a balanced condition from the bridge by retaining the same variable arms. The value of such a short-circuit test lies in the fact that the results may be used as a *substitution measurement* for the calculation of the effects of any second-order terms, such as component residuals and the like; in this instance the *calibrated standard used for the substitution measurement merely happens to have the value zero.* It is of particular importance to note that such a short-circuit test *cannot be conducted in the more conventional case where the unknown fills one complete arm of the bridge.*

There is one proviso to the benefits accruing from the short-circuit test as mentioned above, namely that balance shall be *possible and positive*. More detailed attention is paid to this proviso later.

The Owen Bridge, Taking Account of Residuals

Convergence-to-Balance

The first point to establish is that the use of the balancing variables indicated in Fig. 2 does in fact result in a convergence to balance of the optimum form, the latter being a requirement on what was termed the 'ideal' bridge in the generalized classification of bridge methods[1, 2] and which was satisfied by the Owen configuration of Fig. 1.

The characteristic equation, to be deonoted δ, is given by

$$\delta = Z_1 Z_3 - Z_2 Z_4 \tag{1}$$

The unknown will be denoted $R+jX$ here, with the balancing variable in arm 1 denoted R_1. Therefore substituting the relevant impedances from Fig. 2 into equation (1) yields, neglecting component residuals for the moment,

$$\delta = (R + j\omega L + R_1)(-jX_3) - R_2(R_4 - jX_4)$$

i.e.,

$$\delta = \omega L X_3 - R_2 R_4 + j[R_2 X_4 - X_3(R + R_1)] \tag{2}$$

Equation (2) indicates that the variation of R_4 caters for the zeroing of the real component of δ, while variation of R_1 takes care of the j-term. The use of R_4 and R_1 as bridge balancing variables does therefore result in a convergence of the optimum form.[1]

Conditions at Balance, Taking Account of Residuals

At balance δ is zero, so that the required equation is obtained from (1) by the substitution of the relevant impedances together with their residual content. In this latter connection it can be shown that the impedance of a resistor R possessing the residuals of a self-inductance l henrys and a stray capacitance C_s farads is given by

$$Z_R = R[1 + j(q - \alpha)] \tag{3}$$

$$\text{where } q = \omega l / R \tag{4}$$

$$\text{and } \alpha = \omega C_s R \tag{5}$$

In similar fashion the impedance of a capacitor having a dissipation factor D is given by

$$Z_C = -jX(1 + jD) \tag{6}$$

To specify that the equation to be obtained holds only under the balance conditions the variable arms R_1 and R_4 will possess the additional subscript '0'; thus R_{10} denotes the value of R_1 at balance, and likewise for R_{40}.

Adopting this procedure and substituting equations (6) and (3) for the relevant impedances into equation (1) with δ placed zero, there results the following equation at balance:

$$\left[R + j\omega L + R_{10}[1 + j(q_{10} - \alpha_{10})]\right](-jX_3)(1 + jD_3)$$
$$= R_2[1 + j(q_2 - \alpha_2)]\left[R_{40}[1 + j(q_{40} - \alpha_{40})] - jX_4(1 + jD_4)\right] \tag{7}$$

It proves most convenient to divide through by the term $(1 + jD_3)$ to obtain

$$\left[R + j\omega L + R_{10}[1 + j(q_{10} - \alpha_{10})]\right](-jX_3)$$
$$= R_2 R_{40}[1 + j(q_2 - \alpha_2 + q_{40} - \alpha_{40} - D_3)]$$
$$- jX_4 R_2[1 + j(q_2 - \alpha_2 + D_4 - D_3)] \tag{8}$$

if higher-order terms are neglected.

The relevant simplification of equation (8) and the equating of like components yields the following two expressions

$$L = R_2 C_3 R_{40} + R_{10}(R_{10} C_{s10} - l_{10}/R_{10}) + (R_2 C_3/C_4)$$
$$[l_2/R_2 - R_2 C_{s2} + (D_4 - D_3)/\omega] \tag{9}$$

$$\text{and } R + R_{10} = C_3 R_2/C_4 - \omega^2 C_3 R_2 R_{40}[l_2/R_2 - C_{s2} R_2$$
$$+ l_{40}/R_{40} - C_{s40} R_{40} - D_3/\omega] \tag{10}$$

Equations (9) and (10) are the complete expressions to be used for the determination of the unknowns L and R respectively when the component residuals indicated are taken into account.

Short-Circuit Balance Condition

It is to be noted that equation (9) contains on the right-hand side two terms which involve the balancing variables R_{40} and R_{10} and a third term which is a constant quantity inasmuch as it does not contain the latter two variable elements. The use of a substitution procedure in this instance will then enable information to be obtained as to this latter third and constant expression. If the value of L is made zero for such a substitution measurement a short-circuit test results. In this the unknown is accurately short-circuited and the bridge re-balanced by suitable variation of R_4 and R_1. Let the resulting values be R_{40}' and R_{10}' respectively.

From equations (9) and (10) the two expressions emerging from such a test are

$$0 = R_2 C_3 R_{40}' + R_{10}'(R_{10}' C_{s10}' - l_{10}'/R_{10}')$$
$$+ (R_2 C_3/C_4)[l_2/R_2 - R_2 C_{s2} + (D_4 - D_3)/\omega] \tag{11}$$

and

$$R_{10}' = C_3 R_2/C_4 - \omega^2 C_3 R_2 R_{40}'[l_2/R_2 - C_{s2} R_2 - D_3/\omega$$
$$+ l_{40}'/R_{40}' - C_{s40}' R_{40}'] \tag{12}$$

It is to be noted that the above two equations (11) and (12) have been obtained by mere mathematical manipulation; no attention has been paid to the *practicability* of obtaining such a short-circuit balanced state at this stage. This will be done later.

Determination of the Unknown Inductance

Equation (11) enables a substitution to be made in terms of R_{40}' and R_{10}' for the expression

$$(R_2C_3/C_4)[l_2/R_2-R_2C_{s2}+(D_4-D_3)/\omega].$$

Thus combining equations (11) and (9),

$$L=R_2C_3(R_{40}-R_{40}')+R_{10}(C_{s10}R_{10}-l_{10}/R_{10})$$
$$-R_{10}'(C_{s10}'R_{10}'-l_{10}'/R_{10}') \qquad (13)$$

Here the unknown is determined entirely in terms of the properties of the two variable elements. The statement has been made in other works on the Owen bridge[3, 5, 7] that as the residual content of equation (13) is less than that of equation (9) the measurement of the unknown inductance L has, ipso facto, been achieved more accurately. It is shown here that more argument is required than that contained in this latter reasoning for the advantages, or otherwise, of the short-circuit balance to be borne out. For example equation (13) is the result of mere mathematical manipulation without any attention having been given to the feasibility of such a short-circuit balance. Thus each of R_{40}' and R_{10}' must be investigated in terms of the remaining fixed bridge arms.

Demands of Short-Circuit Balance

Consider firstly the quantity R_{40}', that is the balance value of the element R_4 under short-circuit conditions. From equation (11),

$$R_{40}'=(l_{10}'-R_{10}'^2C_{s10}')/R_2C_3-[l_2/R_2-R_2C_{s2}$$
$$+(D_4-D_3)/\omega]/C_4 \qquad (14)$$

Substituting for the term R_2C_3 here from equation (12) and neglecting higher-order terms yields

$$R_{40}'=(1/C_4)[l_{10}'/R_{10}'-R_{10}'C_{s10}'-l_2/R_2+R_2C_{s2}$$
$$+(D_3-D_4)/\omega] \qquad (15)$$

R_{10}' may be retained in the first term of the above equation as it appears there in the form of a time-constant. In the second term, however, R_{10}' must again be substituted for in terms of equation (12) to yield on neglecting higher-order quantities,

$$R_{40}'=(1/C_4)[l_{10}'/R_{10}'-l_2/R_2+R_2(C_{s2}-C_{s10}'C_3/C_4)$$
$$+(D_3-D_4)/\omega] \qquad (16)$$

The above equation can normally be approximated to the following form without great error

$$R_{40}'\doteqdot(R_2/C_4)(C_{s2}-C_{s10}'C_3/C_4) \qquad (17)$$

Equation (17) indicates that the short-circuit balance may well require a *negative* value of R_{40}', depending on the relative magnitudes of C_{s2} and $C_{s10}'C_3/C_4$. The emergence of such a negative value does not in any way result from what may be termed 'bad design' of the bridge, but merely from a consideration of the difference of certain stray capacitance residuals. C_{s10}' will normally be of the same magnitude as C_{s2}, and it is quite possible for C_3 to exceed C_4 in value, making for a negative R_{40}'. It would appear that this feature has been overlooked in the published literature to date on the Owen bridge.

For the case of no component residual content it is seen from equation (16) that R_{40}' has the value zero.

Coming now to the case of R_{10}', it is seen from equation (12) that

$$R_{10}'=C_3R_2/C_4-\omega^2C_3R_2R_{40}'(l_{40}'/R_{40}'+l_2/R_2-C_{s2}R_2$$
$$-C_{s40}'R_{40}'-D_3/\omega) \qquad (18)$$

As R_{40}' itself is a second-order quantity, the second term on the right-hand side of equation (18) is of fourth order and can therefore safely be neglected, to yield with good approximation

$$R_{10}'\doteqdot C_3R_2/C_4 \qquad (19)$$

The fulfilment of the requirement on the value of R_{10}' is therefore a simple matter.

Determination of the Unknown Resistance

Comparing equations (19) and (10) it is seen that the short-circuit test in the case of the determination of the unknown resistance is merely a substitution for the quantity C_3R_2/C_4 appearing in equation (10) and hence does not accomplish in this instance what it did in the case of the unknown inductance, namely the elimination of certain residual effects. Thus

$$R+R_{10}=R_{10}'+\omega^2C_3R_2R_{40}(C_{s2}R_2+C_{s40}R_{40}+D_3/\omega$$
$$-l_2/R_2-l_{40}/R_{40}) \qquad (20)$$
$$=R_{10}'+\omega^2C_3R_2R_{40}.A \qquad (21)$$

where

$$A=C_{s2}R_2+C_{s40}R_{40}+D_3/\omega-l_2/R_2-l_{40}/R_{40} \qquad (22)$$

Substituting for the term $C_3R_2R_{40}$ appearing in equation (21) from equation (9) and neglecting higher-order terms yields

$$R+R_{10}=R_{10}'+A\omega^2L$$

i.e.,
$$R_{10}'-R_{10}=R-A\omega L=R(1-AQ) \qquad (23)$$

where Q is the 'quality factor' of the inductive impedance being measured and is given by $\omega L/R$.

Thus if, as is customary, the difference between R_{10}' and R_{10} is taken as yielding the unknown resistance R, there is seen from equation (23) to be a proportional error in the measurement given by AQ where A is given by equation (22). It will be shown that *this error determines the upper limit of the bridge operative frequency range for the measurement of resistance.*

The error just mentioned arises by the use of an abbreviated equation for the unknown resistance, and may thus be termed a 'theoretical' error. As the unknown resistance is to be determined as the difference between two quantities, namely R_{10}' and R_{10}, there is seen to enter an additional error for experimental reasons. Thus if the error in the experimental determination of R_{10}' be the proportional amount d and that in the determination of R_{10} be a proportional amount e, and if R_{10}' is a proportional amount m greater than R_{10}, it follows that the experimental error in the determination of the unknown resistance R as the difference between R_{10}' and R_{10} is given by $d+(d+e)/m$.

Determination of the Unknown Inductance (continued)

Having determined R_{40}' by equation (17) and R_{10}' by equation (19) attention can once more be directed to the determination of the unknown inductance from equation (13). The latter can be rewritten in the form

$$L=R_2C_3(R_{40}-R_{40}')+(C_{s10}R_{10}^2-C_{s10}'R_{10}'^2)-l_{10}+l_{10}' \qquad (24)$$

In order to simplify the second term on the right-hand side of this equation it will be assumed that $C_{s10}=C_{s10}'$, that is that the stray capacitance across the balancing resistor R_1 at the normal balance is the same as that pertaining under the short-circuit balance conditions. With $R_{10}' - R_{10}$ given by equation (23) it follows that

$$R_{10}^2 - R_{10}'^2 = R^2(1-A)^2[1-2C_3R_2/C_4(1-A)] \quad (25)$$

Substituting equation (25) into (13) the unknown inductance is determined as

$$L = R_2C_3(R_{40}-R_{40}') + C_{s10}R^2(1-A)^2[1-2C_3R_2/C_4R(1-A)] - l_{10} + l_{10}' \quad (26)$$

The error in the use of the abbreviated form

$$L \doteqdot R_2C_3(R_{40}-R_{10}')$$

is then calculable.

The position where R_{40}' has the value zero becomes rather disconcerting. If the bridge is definitely balanced with this value of R_{40}', that is zero output voltage definitely occurs, the difficulty resolves itself. If, however, as is the more normal occurrence, finite output voltage persists, the operator is left with the decision as to whether a negative value of R_{40}' is in fact required to reduce the minimum, but finite, voltage obtained. In accurate work this decision is not an easy one to make and under these circumstances the author would offer the following solution. The stray capacitance across the resistor R_2 should be *deliberately increased* until the value of R_{40}' is just positive; increasing C_{s2} in this manner in no way affects the accuracy of the determination of the unknown inductance *other than enhancing it*, but the accuracy of the measurement of the unknown resistance is decreased as the quantity A, as given by equation (22), is increased. As the accuracy of the latter determination is in any event lower than that of the inductance measurement, this further decrease is under the normal circumstances a small price to pay.

Résumé

The shielding problems inherent in the 'adjacent balancing-arm' type of bridge have been shown to be capable of solution by adopting the procedure of removing from one of the elements in this arm the function of a balancing variable and giving it instead to a suitable element inserted in the same arm as that containing the unknown. It has been shown that this still allows the convergence-to-balance to be of the optimum form and introduces the feature that a balance can be obtained from the resulting bridge with the unknown completely short-circuited. The use of the results emerging from such a test must be regarded with care, particularly with regard to the value of the resistor R_4, as it has been shown that, contradictory to views now held in the relevant published literature, the case can easily arise in which the short-circuit test decreases, instead of enhancing, the accuracy of the determination of the unknown inductance. A remedy has been suggested which ensures that the value of R_{10}' is always positive, and this has been shown to add slightly to the inaccuracy of the determination of the unknown resistance.

Experimental Evidence

A correctly-shielded Owen bridge configuration was constructed using precision components manufactured by the General Radio Company. Type 1432 decade resistance boxes of specified accuracy within 0·05 per cent and type 1409 standard mica capacitors of specified accuracy within 0·05 per cent were employed in the relevant bridge arms. The two shielded isolating transformers were of type 578.

The results obtained when measuring an unshielded, air-cored inductance of nominal value 100 millihenrys are shown in the accompanying table. An unshielded and air-cored type was specifically chosen in this instance to eliminate considerations of the voltage-dependency of the measured inductance value; in this way a change of bridge input voltage from 5 V to 100 V was found to have no recognizable effect on the emerging results.

TABLE

Frequency (c/s)	Condition	R_2 (ohms)	R_{40} (ohms)	R_{40}' (ohms)	R_{10} (ohms)	R_{10}' (ohms)	Calculated	
							Inductance (mH)	Resist. (ohms)
965·0	normal	5000	387·6	1·2	2470·7	2503·6	96·60	32·9
	(a)	..	385·3	−ve	2470·7	2503·6		32·9
	(b)	..	392·5	6·1	2472·5	2503·6	96·60	31·1
	(a + b)	..	390·2	3·8	2472·5	2503·6	96·60	31·1
	normal	2000	966·6	0·7	965·4	1001·7	96·59	36·3
	(a)	..	965·7	−ve	965·4	1001·7		36·3
	(b)	..	968·6	2·6	966·1	1001·6	96·60	35·5
	(a + b)	..	967·7	1·7	966·1	1001·6	96·60	35·5
	normal	1000	1932·8	0·2	466·2	499·2	96·63	33·0
	(a)	..	1932·4	−ve	466·2	499·2		33·0
	(b)	..	1933·8	1·2	466·5	499·2	96·63	32·7
	(a + b)	..	1933·4	0·8	466·5	499·2	96·63	32·7
1864	normal	5000	387·8	1·2	2472·0	2503·6	96·65	31·6
	(a)	..	385·5	−ve	2472·0	2503·6		31·6
	(b)	..	392·7	6·1	2478·4	2503·6	96·65	25·2
	(a + b)	..	390·3	3·7	2478·4	2503·6	96·65	25·2
	normal	2000	966·9	0·4	966·1	998·5	96·65	32·4
	(a)	..	966·0	−ve	966·1	998·5		32·4
	(b)	..	968·9	2·4	968·6	998·5	96·65	29·9
	(a + b)	..	968·0	1·4	968·6	998·5	96·66	29·9
	normal	1000	1933·3	0·2	467·1	499·2	96·655	32·1
	(a)	..	1933·0	−ve	467·1	499·2		32·1
	(b)	..	1934·4	1·2	468·4	499·2	96·666	30·8
	(a + b)	..	1934·0	0·7	468·4	499·2	96·665	30·8
3869	normal	5000	388·3	1·2	2475·8	2503·7	96·775	27·9
	(a)	..	385·9	−ve	2475·9	2503·7		27·8
	(b)	..	393·2	6·1	2503·8	2503·6	96·775	−ve
	(a + b)	..	390·8	3·7	2503·7	2503·5	96·775	−ve
	normal	2000	968·1	0·4	967·8	998·5	96·77	31·3
	(a)	..	967·2	−ve	967·8	998·5		31·3
	(b)	..	970·1	2·4	979·0	998·5	96·77	19·5
	(a + b)	..	969·2	1·4	979·0	998·5	96·78	19·5
	normal	1000	1935·7	0·2	470·0	499·2	96·775	29·2
	(a)	..	1935·3	−ve	470·0	499·2		29·2
	(b)	..	1936·7	1·2	475·6	499·2	96·775	23·6
	(a + b)	..	1936·3	0·7	475·6	499·2	96·78	23·6
5727	normal	5000	389·0	1·2	2482·0	2504·0	96·95	22
	(a)	..	386·7	−ve	2482·0	2504·0		22
	(b)	..	394·0	6·1	2543·0	2504·0	96·975	−ve
	(a + b)	..	391·6	3·7	2543·0	2503·0	96·975	−ve
	normal	2000	969·9	0·7	971·0	1001·6	96·92	30·6
	(a)	..	969·0	−ve	971·0	1001·6		30·6
	(b)	..	971·9	2·6	995·0	1001·5	96·93	6·5
	(a + b)	..	971·0	1·7	995·0	1001·5	96·93	6·5
	normal	1000	1939·5	0·2	475·0	499·1	96·965	24·1
	(a)	..	1939·0	−ve	475·0	499·1		24·1
	(b)	..	1940·5	1·2	487·0	499·1	96·965	12·1
	(a + b)	..	1940·0	0·7	487·0	499·1	96·965	12·1
7600	normal	5000	390·1	1·2	2491·0	2503·6	97·23	12·6
	(a)	..	387·7	−ve	2491·3	2503·6		12·3
	(b)	..	395·3	6·1	2599·0	2503·3	97·30	−ve
	(a + b)	..	392·7	3·7	2598·8	2502·9	97·25	−ve
	normal	2000	972·6	0·7	975·0	1001·7	97·19	26·7
	(a)	..	971·7	−ve	975·1	1001·7		26·7
	(b)	..	974·7	2·6	1018·3	1001·6	97·21	−ve
	(a + b)	..	973·7	1·7	1018·4	1001·6	97·20	−ve
	normal	1000	1944·8	0·2	481·6	499·2	97·23	17·6
	(a)	..	1944·4	−ve	481·6	499·2		17·6
	(b)	..	1945·9	1·2	503·3	499·2	97·235	−ve
	(a + b)	..	1945·4	0·7	503·3	499·2	97·235	−ve
9476	normal	5000	391·4	1·2	2503·0	2503·0	97·55	0
	(a)	..	389·1	−ve	2503·0	2503·0		0
	(b)	..	396·8	6·1	2670·0	2503·0	97·68	−ve
	(a + b)	..	394·1	3·7	2670·0	2502·0	97·60	−ve
	normal	2000	976·0	0·7	981·0	1002·0	97·53	21·0
	(b)	..	978·4	2·6	1052·0	1001·0	97·57	−ve
	(a + b)	..	977·5	1·7	1052·0	1001·0	97·57	−ve
	normal	1000	1952·0	0·2	492·0	499·0	97·59	7·0
	(b)	..	1953·0	1·2	522·0	499·0	97·59	−ve
	(a + b)	..	1952·0	0·7	522·0	499·0	97·565	−ve

$C_3 = 0{\cdot}05\ \mu F \pm 0{\cdot}05$ per cent

$C_4 = 0{\cdot}1\ \mu F \pm 0{\cdot}05$ per cent

Condition 'normal' denotes the use of no additional stray capacitances

Condition (a) denotes the use of 100 pF additional capacitance across R_1

Condition (b) denotes the use of 100 pF additional capacitance across R_2

Condition (a + b) denotes the simultaneous application of conditions (a) and (b)

Consider firstly the experimental verification of equation (17). Measurements were taken under four separate conditions, firstly that, denoted 'condition normal', in which no additional capacitances were placed across the resistance arms, secondly that, denoted 'condition (a)', in which a 100-pF capacitance was placed across the resistance R_1 only, thirdly that, denoted 'condition (b)', in which a 100-pF capacitance was placed across the resistance R_2 only, and lastly, denoted 'condition (a+b)', where conditions (a) and (b) were applied simultaneously.

The results obtained indicate in each case that increase in C_{s1} alone causes R_{40}' when zero to leave a considerable output voltage from the bridge; it is therefore presumed correct to state that a negative value of R_{40}' was called for under these circumstances. This opinion is strengthened by the feature that in each case the value of R_{40} under condition (a), when taken with a zero value of R_{40}', would have resulted in a value of the unknown inductance *lower* than that given by the other accompanying tests when condition (a) alone was not employed. A negative value of R_{40}' would have the result, by equation (26), of causing the determined value of L to increase.

With regard to the application of condition (b) alone, it is seen that the value of R_{40}' emerges as large and positive, in accordance with equation (17). Considering the condition (a+b), it is seen that as predicted the addition of capacitance across the resistance R_2 overcomes the previously existing negative value of R_{40}'. Consistency is indicated between the values of the unknown inductance as measured under the conditions of normal, (b) and (a+b).

Coming now to the attempted verification of equations (22) and (23), it is seen that the placing of additional capacitance across R_1 has no effect on the resultant measurement of the unknown resistance, whereas placing such capacitance across R_2 [that is, condition (b)] causes the value emergent to be markedly lower than the true. For any given value of such capacitance it is seen that the decrease becomes more marked as the value of R_2 is increased, in accordance with the theoretical prediction contained in equation (22). For any given stray capacitance across R_2 and any given value of R_2 the accompanying tables indicate that the reduction to the determined value of the unknown resistance increases as the frequency increases, in accordance with the predctiions of equation (23).

With regard to the verification of equation (19) it is seen, to take a specific example, that in the case of R_2 being 5,000 ohms the variation in the value of R_{10}' under all conditions and from frequencies from 965 to 9,476 cycles per second is from 2,502 to 2,504 ohms, that is some 0·08 per cent.

For purposes of comparison the inductance measurement as performed here was repeated at the frequency of 5,727 cycles per second on a new three-terminal bridge[8] in which residuals are shown to play an extremely minor role. Using the same components in the four-terminal and in the three-terminal cases, the measurement in the latter instance yielded a value of 97·01 millihenrys for the inductance and a figure of 46·58 ohms for the unknown resistance. If the most optimistic value is taken from the Owen bridge inductance results at this frequency, a discrepancy of some 0·035 per cent is indicated, and taking the most pessimistic a discrepancy of some 0·09 per cent. Each of these differences is well within that allowed by component accuracies.

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STEVI Provides Safety Shut-down

Bristol Siddeley has ordered a number of STEVI (Sperry Turbine Engine Vibration Indicator) systems to monitor and, if necessary, shut-down one or all the four jet engines and associated free turbines which together form generating sets ordered by the Central Electricity Generating Board. Operation of the whole system, including STEVI, is automatic.

The jet efflux of four Bristol Siddeley Olympus gas generators drives four free turbines carried on a common shaft coupled to a 70/80 MW alternator, the power being available at short notice to meet peak load demands.

Sperry pick-ups and high-temperature cables are fitted to each engine and to pedestals along the power-turbine shaft. The pick-ups are scanned electronically and their outputs displayed as vibration amplitude. In the unlikely event of the vibration level exceeding a critical value a warning system operates. If this is caused by gas-generator vibration, the offending unit is shut down. Excessive vibration of the power turbines will result in the automatic warning system shutting down the whole plant.

For further information circle 47 on Service Card

A STEVI turbine vibration warning unit

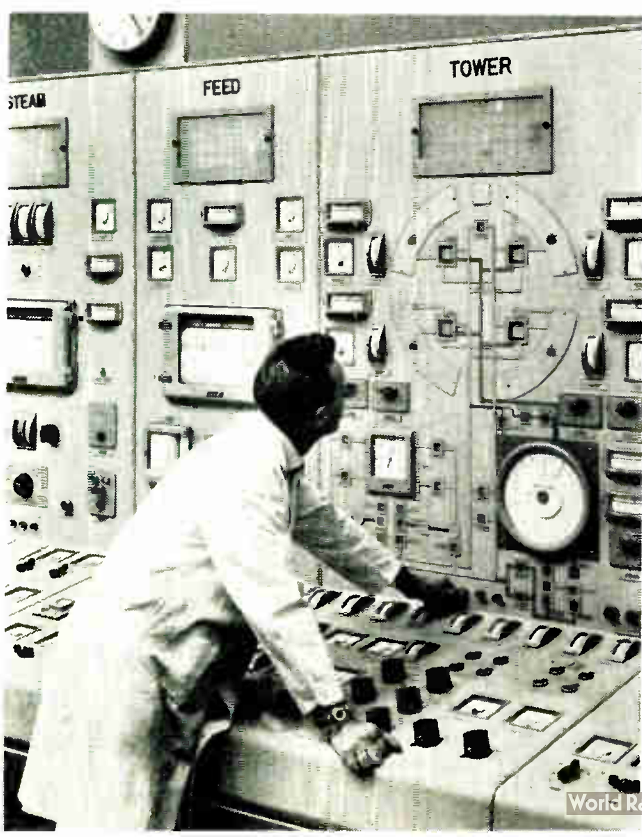
1

RUGELEY GENERATING STATION

The complete instrumentation and control system for the five 120-megawatt units at the Central Electricity Generating Board's new generating station at Rugeley, which was officially opened on Tuesday, 1st October 1963, by Lord Robens, has been supplied, installed and commissioned by Elliott Process Automation Limited.

The entire station is run from a vast central control room containing more than 135 feet of control panels. A single operator at each of the three consoles can control every stage of the power generation process—the feeding of coal to the milling machines, the supply of milled coal to the boilers, the regulation of the combustion and flue gases, the superheating and delivery of the steam to the turbines, the turbines themselves, the generators and the cooling system.

3



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1 The main control room at Rugeley. Two 120-megawatt generating sets are controlled from each of two panels. The third panel controls the remaining set

2 The control panel for No. 1 and No. 2 generating sets. The open-loop system of control adopted at Rugeley is based on 'Electro-flo' electronic transmission equipment. The system is designed to 'hold' in the event of either power supply or component failure. The amplifier unit in each control circuit can be removed for inspection or replacement, leaving the final servo-motor under remote manual control

3 The control panel of the No. 3 generating set contains a mimic diagram and the instrumentation for the first 'dry' cooling tower to be built in this country

DYNAMIC BALANCING MACHINES

This article discusses the various methods employed to determine where balancing weights should be placed on rotating devices in order to minimize vibration. In most cases balancing weights placed in two different planes suffice, but sometimes they must be in three or four planes.

By
D. E. TYZACK*

WHEN a motor-car engine begins to be noisy and to vibrate, it is usual to suspect trouble. Often something is wrong and vibration and noise come to be associated with faulty operation. In fact, a considerable amount of wear is normally caused by excessive vibration and even if there is no permanent effect a vibrating or noisy product is less desirable than one with smooth operation.

In rotating machines static or knife-edge balancing of the rotating parts is insufficient as can be readily appreciated from the diagram of Fig. 1.

Consider a uniform disc with a spindle which is statically balanced on knife edges, as in (a). If this is then cut in half along a diameter and the two halves pushed apart along the spindle without turning either, as in (b), the device is still statically balanced.

However, if the device is now removed from the knife edges and rotated it will tend to wobble.

This wobble will, in the absence of external forces, be about the centre of gravity. The wobble is the motion resulting from the couple exerted by the non-planar centrifugal forces on the two halves. These centrifugal forces are proportional to the weight of unbalance, its distance from the centre of turning and the square of the speed of rotation.

If this device is supported in suspended bearings as most rotary devices are, it will be constrained to rotate about the journal axes. To constrain it, forces must be exerted by the bearings which are of equal but opposite moment to the unbalance forces. In any plane passing through the journal axes, they will alternate at the frequency of rotation of the body.

These forces may rise to extremely high values particularly in view of ever increasing demands for high speed.

To-day 3,000 r.p.m. is commonplace, 8,000 r.p.m. is typical for textile machinery, while 10,000 to 20,000 r.p.m. is the range for gas-turbine rotors. In precision grinders and gyroscopes speeds of 60,000 r.p.m. are approached.

Unbalance Detection

Unbalance forces can be determined in terms of the deflection caused by them in suitably suspended bearings.

In most forms of balance detectors the bearings are so mounted that deflection in one line only is possible. In this line or direction a restoring force is provided to maintain a proportional relationship between force and deflection.

A suitable transducer then converts the deflection so produced into a proportional electrical analogue, normally a voltage.

As the electrical output is proportional to the bearing reaction in one plane only, the voltage is an a.c. output of frequency equal to the rotational frequency of the workpiece. In the same way the phase of the output waveform directly indicates the angular position of the unbalance weight causing the bearing reaction.

The Wattmeter Method

In one simple method of unbalance detection, the rotor to be balanced is directly coupled to a two-pole a.c. generator. In addition an unbalance transducer or pick up is connected to one of the bearings, as shown in Fig. 2.

When the rotor is spun, two voltages will be produced. One of these is from the pick up and results from an unbalance of the rotor, the other is from the two-pole generator and is solely a function of the angular position and speed of the rotor. The two voltages will be of the same frequency but differing phase and amplitudes.

These two voltages are applied to the two coils of a wattmeter. A wattmeter is designed so that the output indication is equal to the product of the two input signals times the cosine of the phase angle between them. If the generator

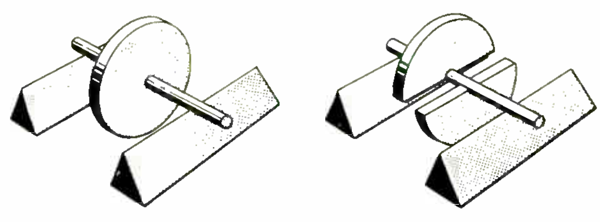

Fig. 1. Static balance is achieved in both (a) and (b), but whereas (a) is also dynamically balanced (b) is not

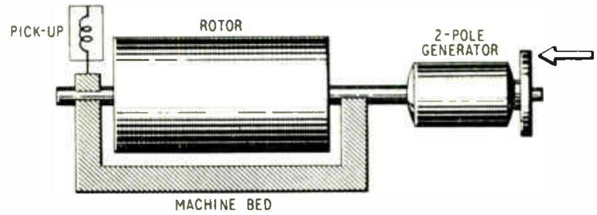

Fig. 2. The rotor to be balanced is connected to a two-pole a.c. generator and a pick-up device at one of the bearings produces an output when the rotor vibrates

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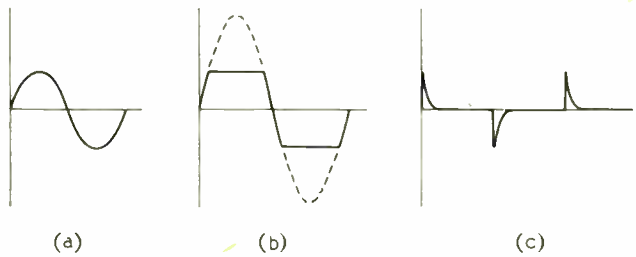


Fig. 3. The pick-up signal (a) is amplified and squared (b) and is then differentiated to produce pulses (c) which occur at the zeros of the sine wave

stator is turned until its output is at 90° to the unbalance pick-up output, the indicated reading will be zero.

In use the generator body is moved to null the meter. The angle indicated by the protractor on the body then defines the position of the unbalance on the test rotor with respect to the position of the generator rotor.

The amount of unbalance can be determined from the maximum meter reading at 90° away from the null.

Stroboscopic Method

In this system the unbalance pick-up output is first amplified electronically and is of the form shown in Fig. 3(a). This signal is then squared or amplified beyond the linear range of the amplifier (b). The resulting square wave is then passed through a simple capacitance-resistance network which allows only the leading edge of the wave to pass and so produces a train of pulses each corresponding to the starting and finishing of a square wave (c). Now these pulses occur at exactly the instant at which the pick-up output sine wave passes through zero; thus they are directly related to the position of the unbalance, providing the necessary precautions are taken to avoid phase shift in the amplifier, and bearing suspension.

The pulses are used to trigger a flashing discharge tube known as a stroboflash, so that the lamp illuminates the rotor at the instant when the unbalance is at the top or the bottom.

The actual 'frozen' angular position can then be identified by one of a number of ways.

Sticky tape with figures distributed along its length is sometimes used in conjunction with a fixed pointer. Even a single chalk mark is sometimes sufficient in high production units.

Two-Plane Balancing

Unbalance masses or holes may occur at any position in the structure of a rotor to be balanced. It is clearly impractical to compensate the unbalance in the plane in which it exists as this may result in an infinite number of compensations being required. It can readily be shown,[1] however, that compensation in two planes is sufficient for complete dynamic balance. In practice these planes are conveniently chosen near the bearings and compensations are made so that the total moment due to all centrifugal forces about each bearing in turn is zero. This condition ensures complete balance as by the laws of statics no moment can then exist about any other similar axis.

Unbalance in one balancing plane will however produce a bearing reaction in both suspended bearings. If no action were taken to avoid this effect balancing could probably only be achieved by successive approximation. So for production balancing it is necessary to remove the output from the bearing not associated with the plane in which the unbalance exists.

The signal representing the unwanted bearing reaction is a voltage of the same frequency but different phase and amplitude from the wanted signal. For a given rotor, due to its geometrical shape, the unwanted signal bears a fixed ratio to the wanted signal. It is therefore an easy matter to inject a suitable proportion of the wanted signal voltage in antiphase so as to cancel the unwanted output. When this is done from each bearing output to the other corrections at one end may be done without interacting with the output from the other.

Bearing Cradles

Bearings are supported or suspended by a variety of methods all involving low friction mountings. Two methods are illustrated.

In the hanging version, an inverted V frame supports a half bearing at the top of the Λ, while the legs of the Λ are supported by thin steel cables and phosphor bronze tapes. Moving parts are kept to the smallest possible mass to enable maximum deflection to be obtained with small rotors under dynamic conditions.

In the second method the cradles are supported by ball bearings. These balls are housed in grooves which might best be described as boat shaped. Point contact only is achieved, yet the cradles run down-hill to the middle of the travel, to the broadest beam of the grooves.

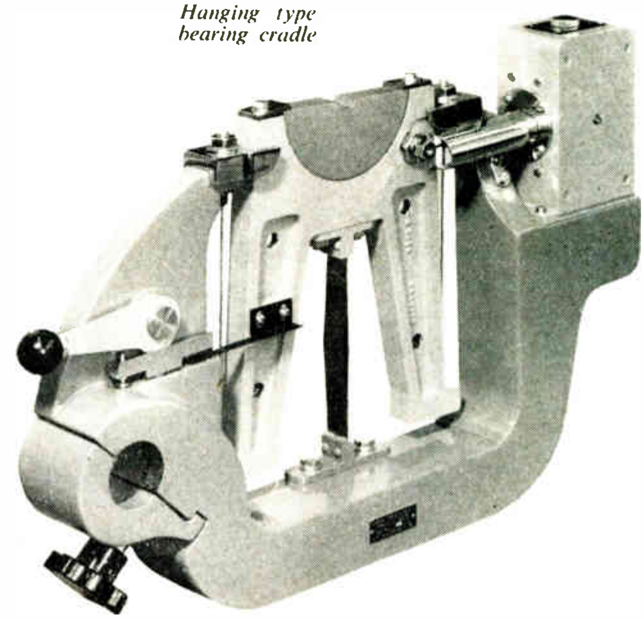
This latter is a method of construction which has been successfully employed for large loads of up to 300 to 400 lb and yet retains instrument type response.

Pick-ups

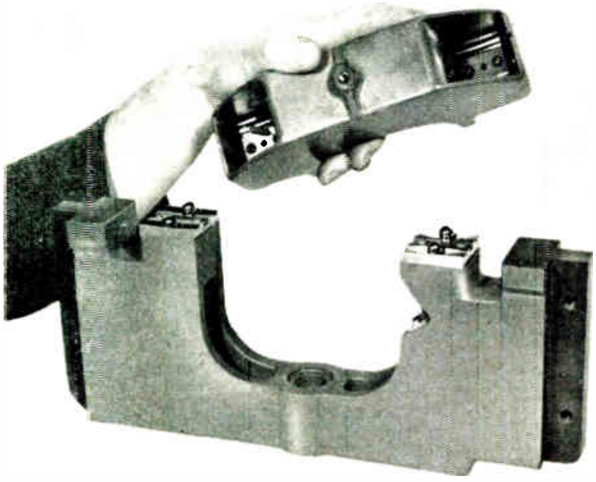
Transducers for converting small physical movements into electrical energy are numerous. Two types are shown. In the first, a simple moving-coil type, a coil is moved in the field created by a permanent magnet with a very small air gap. This produces a voltage output proportional to the instantaneous velocity of movement of the coil.

In the second case, the transducer is sometimes referred to as a seismic type. It consists of a differential transformer comprising in principle a small stack of E-type laminations and a polepiece freely suspended. The a.c. energized coils are mounted on the outer limbs of the E. A pick-up coil is mounted on the central limb. When the freely-suspended pole symmetrically straddles the centre limb, making the

Hanging type bearing cradle



[1] Den Hartog, 'Mechanical Vibrations', McGraw Hill, pp. 232-234.



In this support the cradles are supported by ball bearings

gaps either side equal, the voltage induced in the centre coil is zero. A movement of the pole piece toward either the right-hand or left-hand limb upsets the symmetrical flux pattern and produces an a.c. induced voltage in the pick-up coil. The polarity of this a.c. induced voltage, with respect to the energizing current in the outer limbs indicates the direction of displacement of the pole piece. This produces an output proportional to the acceleration of the bearings.

A third possible type of transducer consists of a simple plane cut crystal in which the piezo-electric effect is employed. In this, of course, the crystal produces electrical charges on its surfaces which depend upon the mechanical strains to which it is subjected.

Work Supports

The principle consideration in the mechanical design of the balancing-machine structure and of the bearing suspensions is that the phase and amplitude of the bearing deflections should be strictly related to the unbalance forces causing them.

Lack of rigidity in the structure may result in resonances or near resonances occurring within the range of workpiece speeds. A similar effect will be experienced if the bearing suspension resonates at near workpiece speed. With the former it is usual and convenient to make the structure extremely stiff to make any resonances occur at frequencies above working speeds. With the latter, it is normally only practical to make the resonance very low by comparison.

Damping or friction is another factor to be minimized as this will again introduce spurious phase shifts.

A troublesome effect resulting from lack of attention to the factors mentioned above is that the crosstalk output, or the reflected output in one transducer resulting from unbalance in the plane of the other transducer, is not necessarily in strict antiphase with the primary output and so cannot be simply balanced out by a simple resistive network.

Rotor Drives

The most used method of driving rotors in balancing machines is by means of flat belts. These allow the workpiece freedom of movement in the essential direction along the axis of the transducers.

Belts are made of smooth uniform strip usually of rubber or laminated woven tubular material which is suitably impregnated. Belt tension can be a critical factor and it is usually found necessary to provide an adjustable tension arm supporting a belt idler pulley in order to obtain sufficient tension to accelerate rotors rapidly for production balancing. Due to their different shapes, to the different ratios of driven to maximum diameter and indeed to the variation of weight alone, differing minimum tensions for quick acceleration are necessary.

It is not possible merely to use a constant tension equal to the maximum for several reasons. The response for a small rotor would be reduced; the small rotors might be lifted from the cradles in the case of topside drives; and finally wrong tension in the belt will result in undesirable belt resonances. When the frequency of the belt resonance is near to that of the rotor rotation the tension must be adjusted so that the new belt resonant frequency will not be excited by the rotational speed of the workpiece.

In larger machines the rotor can be driven by a suitable coupling directly on to the end of the shaft.

Spurious Signals

In most practical balancers the limit of balancing achievable is largely set by the level of undesired signals or noise present.

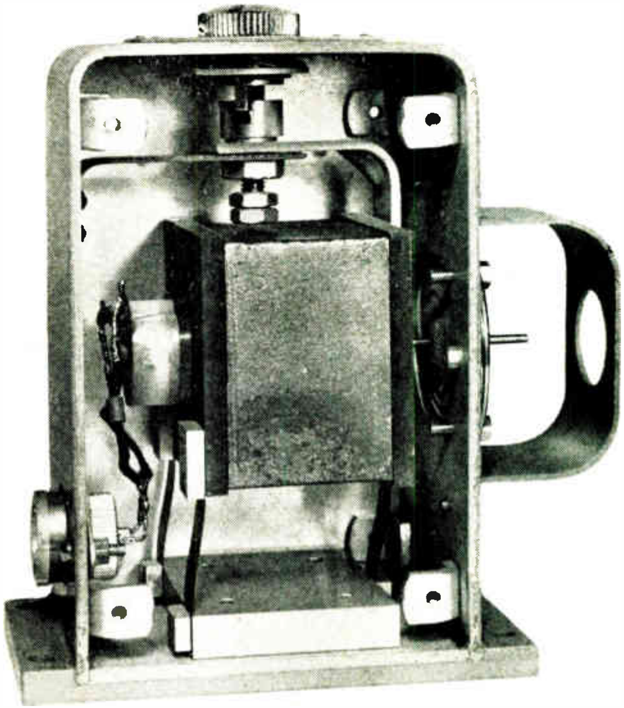
The noise takes various forms. It could be spurious electrical signals such as are produced by stray transformer or motor fields. It could be due to drive belt resonance or even frame or work support resonances.

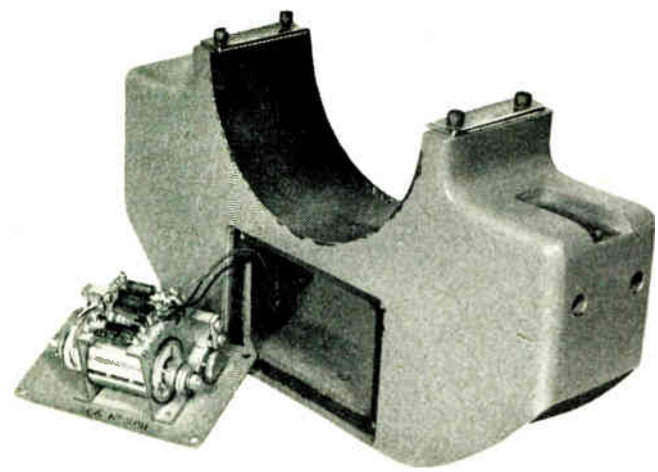
These effects are normally dealt with by suitable electrical filter networks. These remove the signals at frequencies other than that to which the filter is tuned. The filter is made adjustable and is adjusted to the frequency of vibration or unbalance output.

Precision Balancing

For some components even these frequency filtering techniques are insufficient and more discriminating methods must be used. In particular, when balancing precision components, it is necessary to rotate them in their own ball bearings. In this case the noise output, although not at the

Simple moving-coil transducer for vibration pick up





Seismic transducer comprising a differential transformer with a suspended polepiece

rotational frequency is many times the amplitude of the maximum allowable unbalance output.

Several methods of measuring unbalance in the presence of considerable noise are in use. In principle they all use a reference signal of the same frequency as the rotation of the tested rotor.

This reference signal is used in one form or another in a phase-sensitive detector and is usually generated by a white spot on the end of the rotor together with a photocell system.

In one system the photocell output is added to the output from the vibration pick-ups, so that the resulting output is the vector sum of the reference voltage and the vibration output. Considerable filtering of unwanted frequencies is then done. The sum output is then made a minimum by successive adjustment of the phase and amplitude of the fraction of the reference photocell output which is added to the vibration output.

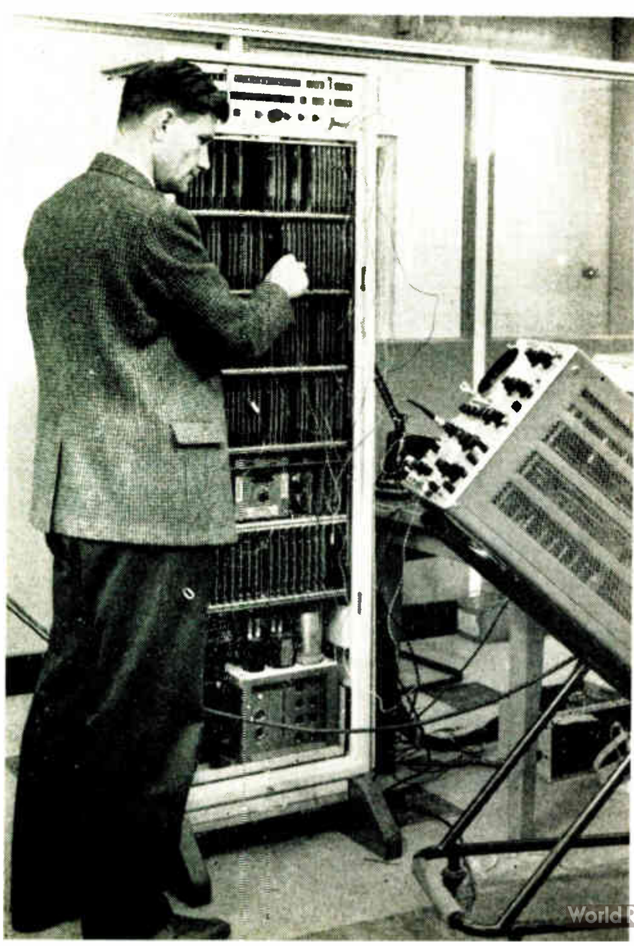
When a satisfactory null has been obtained the vibration pick-up output is switched off and the phase and amplitude of the fraction of the reference employed indicate the out of balance details required.

In another system the reference signal and vibration signals are fed, after filtering, to the two coils of a wattmeter. Again, an adjustment of amplitude and phase of the reference signal is made until a null is obtained. From this again the required details can be obtained.

Specially selective filtering can also be performed by modulating a carrier of several thousand cycles per second with the signal from the vibration pick-up outputs. Filtering is then performed with a band-pass filter. A filter can be designed more readily to have a narrow pass band at these frequencies than at the frequency of rotation of the work-piece.

Long slender rotors running at high speeds are in use in turbo-generators. Special balancing problems are associated with these due to the fact that their working speed is near to or in excess of the first critical speed. At this speed the rotor is in bowing resonance and simple two-plane balancing performed at low speed does not hold good at the increased working speed. For very high rotor speeds two-plane balancing, even done at correct working speed, is insufficient. Here the solution has been found by balancing in three and sometimes four planes.

New Real-Time Computer



The latest addition to the range of Ferranti computers is 'Hermes', a small, very fast and flexible, transistorized machine, which has been developed for real-time on-line applications, such as airline and railway seat reservations, air-traffic control systems, simulators, and numerous classified military requirements.

The prototype Hermes initially will have a 4,096-word core store, one paper tape punch and one paper tape reader, and drum and magnetic tape units will be added early in 1964.

An order for a Hermes computer has already been placed with Ferranti Ltd., by the Autonomics Division of the National Physical Laboratory at Teddington. This machine will be used initially for data processing and for optimal control of a pilot scale distillation column. Delivery is expected at the end of March 1964.

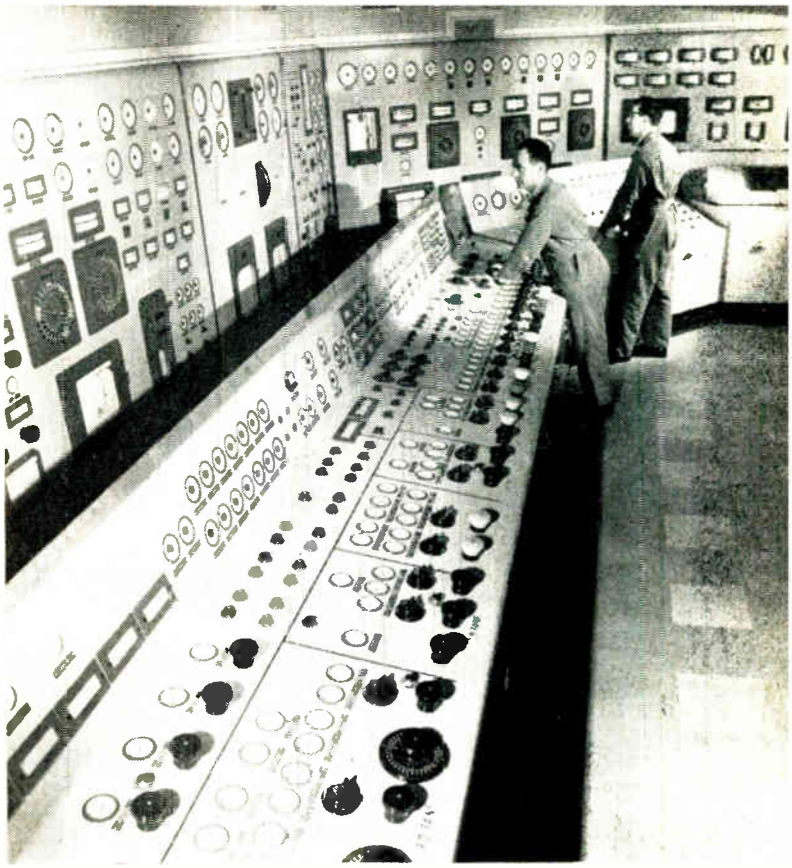
Hermes is a parallel machine with germanium NOR-logic operating at a clock rate of 1 Mc/s which allows a transit time through the network of gates of 0·65 μsec maximum.

In the basic machine, which has a word length of 24 bits, the core store can have either a 3 or 6 μsec cycle time. Using a store with a cycle time of 6 μsec, an addition time of 24 μsec and a multiply time of 44 μsec maximum can be obtained.

For further information circle 48 on Service Card

The basic Ferranti Hermes computer undergoing commissioning trials at the new Ferranti research and development laboratories at Bracknell, Berks

Elliott-Automation has supplied the complete automatic control systems for the six generating units at the C.E.G.B.'s Northfleet power station. Remote control of the 120-MW units is maintained from six separate 30-ft long control panels. The control system of each generating unit incorporates a comprehensive automatic data-logging system. Northfleet is the first conventional power station in Britain to have equipment of this kind to scan conditions at all important points throughout the plant, printing out an hourly log and giving an alarm signal in case of abnormal conditions. This system eliminates the necessity for a considerable number of conventional instruments and relieves operators from much dial-watching and form-filling.



1

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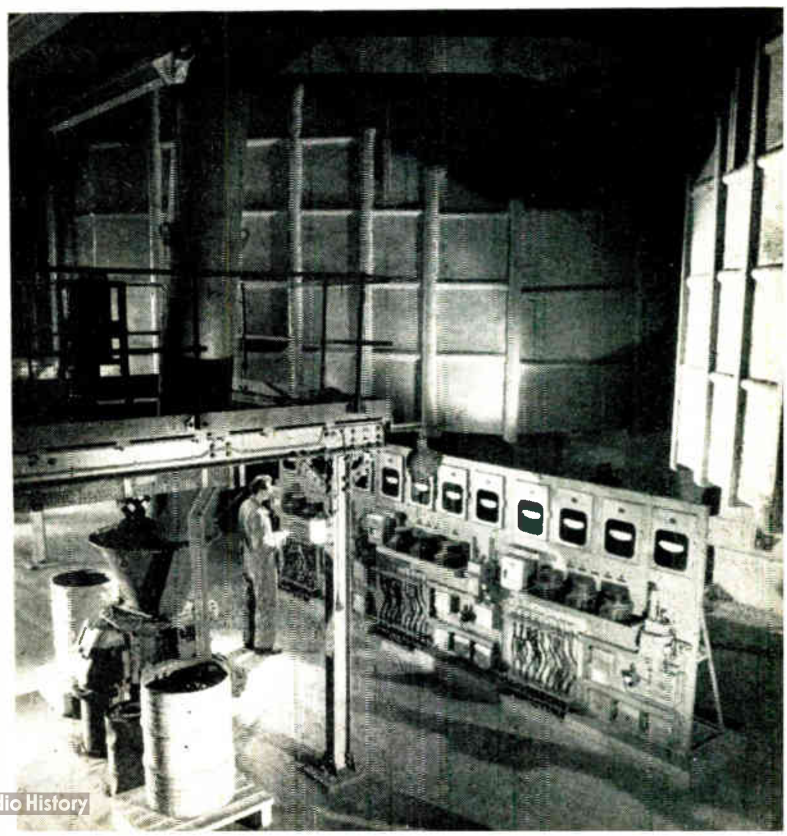
AUTOMATIC CONTROL SYSTEMS AT NORTHFLEET

3



1 One of the six 30-ft control panels which contain the instrumentation and remote controls for each 120-MW generating unit.

2 Six Elliott data-logging and alarm scanning systems cover over two hundred points on each of the generating units; this photograph shows the print-out end of one of them. The equipment also provides a trend record to give an indication of future operating performance.

3 This local transmitter panel (there are three for each of the six generating units) contains all the instruments associated with the coal pulverizers and furnace chamber which transmit signals to indicators in the main control room.

INDUSTRIAL NEWS

Personal and Company News

Harold P. Martin has been elected chairman of the BEAMA Export Panel in succession to Leonard H. Short, C.B.E., M.C. The vice chairman of the panel will now be **Frank Rostron, M.B.E.**

John Ayres, M.I.E.E., has been appointed managing director of **G.E.C. (Telecommunications) Ltd.**, and has accordingly resigned his positions with the Sears Engineering Group.

Bedford Computer Service Ltd., which began operations eighteen months ago, is shortly to move from its temporary accommodation at Gwyn Street, Bedford, into premises now being completed in one of the town's new development areas.

Rodney G. Kent has been elected chairman of the Federation of British Industries' Eastern Regional Council.

Frederick Arthur Robins, sales engineer at the Bristol office of **Brookhirst Igranic Ltd.**, has been appointed Bristol area manager.

The board of directors of **Beckman Instruments** have announced the appointment of J. R. McNally as managing director.

Harvey Hubbell Ltd. of Camberley, Surrey, announce the purchase of Grelco Ltd., manufacturers of electrical accessories. Grelco, whose London office is at 123A Gloucester Road, London, S.W.7., will operate as a wholly-owned subsidiary.

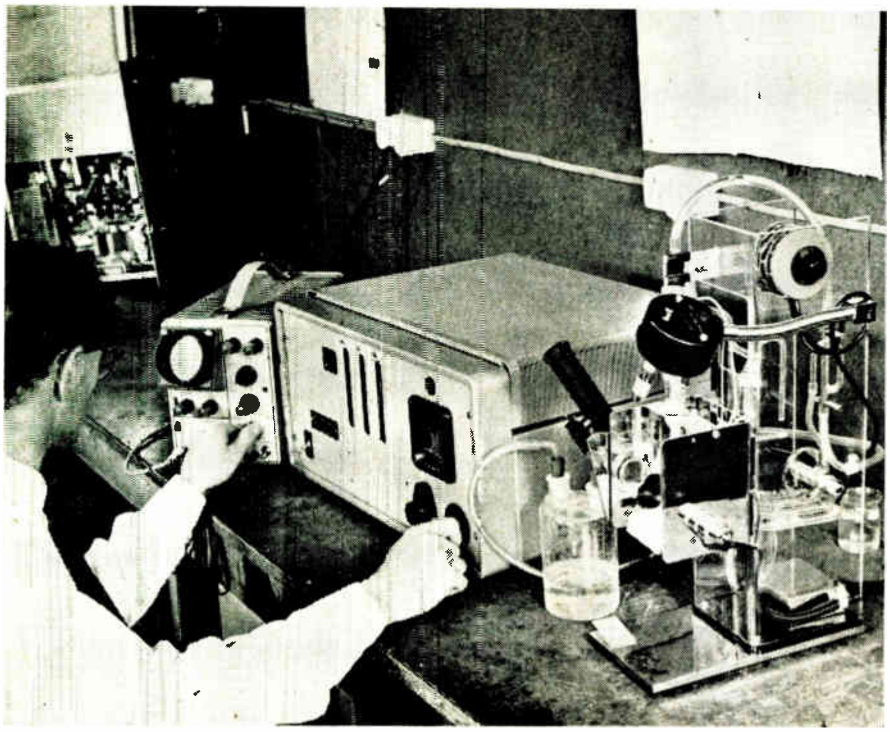
The Reliance Telephone Co. Ltd. have announced that E. Silbermann has retired as managing director. He will remain chairman and act in a consultative capacity. His successor as managing director is D. H. Broome, M.A.

General Precision Systems Ltd., formerly Air Trainers (Link), announce the appointment of W. B. Horner, Assoc. Brit.I.R.E., as manager of their Industrial Products Division.

It is announced that **Elliott-Automation Ltd.** has taken over from Evershed & Vignoles Ltd. their business in polarographs, thus extending their range of process and analytical quality control instruments.

Vactric Control Equipment Ltd. announce that they have installed a Telex system in their new head office at Garth Road, Morden, Surrey. The Telex number is 27796.

The Marconi International Marine Co. Ltd. announce that L. A. Hooper has relinquished his post as personnel and training manager to become manager, Establishments and Services. P. V. G. Lintzgy, previously manager, Operating and Traffic, becomes manager, Personnel and Operating.



The performance of a Coulter counter being observed by means of a Telequipment S32A Serviscope oscilloscope during an experimental test to check its efficiency. The Coulter counter can count particles at a speed in excess of 6,000 a second and produce particle size distributions in a range from 0·3 to 400 microns diameter. This technique considerably reduces the statistical error experienced in a conventional microscope count

S. Smith & Sons (England) Ltd. announce the appointment of three new directors to the board. They are: J. A. Blair, company secretary; R. G. Cave, managing director of Smiths Motor Accessory Division; and A. M. A. Majendie, who becomes managing director of Smiths Aviation Division.

R. M. Lustig, for three years publicity officer with **Racal Electronics** at Bracknell has joined United Kingdom Advertising at Reading. Racal's new publicity officer is A. E. Cutting who has moved from the Company's commercial division.

Richard Klinger Ltd. announce the appointment of H. Riley as home sales manager.

Gerrard Engineering Ltd. announce that the newly enlarged laboratory of their Swindon research and development department is now almost complete and that its staff of engineers and scientists has been increased to 70.

M. J. David, has been appointed general sales manager of **Lancashire Dynamo Electronic Products** and **Lancashire Dynamo Nevelin.** G. R. Minto, senior field sales engineer in the Scottish region for L.D.E.P., has been appointed central and S.E. London area manager. A. J. Lodge takes over in Scotland.

Baird Atomic Inc. of Cambridge, Mass., has been granted a licence by **Elliott-Automation Ltd.** to manufacture and sell throughout North America the Elliott X-ray fluorescence spectrometer.

J. A. Avery, chief inspector at **Avo Ltd.** has been appointed chief engineer.

The formation has been announced of **Parker PR Associates Ltd.,** a public relations company specializing in the industrial, scientific and technological fields. The directors of the new company, which incorporates the Press Relations Division o' Roles and Parker Ltd., are H. T. Parker (chairman), Norman Manners, W. W. Chick, Alexander Thomson and H. Burson. Offices of the company are at 22 Red Lion Street, London, W.C.1. Telephone: Holborn 3353.

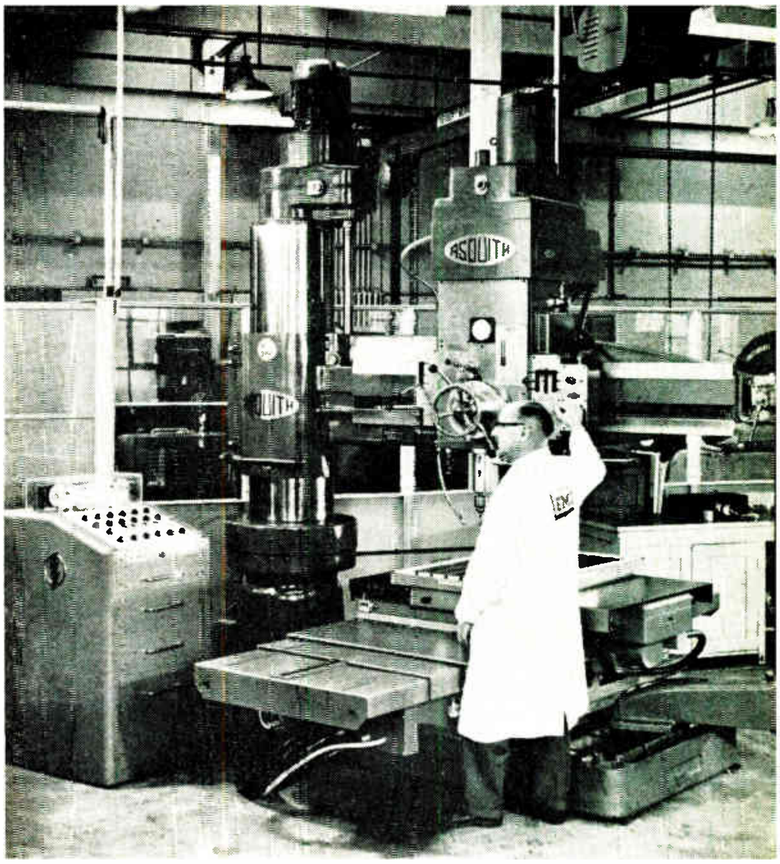
Kerry's (Great Britain) Ltd. have acquired the whole of the issued share capital of P. G. Day (Electronics) Ltd. of Wilbury Way, Hitchin, Herts. This new subsidiary has for some time been manufacturing the electronic equipment incorporated in the products of Kerry's (Ultrasonics) Ltd.

Waldo Thorn, general manager of **International Rectifier Co. (Great Britain) Ltd.** of Oxted, Surrey, has been appointed a director.

R. M. Herbert, D.F.H., A.M.I.E.E., has been appointed sales manager for **Hirst Electronic Ltd.**

B.I.C.C. and I.C.I. announce that they have now completed the formalities involved in setting up **British Kynoch Metals Ltd.** The registered office of the company is at 6 Laurence Pountney Hill, London, E.C.4., with the operating headquarters at Prescot, Lancs.

The following new appointments in the **A.E.I.** publicity department are announced:—manager, Publicity Services—O. W. J. Farmer; manager, Company Information—Peter Gillibrand. Group publicity managers are appointed in Leicester, Manchester, Rugby and London. They are responsible to the general manager of the publicity department.



The David Brown CPT 30 co-ordinate table with Emicon B100 electronic positioning control has now been successfully applied to the Asquith 3 PS radial drilling machine. A zero-shift facility allows the setting of a workpiece anywhere on the table irrespective of the programming of the component, and also enables two or more similar components sited at different positions on the table to be machined in turn from a single tape. The 5- or 8-channel control tape is produced on a simple keyboard tape-perforator, or alternatively a teleprinter may be used which at the same time as producing the tape prints a check sheet which can be compared with the original table of 'X' and 'Y' co-ordinates

The Communications Division of **Redifon Ltd.** has appointed an agent for the sale of Redifon communications equipment throughout Germany. He is H. Rikard-Petersen of Copenhagen, Denmark, who also handles the sales of Redifon communications equipment in Iceland, Greenland and Denmark.

Submarine Cables Ltd., owned jointly by A.E.I. and B.I.C.C., announce that the registered office of the company is now at Christchurch Way, Greenwich, London, S.E.10., telephone: Greenwich 3291.

Institution of Electrical Engineers

The *Journal of the Institution of Electrical Engineers* will have a new title next year—*Electronics and Power*. The Council of the Institution want to emphasize the range of the Institution's activities, and feel they have chosen a name that reflects the breadth of electrical technology. The first copy of *Electronics and Power* will appear in January 1964. It will be published monthly and its cost to non-members will be 10s. 0d. a copy, or £5 a year. Also to be renamed are the three quarterlies; they will become *Electronics Record*, *Power Record* and *Science and General Record*.

Exhibition

The annual exhibition of The Institute of Physics and the Physical Society will be held at the Horticultural Halls, London, from 6th to 9th January 1964.

Continuous viscometers manufactured by Elliott-Automation monitor lubricating oil product streams on a clay treatment plant at Esso's Fawley refinery

For further information circle 49 on Service Card

Cables Help to Find the Fish

The finding of fish remains largely a question of experience, but now echo sounders are coming to the aid of the fishing trawlers. Having been located by means of this equipment the fish can be recorded actually entering the net, the depth of the shoal and its density are readily ascertained and many hours of trial and error are saved.

With a mid-water (floating) trawl success depends on information of the trawl behaviour being available on board the vessel while the operation is in progress. One such system with which good results have been achieved by the M.O.F. Fisheries Laboratory, was recently operated from the research vessel 'Clione'. A transducer or 'fish spotter' was attached to the trawl headline, the other equipment consisting of a commercial echo sounder (the Kelvin Hughes M.S.29 paper recorder), a cable winch, and special cable.

To link the echo sounder on board with the transducer a coaxial type cable with the necessary tensile and electrical properties was essential. The cable was manufactured and supplied by B.I.C.C. and consists of a 40/0·0076 sq in. tinned copper wire inner conductor, polythene insulated; tinned copper wire outer conductor; p.v.c. taped with a stainless steel wire braid strain member and p.v.c. sheathed overall.

This cable has proved completely satisfactory in use, successfully withstanding repeated winching under severe tension. It has been employed in home fishing grounds, as well as in the most arduous conditions in deep Arctic waters, where the p.v.c. sheath resisted the intense cold without being affected in any way.

For further information circle 50 on Service Card

Northern Polytechnic

Part 2 of a course of 26 lectures on The Principles of Modern Network Theory is being given by F. E. Rogers, A.M.I.E.E., A.M.Brit.I.R.E. at the Northern Polytechnic, Holloway, London, N.7, starting on 10th January 1964. Part 2 is an Introduction to Synthesis and the fee for it is 30s. plus 1s. registration fee. It is intended for graduates or those possessing similar qualifications.

Electronics R & D Study

The D.S.I.R. and a panel of trade associations representing the electronics industry have agreed to undertake an economic and technical study of the research and development problems of sections of the electronics industry. This has been prompted by the growing importance of electronics and electronic apparatus for technological progress in other industries, especially in the field of automation. A more detailed understanding of the directions in which the electronics industry is developing will help both industry and Government to use available resources to the best advantage. Because of their particular interests in electronics the Ministry of Aviation, Board of Trade, Admiralty and Post Office are also taking part.

The following seven trade associations are co-operating in making arrangements for the study: British Electrical and Allied Manufacturers' Association, Business Equipment Trades Association, Electronic Engineering Association, Electronic Valve and Semi-Conductor Manufacturers' Association, Radio & Electronic Component Manufacturers' Federation, Scientific Instrument Manufacturers' Association of Great Britain, Telecommunication Engineering & Manufacturing Association.

The study is to cover those firms which produce electronic equipment for the civil market, but not consumer products such as domestic radio, television, sound reproduction equipment, etc. Since a significant proportion of the total effort of the industry is employed on defence contracts, an examination will be made of the extent to which such work is, or could be, applied to products for the civil market. Similar considerations apply to work on line telecommunications and broad-band radio-relay equipment which is also to a large extent separate from the ordinary civil market. Research and development in electronic components, including semiconductors, will be considered in so far as they affect the development and production of electronic capital goods for the civil market.

Related fields of research in universities, Government establishments and user industries will also be surveyed. The field work will be carried out by a team composed of economists, scientists and engineers and it is hoped that the study will be completed in eighteen months to two years.

New Members of Research Council

The Minister for Science, Lord Hailsham, has appointed two new members to the Council for Scientific and Industrial Research. They are Sir Leon Bagrit, Chairman of Elliott-Automation Ltd., and Sir Lindor Brown, F.R.S., Waynflete Professor of Physiology, Oxford University. They replace Professor C. F. Carter, who has resigned on his appointment as first vice-chancellor of the University of Lancaster and Vice-Admiral Sir Frank Mason, K.C.B., who has completed his term of office.

Conference on Solid-State Physics

The Institute of Physics and The Physical Society is arranging a conference on solid-state physics at the H. H. Wills Physics Laboratory, University of Bristol, from 1st–4th January 1964. This meeting will be an opportunity for the presentation and discussion of new work in the field of solid-state physics generally; meetings of this type may be held annually in future. It is not intended to restrict the programme to any particular theme, but invited lectures have been arranged this time on the following subjects: Fermi surfaces; Mössbauer effect in magnetic materials; defects in solids—some current problems. The meeting will also include sessions on semiconductors, spin resonance and other topics.

Correspondence

Equivalent Circuits

Sir,—Under the heading 'Equivalent Circuits' in your September issue you point out that while either series or parallel forms of the 'equivalent generator' can be used for calculating the power received by a load from an actual generator of any configuration, these 'equivalents' are not equivalent internally. In particular, the power dissipated in the internal resistance, and therefore the total power supplied by the fictitious resistanceless generator, are in general different in the two forms. Only when the load is matched are they equal.

The series form of equivalent is a direct application, generalized for a.c., of the theorem called Thévenin's (though Helmholtz anticipated it by 30 years), which is a device for simplifying calculation of the current (and, by implication, the power) in a resistance connected to two points in a generating circuit. There is nothing in the theorem to suggest internal equivalence. The comparatively modern use of the word 'equivalent' justifies your warning.

There is one respect however in which your warning might itself possibly mislead, when you say 'Attempts to evaluate the internal dissipation *may* be invalid, for instance. Only under the condition of a matched load do the two values of internal dissipation become identical.... When it is desired to evaluate the internal dissipation of a generator some care must be taken in the choice of an equivalent circuit for it' (My italics). This might be taken to imply that (a) when a matched load is used, giving the same values of dissipation in the two 'equivalents', that value is valid, and (b) one or other of the two usual equivalents, provided it was carefully chosen, would give the right answer. So it ought perhaps to be emphasized that (i) even when the load matches the generator, the internal dissipation in the 'equivalent' is in general not the same as in the actual generator circuit, and (ii) to devise an equivalent circuit for the purpose of calculating the internal dissipation would usually be more laborious and less reliable than referring to the actual circuit.

By far the commonest subjects for 'equivalent generators' are valves and transistors. In these the internal dissipation is made up of d.c. and a.c. parts, whereas the 'equivalent' recognizes only the a.c. part, and its internal dissipation manifestly bears no relationship to that in the actual valve.

The limited nature of the 'equivalent' in relation to valves was pointed out in *Wireless Engineer*, April 1947, by Dr. Salzberg, who claimed that the series form was more fundamental than the parallel. This question was examined in the same issue by Prof. Howe, who came to the conclusion that *for practical purposes* it was. Since the parallel form is the dual of the series form, theoretically neither can be more fundamental than the other, and if an unprejudiced basis for comparison is used (i.e., the ratio of actual load to matching load, in resistances or conductances as appropriate) that can indeed be shown to be so.

With reference to your preceding section, on the use of duality in teaching, may it be taken that you would have no objection to the procedure of introducing students to, say, the series 'equivalent'; then, when that was understood, using the principle of duality to derive from it the parallel form? If you did object, your choice of the word 'cavil' would seem to be apt. I have not myself come across books that introduce both forms simultaneously (by parallel columns?) nor any that present one and leave the other to be inferred by duality, with the intention of simplifying it for the reader. I agree that the latter would be deplorable, and the former (while emphasizing the essential symmetry) would probably be inferior in practice to the procedure previously mentioned, but it would be better, in my opinion, than expounding both forms and omitting to point out their dual relationship.

M. G. SCROGGIE.

Bromley, Kent.

[*Further comment on this subject will be found on p. 753. Ed.*]

NEW BOOKS

Electronic Circuits and Instrumentation Systems

By JACK J. STUDER. Pp. 423 + xiii. John Wiley & Sons Ltd., Glen House, Stag Place, London, S.W.1. Price 80s.

There are three sections in this book covering circuits, electronics, and electronic instrumentation systems. The first contains five chapters dealing with sinusoidal signals and the basic elements of circuits, the responses of one- and two-port circuits and the step-response of circuits. A great deal of this is very elementary.

The second section on electronics is the largest. It starts by dealing with electron flow in a vacuum and goes on to deal with triode characteristics using the usual graphical methods. This is all quite well done, but tetrodes and pentodes are treated very cursorily. This is followed by a long chapter on current flow in semiconductors. After that come chapters on amplifiers and feedback, electron flow in gases, rectifiers and electron-beam display tubes. Sandwiched between these and the final chapters on modulation and demodulation is, rather oddly, a chapter dealing with valve voltmeters.

The third section, to which the earlier part is supposed to lead up, is by far the shortest. Strain-gauge systems are dealt with and systems with d.c. inputs, which include chopper modulation. Whole chapters are then given to systems for nuclear magnetic resonance spectroscopes and infra-red spectroscopy.

Elements of Transistor Technology

By ROBERT G. MIDDLETON. Pp. 288. Howard W. Sams & Co. Inc., Indianapolis 6, Indiana, U.S.A. $6.95.

Nearly one-half of this book is devoted to explaining how semiconductor diodes and transistors work. The remainder deals with their use. The various common circuit arrangements are described and their operation is explained with the aid of transistor characteristics and load lines. There is a chapter on bias stabilization and others cover amplifier fundamentals, equivalent circuits and a.f. amplifiers with negative feedback. The last chapter deals with the fundamentals of logic and computers.

There is very little mathematics indeed in the book and the treatment is almost wholly explanatory. It forms a useful introduction to the transistor.

Digital Techniques

By D. W. DAVIES. Pp. 158 + xi. Blackie & Son Ltd., 5 Fitzhardinge Street, Portman Square, London, W.1. Price 30s.

The fact that the author belongs to the Autonomics Division of the National Physical Laboratory might lead one to expect that this book would be a very highbrow one. Such an expectation would be quite wrong. For its subject the presentation is unusually simple and hardly any mathematics are used.

According to the author 'This book should be particularly suitable for someone who uses digital electronics as a tool rather than as an end in itself; the experimenter who wishes to prepare data for a computer rather than the computer designer'.

The early chapters cover the coding and collection of digital data and the logical design of digital systems in a fairly elementary way. Chapter 4 deals with digital circuits of both valve and transistor types. Although their modes of operation and design requirements are explained, the treatment is rather brief and is sometimes marred by jargon which will not be understood by everyone. This chapter, in fact, is likely to be completely intelligible only to an electronic engineer who is familiar with pulse circuitry. In general, this is not the sort of person for whom the author intends the book.

The next chapter deals with digital circuits using reactive components. Then there is one on pulse counting circuits and devices, followed by chapters on long-term storage and the use of digital data. The book ends with a chapter on the design of a digital system.

Recent Developments in Network Theory

Edited by S. R. DEARDS. Pp. 250 + xii. Pergamon Press Ltd., Headington Hill Hall, Oxford. Price 84s.

This is the proceedings of a Symposium which was held at the College of Aeronautics, Cranfield, in September 1961. The sessions covered linear passive network theory, linear active network theory and non-linear network theory and each was divided into two sections on analysis and synthesis. All told there are 14 papers in the book, and they are mainly for the specialist in network theory.

Electronic Tests and Measurements

By ROBERT G. MIDDLETON. Pp. 288. Howard W. Sams & Co., Inc., Indianapolis 6, Indiana, U.S.A. Price $6.95.

This book is intended for the technician and it should certainly be useful to anyone who is a newcomer to testing and measurement but has already a sound elementary knowledge of electronic theory. It is not for the complete beginner, nor is it for the qualified engineer.

Some will consider it a fault that no stress is laid upon accuracy of measurement nor on the possibility of faults arising in the measuring equipment. It is a commonplace that the newcomer to measurement is much too apt to accept the indications of his instruments as true and to forget that it is just as possible for faults to develop in them as in any other apparatus.

The utility of the book to the technician, which is considerable, would have been much greater had a more suspicious attitude to measurement been impressed upon him.

Manufacturers' Literature

Nuclear Enterprises 1963/64 Catalogue. This 94-page publication is an excellent example for producers of catalogues to follow. It lists the company's range of products, illustrates them, includes relevant specifications and gives prices. This particular catalogue covers scintillators, nucleonic instruments and low-level counting installations produced by
Nuclear Enterprises (G.B.) Ltd., Sighthill, Edinburgh.

For further information circle 51 on Service Card

Ultra-Pure and Semiconductor Materials. A 41-page catalogue which contains the properties and specifications of more than 15 different products used by research laboratories and the electronics industry. The four main section headings are: Germanium, Silicon, Intermetallic Compounds and Ultra-Pure Elements. Manufactured by Hoboken and marketed by
Société Générale des Minerais, S.A., 31 Rue du Marais, Brussels 1, Belgium.

For further information circle 52 on Service Card

Decca Waveguide Switches. Described in this 14-page brochure is a complete range of manual and automatic (electro-mechanical) switches which have been designed for use in microwave systems, laboratory measurements and test circuits. These switches provide greater than 100 dB isolation over the whole waveguide band.
Decca Radar Ltd., Decca House, Albert Embankment, London, S.E.1.

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Complete Newspaper Page Transmission. The fastest newspaper page facsimile equipment available in the world today is described in this 10-page brochure. With this a newspaper page can be transmitted over any distance in 4½ minutes.
Muirhead & Co. Ltd., Beckenham, Kent.

For further information circle 54 on Service Card

Keyswitch Relay Calculator. A single-sheet publication which provides a compact and complete reference to the 3,000 and 600 type relays produced by
Keyswitch Relays Ltd., 120-132 Cricklewood Lane, London, N.W.2.

For further information circle 55 on Service Card

'Data-Trak' Curve Following System. This 4-page leaflet briefly describes a curve follower which positions its own output potentiometer in accordance with a time-based programme plotted on metallized graph paper. Distributed in the U.K. by
Systems Engineering Services Ltd., 34 Bloomsbury Street, London, W.C.1.

For further information circle 56 on Service Card

Trinistor A.C. Power Regulators. This 8-page Engineering Publication No. 22-4/2 describes single and three-phase 50-c/s regulators. Full technical details and explanatory diagrams are included.
Westinghouse Brake and Signal Co. Ltd., 82 York Way, London, N.1.

For further information circle 57 on Service Card

★ FOR THE BUYER

You must have read about a number of products and processes in this issue of which you would like further details. You can obtain this information very easily by filling in and posting one or more of the enquiry cards to be found inset in the front and back of the journal.

INDEX

VOL. 1 INDUSTRIAL ELECTRONICS 1962-63

This index to Volume 1 covers the issues of Industrial Electronics *from October 1962 to December 1963 inclusive. References to the October to December issues of 1962 may be distinguished from those of 1963 by the page numbers, which are all less than 185 for 1962*

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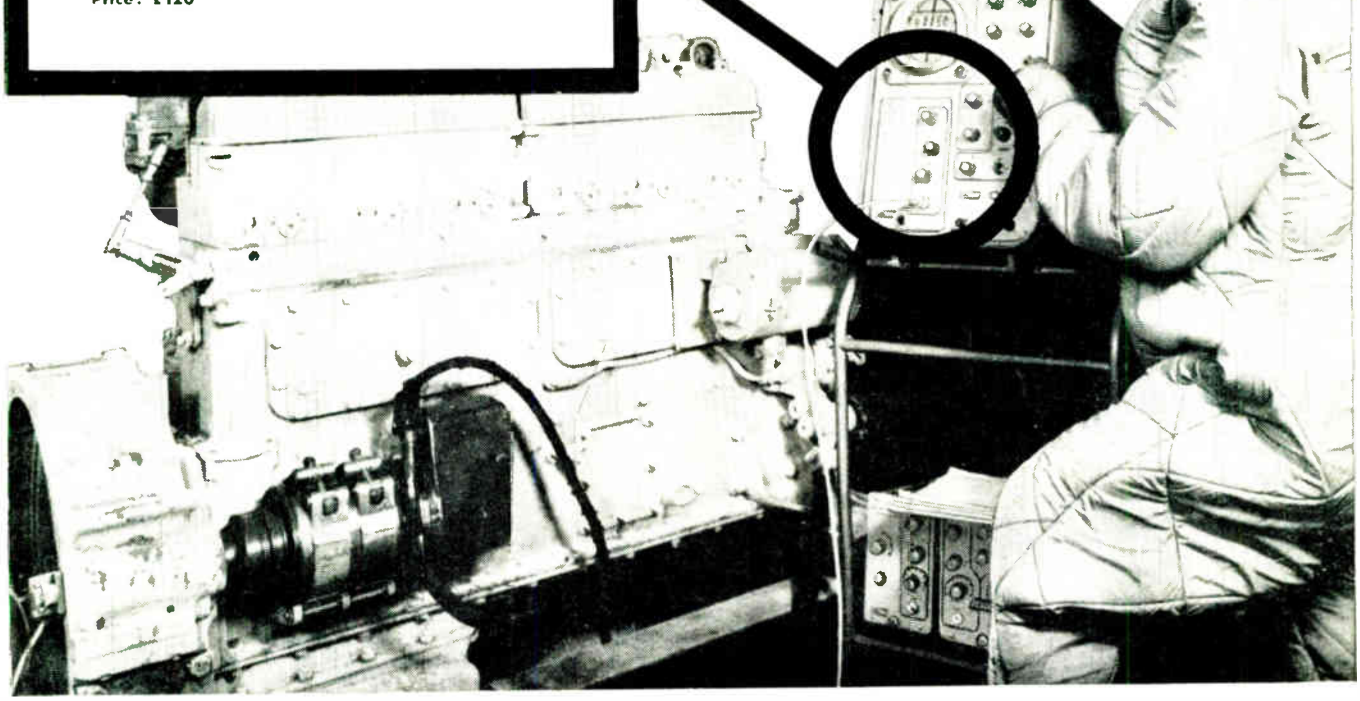

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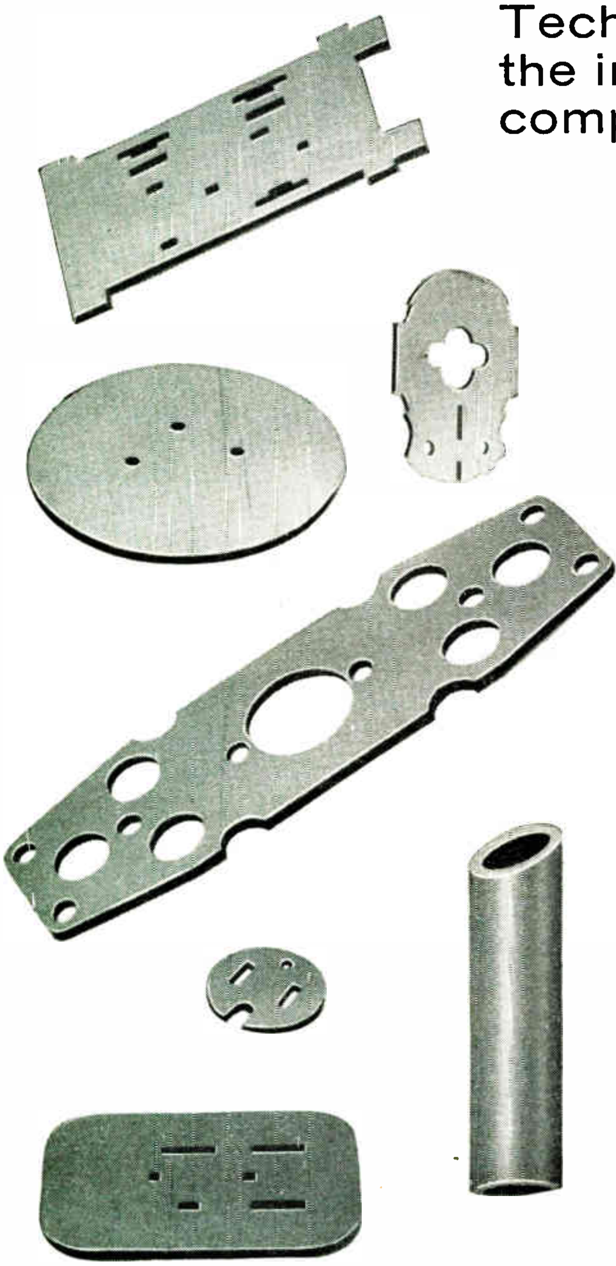

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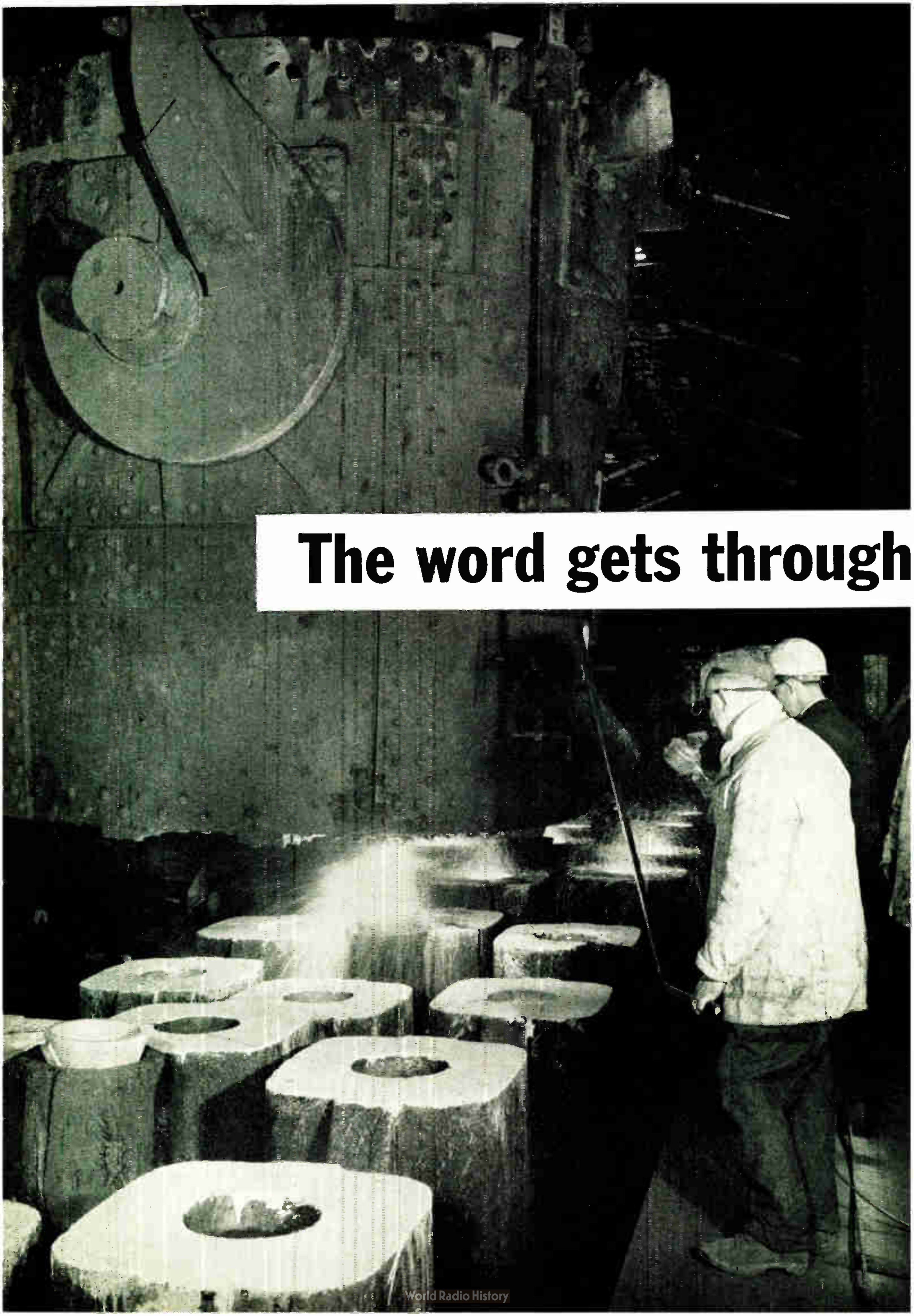

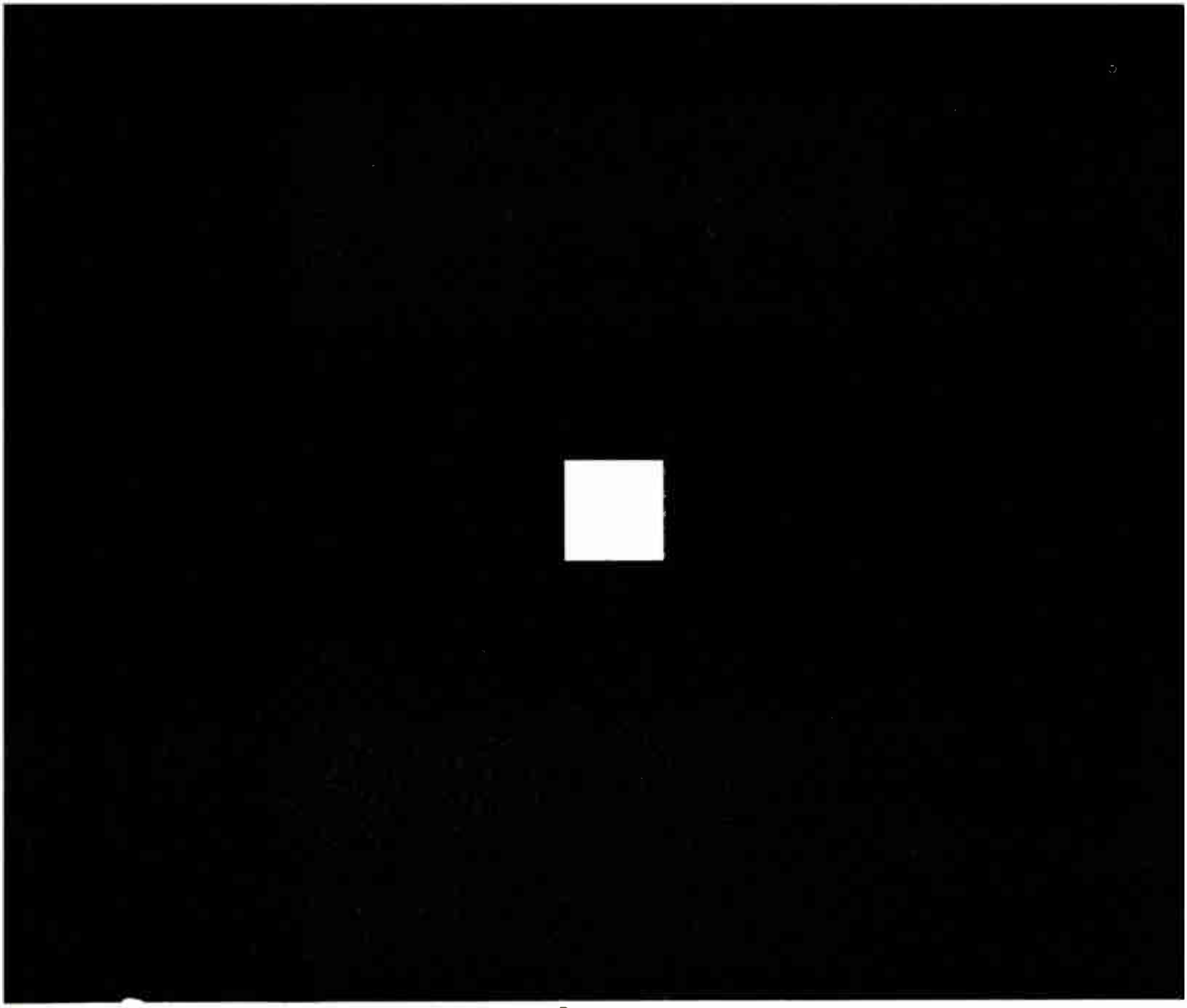

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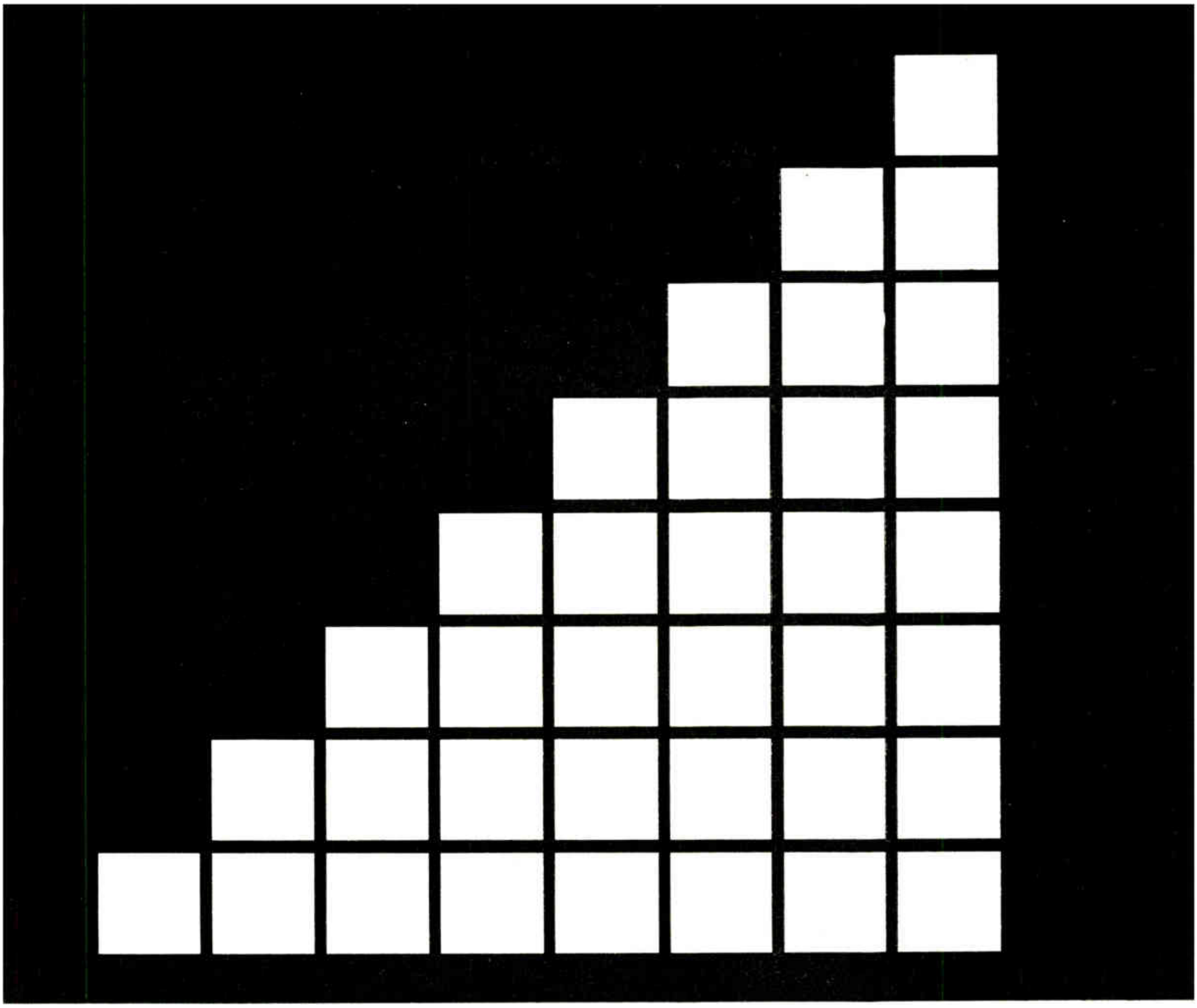

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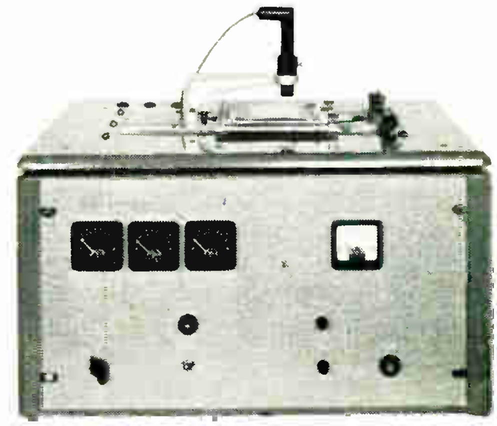

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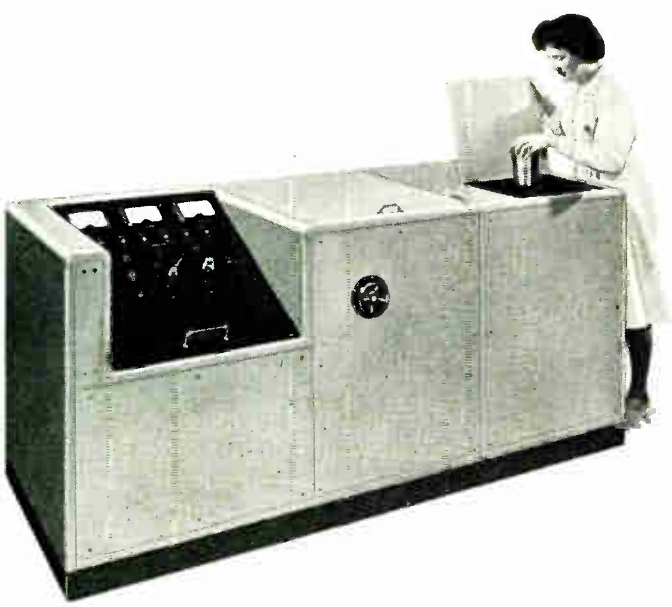

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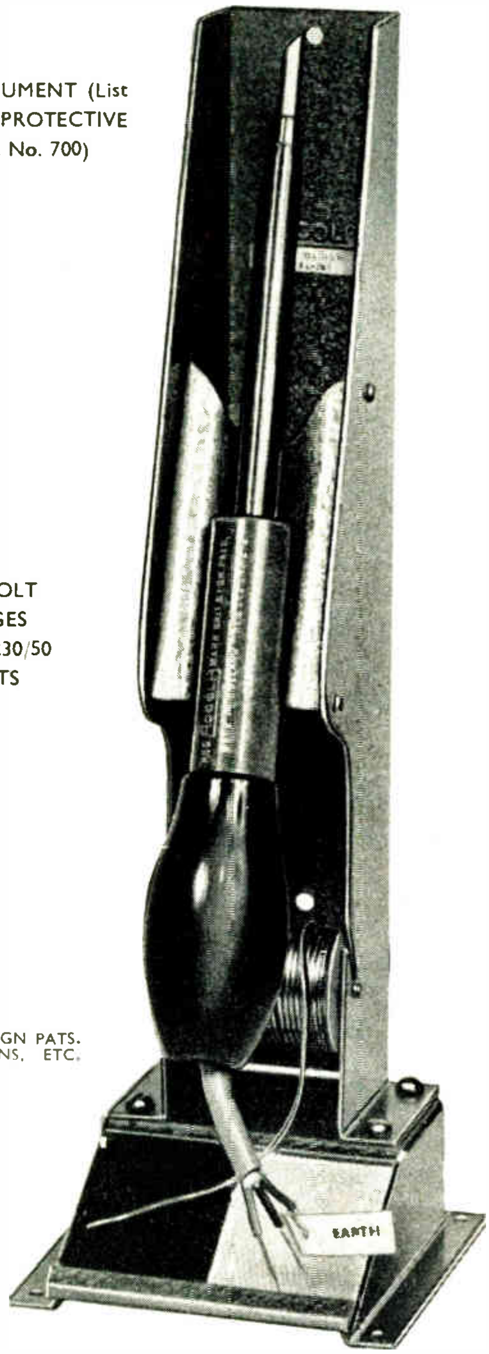
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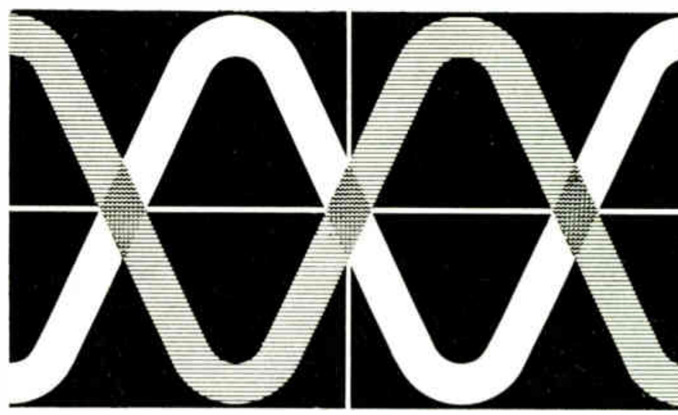

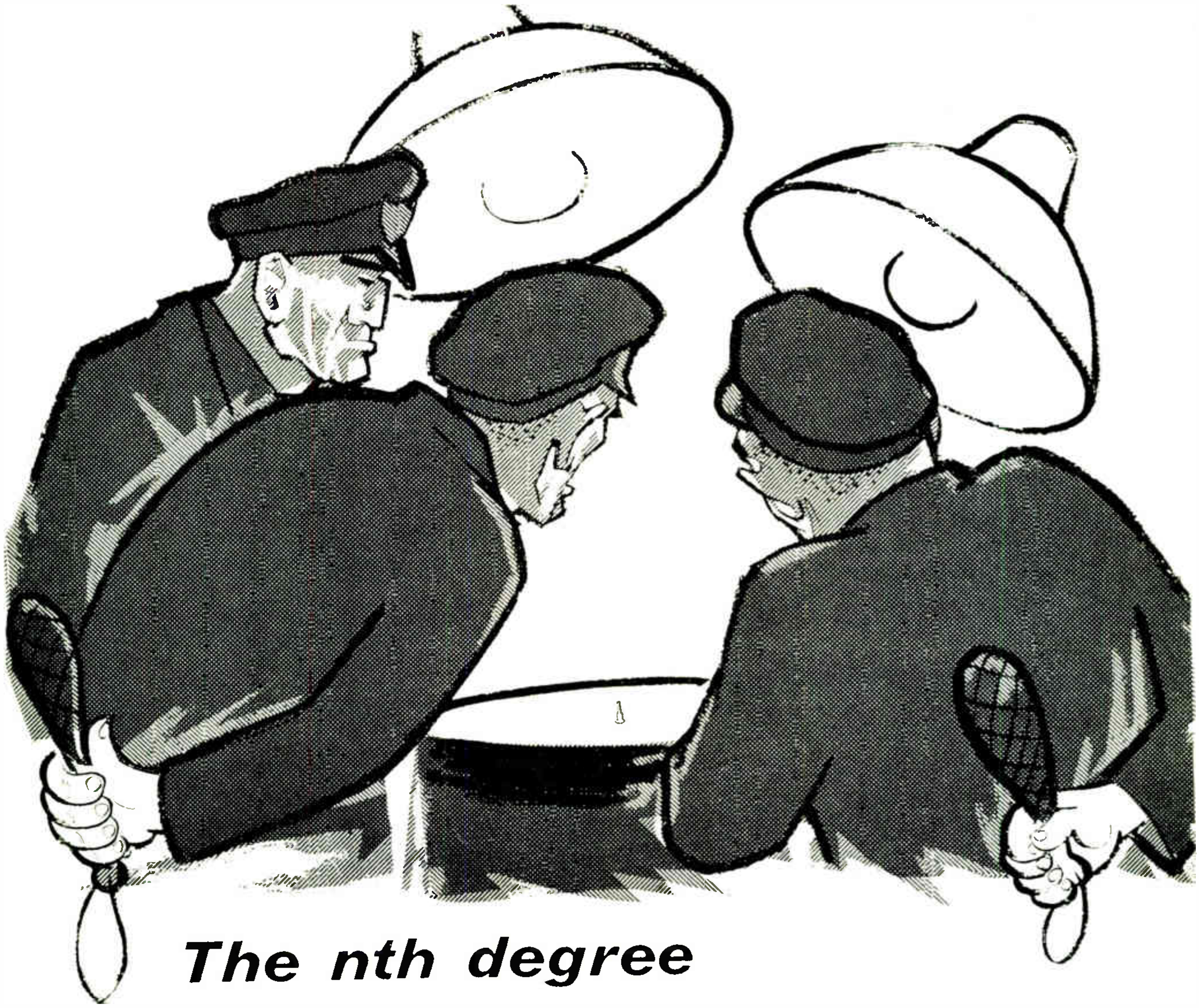

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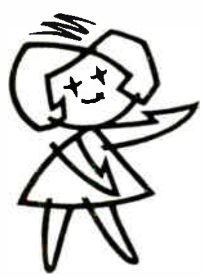

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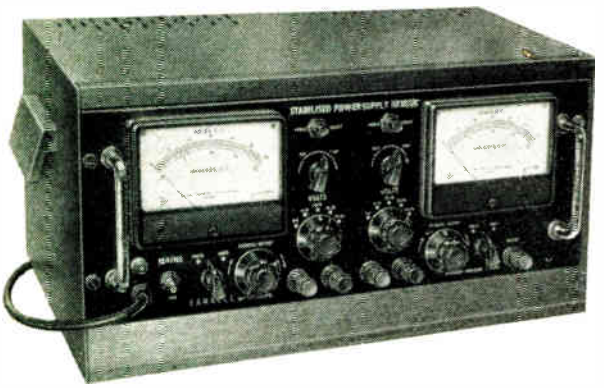

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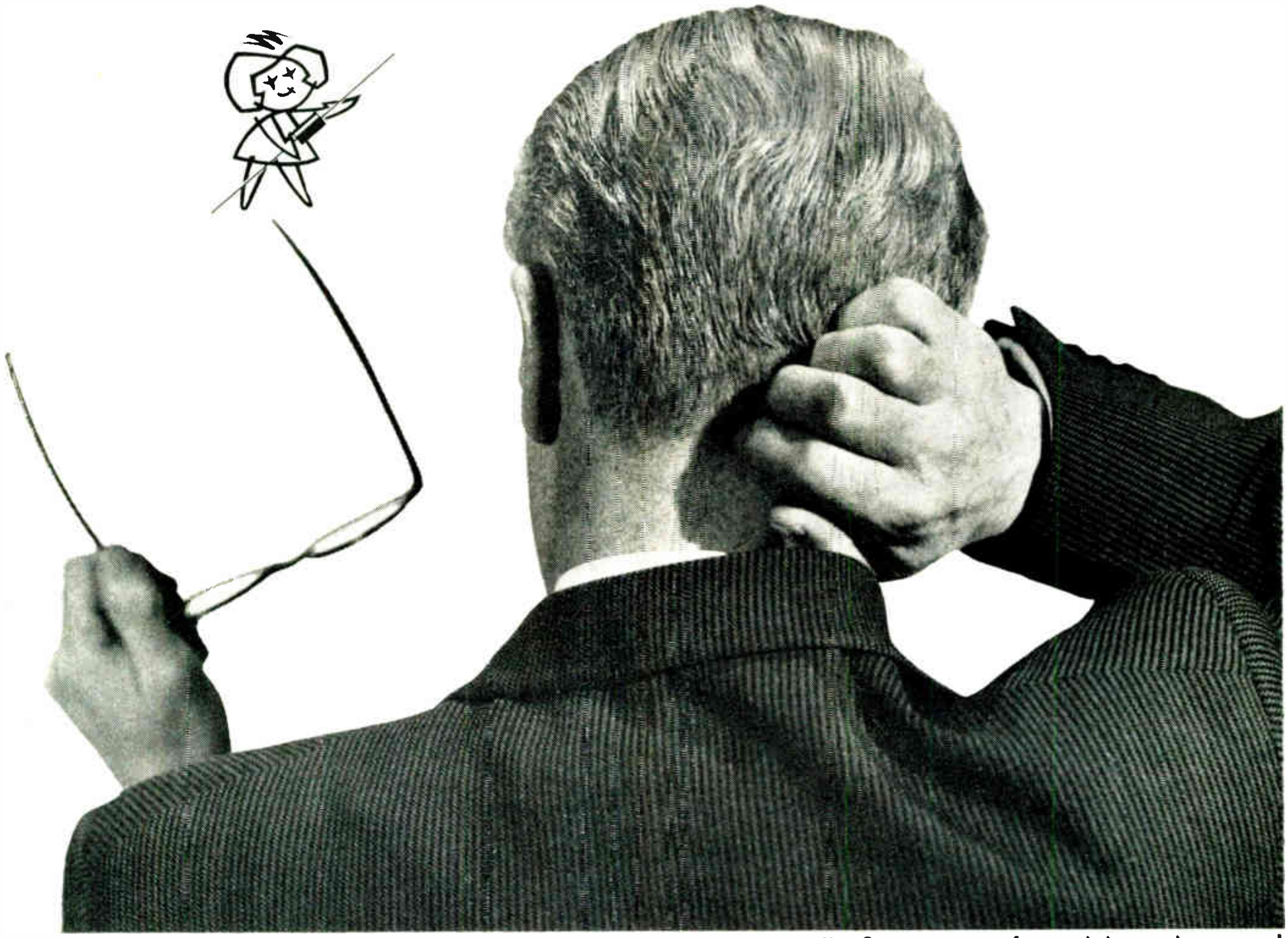

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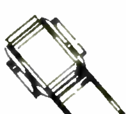

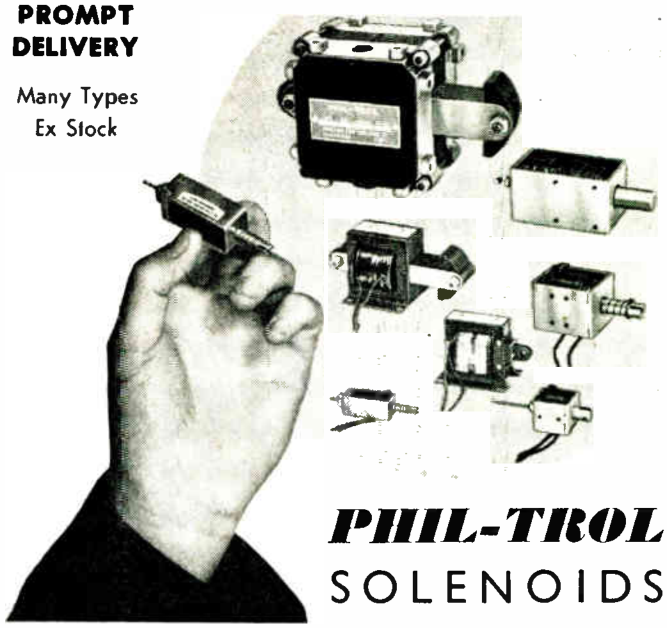

INDUSTRIAL ELECTRONICS

Press date for the January 1964 issue is first post 23rd December 1963

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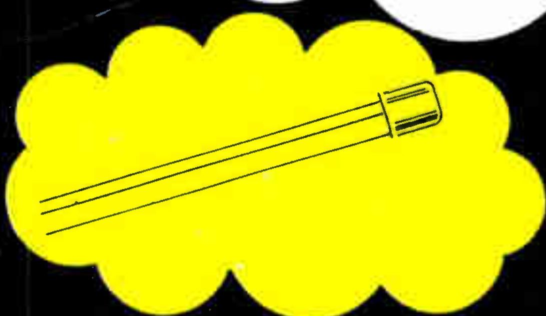

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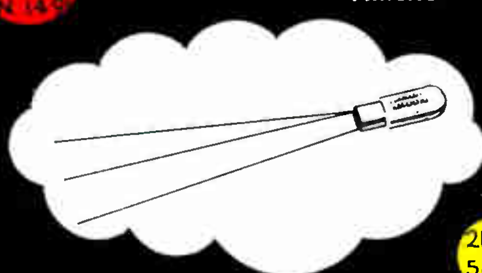

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