

by R. H. BRADBROOK and L. F. HOWARD

# 40/55kW U.H.F TELEVISION TRANSMITTER

## INTRODUCTION

The demand for u.h.f television transmitters throughout the United States and Western Europe, and to a lesser extent Eastern Europe, is increasing. But at the same time the user is concerned that the equipment he purchases contains the latest advances in design techniques and is reliable, and that running costs are kept to a minimum. Manufacturers must therefore keep abreast of the latest advances in technology in order to remain competitive.

Past generations of u.h.f transmitters have used four-cavity klystron amplifiers in the final stage. Such klystrons with output powers greater than 10kW have insufficient gain to be driven directly from current solid-state drivers, resulting in the need for an intermediate broadband amplifier to give the required drive level at the klystron input. One of two methods is generally adopted to overcome this problem. The first is to use a high gain travelling wave tube driven from a low output drive, and the second is to use a less complex valve amplifier, which requires a higher drive level of up to 5W. The latter arrangement is used successfully in the 40kW u.h.f transmitter B7308 when driven from the well-proven solid-state television driver.<sup>1</sup>

The introduction of a high gain five-cavity klystron, which can be driven directly from the solid-state driver, eliminating the need for an intermediate amplifier and its associated stabilized power supplies, is a major step forward in the design and reliability of high-power u.h.f television transmitters.

The high output level available from the driver allows the possibility of a pair of 55kW amplifiers, each using a klystron with a gain of 50dB, to be driven from a single drive unit to give an output of 110kW.<sup>2</sup>

The requirement for a klystron with a broadband output power of 55kW at peak sync and a gain of 50dB is met by the newly developed Varian VA953 series of u.h.f klystrons (Fig.1). This family is the basis of the 40/55kW u.h.f television transmitter type B7318 which is suitable for NTSC, PAL or SECAM colour, or black-and-white operation and is adjustable to give 55kW peak sync power for the

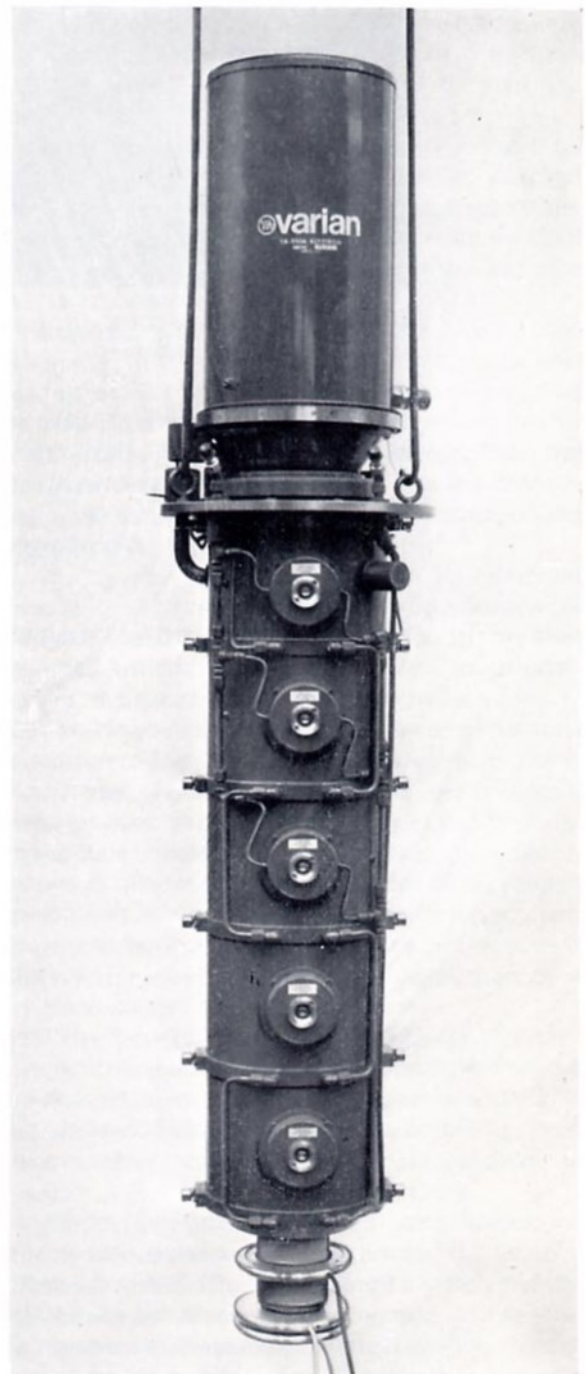
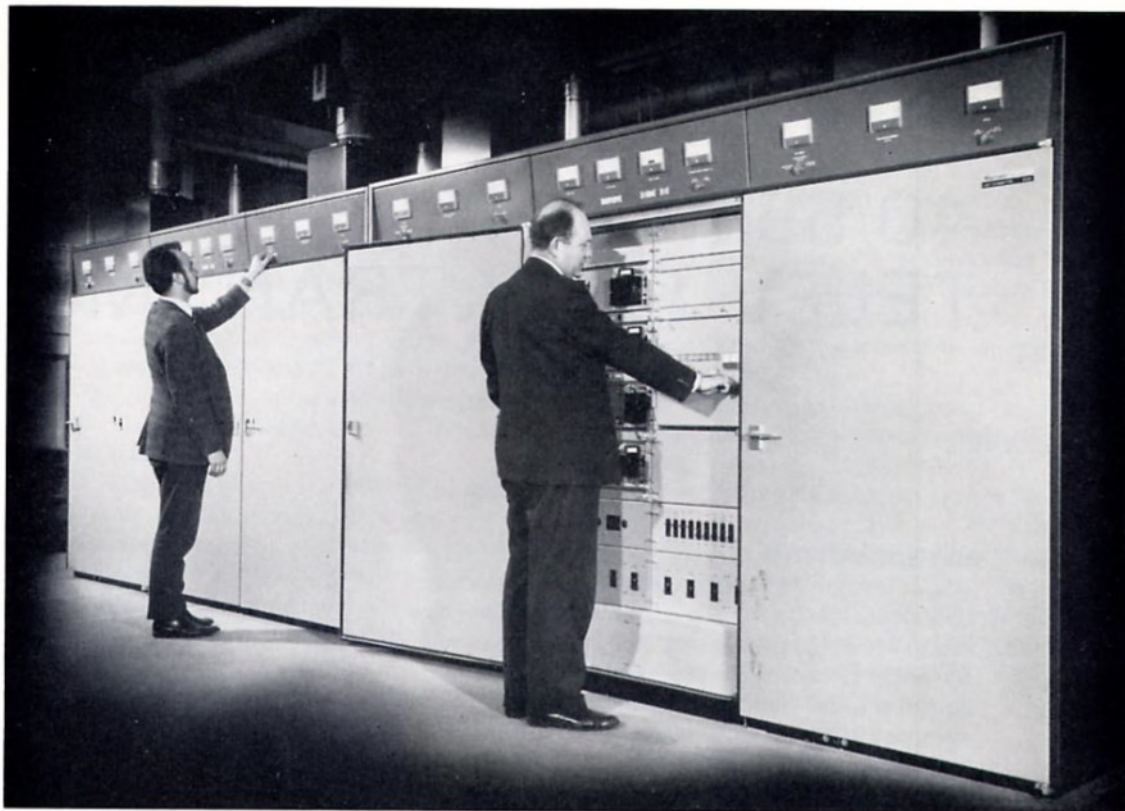


Fig.1 A klystron of the VA953 series.



*Fig.2 A pair of paralleled 55kW u.h.f transmitters. This transmitter is to be installed at Crystal Palace to provide the ITV colour service in the London area.*

American FCC standards or 40kW peak sync power for European CCIR, OIR, BBC, or ITA standards.

The transmitter incorporates the solid-state driver units,<sup>1</sup> and solid-state control circuits specifically designed for use in high-power broadcasting equipment.

#### **TRANSMITTER CONSTRUCTION**

A new transmitter cabinet has been produced in conjunction with industrial design consultants<sup>2</sup> which has an attractive appearance and which gives excellent accessibility both at the assembly stage and subsequently during operation.

The cabinet and enclosure framework dimensions are specifically tailored to suit the container method of transportation. This allows the equipment to be packed in a container at the factory and sealed. It can then be transported directly to site arriving complete and undamaged. The resultant cabinet is a free-standing unit approximately 1.12m wide, 1.12m deep and 2.04m high, constructed from aluminium alloy. Each one is mounted on a welded steel plinth for ease of transportation and rapid installation. Separate plinths to overcome irregularities in the floor surface are therefore unnecessary.

The transmitter (Fig.2) consists of three such cabinets and a h.t enclosure bolted together to give a frontal length of 3.25m and a depth of 4.12m. The outer cabinets house the sound (aural) and vision (visual) klystrons, while the centre one contains the control unit, solid-state driver units, monitoring services, and low voltage power supplies required

for the control circuits. The fully interlocked enclosure at the rear of these three units contains the klystron h.t power supply, smoothing circuits and water pumping unit, although the latter may be mounted externally if the customer so requires. Operators are protected from voltages in excess of 70V peak by a mechanical key interlock system which only allows access to the enclosure and klystron gun assemblies after the incoming main three-phase supply has been isolated and the h.t transformer secondaries and the smoothing capacitor terminals are earthed.

An auxiliary three-phase mains supply remains energized after access is gained and labelled protective covers prevent accidental contact with lethal voltages. This arrangement allows low power measurements to be made in safety.

The exterior of the equipment is finished in durable two-tone grey stoved hammer paint, except for the angled meter panel which is azure blue.

The front doors of the equipment are not interlocked giving access to the klystron tuning controls, solid-state driver, overload and status indicating unit, protective circuit breakers, oscilloscope and v.s.b demodulator units.

#### **THE KLYSTRON**

The development of the high gain Varian klystron originated from the need for higher power u.h.f television transmitters for the American networks. It is not intended to extol the virtues of four and five-cavity klystrons, but rather to give a brief



account of the evolution of the five-cavity klystron from an existing four-cavity design, widely used in the United States. The choice of an integral cavity klystron was based primarily on the consideration that r.f leakage currents from the many sliding finger contacts and joints of an external cavity design can cause external feedback at the higher gain levels and must therefore be minimized. The design approach was simply to add an additional driver cavity to the existing four-cavity arrangement, resulting in a klystron which produces a minimum of 62kW saturated output power with a gain of 48-50dB.

Typical saturated efficiency is 38% when tuned for a 1dB bandwidth of 8MHz. Operating at 55kW peak sync, the linearity with a ten-step staircase signal is approximately 70%. With colour sub-carrier bursts superimposed on each step the high-frequency differential gain is also about 70%, with a differential phase error of about 3°. When operated in sound service at one fifth of the vision peak sync power a similar efficiency can be obtained by suitably biasing the modulating anode.

Each tube is completely tunable over its portion of the u.h.f frequency range with no adjustment necessary to the input and output cavity coupling. Furthermore no external cavity loading is required to achieve a smooth frequency response over the required bandwidth.

There are klystrons in the series suitable for trans-

mitter powers of 25kW, 40kW and 55kW, with a common electromagnetic focussing assembly for any given frequency band.

An impregnated tungsten cathode of relatively low wattage (120W) is used for long life. Klystrons of similar design have achieved lives in excess of 16,000 hours in television service without loss of emission.

#### THE R.F UNIT

Despite the fact that the combined weight of a klystron and its focussing assembly exceeds 450kg, a quick and easy method of loading them into their cabinet has been devised.

The klystrons of the VA953 series are fitted with sets of rollers which run between rails both within the electromagnet and the packing case. Advantage has been taken of this roller system by designing a trolley which enables the klystron to be loaded into the electromagnet without the aid of a hoist. A second trolley has been designed to load the electromagnet into the transmitter.

Each electromagnet has a pair of trunnion pads on its outer shell. Side plates with rollers are attached to these and are used to mount the assembly in the cabinet. Once in position the magnet can be tilted from the vertical to the horizontal position and *vice versa* by means of a leadscrew.

On installation, the magnet fitted with its side plates is lifted onto its trolley where guide rails ensure correct alignment. The trolley is positioned in front of the r.f cabinet and dowels ensure that its rails line up with those in the cabinet. Then the magnet is rolled from the trolley into the cabinet, its final position being determined by stops on the cabinet rails.

The klystron trolley has provision for mounting two klystrons, one above the other, on a framework which pivots about its horizontal axis. The klystron is rolled from its packing case into the lower position and is retained by a latch. To replace a faulty klystron the magnet assembly is tilted to the horizontal position in the cabinet. The klystron trolley is wheeled to the front of the cabinet and is aligned with dowels. The faulty klystron is pulled from the electromagnet onto the rails in the upper position on the trolley, the trolley frame then being rotated to bring the replacement klystron to the top position from which it is pushed into the magnet. Figures 3 and 4 show two stages in the installation of a klystron.

Where frontal access to the transmitter is restricted, the klystron can be loaded into the magnet while the latter is on its trolley, either vertically by a hoist or horizontally from the klystron trolley. Then the complete klystron and magnet assembly is loaded as described for the magnet alone.

With the exception of the three high-voltage connections to the modulating anode and the heaters, all the electrical connections to the klystron and the electromagnet are made by plug and socket. The water connections are of the self-sealing, quick-release type; the output coaxial feeder is also of a quick-release design and is held by a pair of band

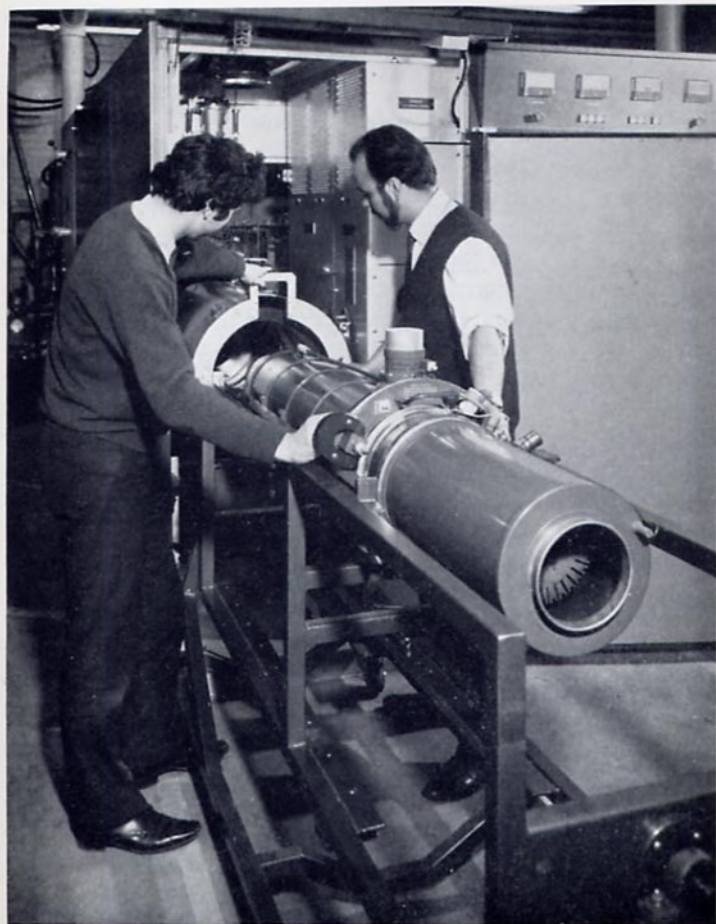


Fig.3 Loading a klystron into its focussing assembly.



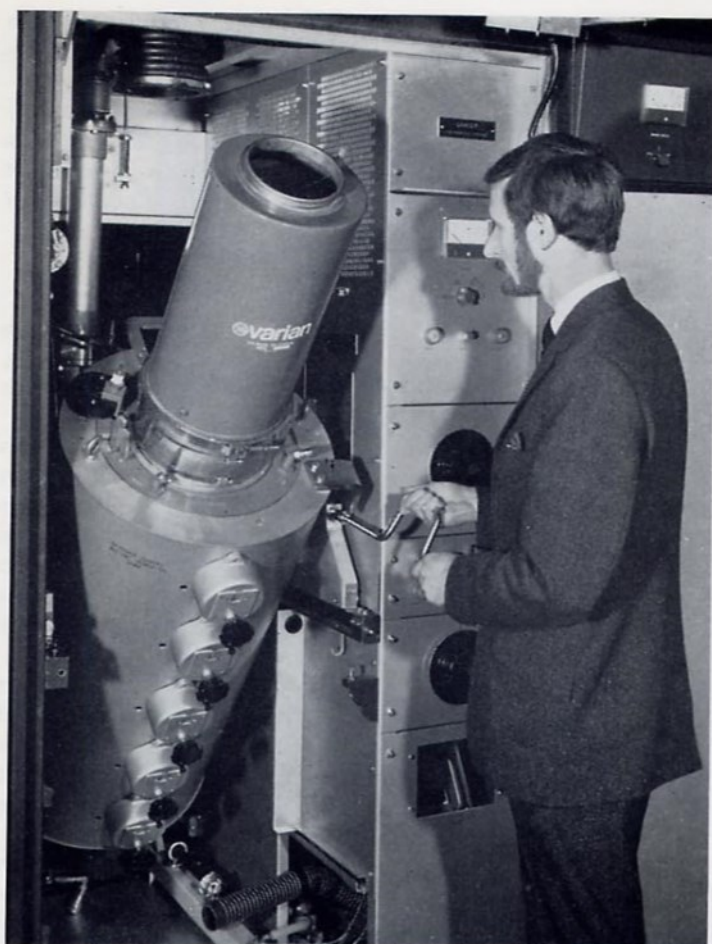


Fig.4 Tilting the klystron and focussing assembly from the horizontal to the vertical position.

clamps. Thus the time taken completely to disconnect the klystron assembly is kept to a minimum. A practised operator can complete the changing and warming-up of a klystron in less than fifteen minutes.

The r.f. cabinets house all the klystron auxiliary supplies, leaving the control cabinet free from high voltage sources. The arrangement permits an additional vision klystron cabinet to be included in the transmitter assembly with the minimum of modification. The outputs of the two vision klystrons can be paralleled to give twice the vision output power. The output of the sound klystron is raised to maintain the usual 5:1 power ratio. The driver is used to drive both klystrons, eliminating the need for complex phasing equipment.

The heater supply can be adjusted to cater for both the 40kW and 55kW klystrons. The focus supply is also variable to cover the differing requirements of sound and vision klystron operation. Protection circuits ensure that the h.t. cannot be applied until the focus current is within predetermined limits.

An ion pump is fitted primarily as a vacuum gauge, but it can be used to pump down the klystron in the event of any gassing in operation or storage. A trip circuit within the ion pump supply removes the h.t. when the ion current exceeds  $50\mu\text{A}$ .

## DRIVER AND R.F. CIRCUITS

To maintain a compact design, the solid-state driver is mounted within the transmitter. It is of modular construction and so its composition can be varied to suit the system of operation of the transmitter.<sup>1</sup>

The vision r.f. output of the driver is coupled to the vision klystron input circuit via the vestigial side-band filter, which imparts the final shaping to the amplitude/frequency response.

The r.f. input circuits for both the sound and vision klystrons are identical and comprise a probe mounting assembly, which houses adjustable probes for metering and monitoring purposes, and a four-port circulator. This not only isolates the driver from any mismatch in the klystron input circuit, but functions with a variable mismatch section connected to its second port as a variable input attenuator.

The attenuator in the vision klystron input circuit is used to adjust the drive level to that which will produce the required output power when the klystron is operated with the optimum beam current and h.t. voltage. The sound klystron input attenuator is adjusted to give the drive level specified by the klystron manufacturer which is typically 100mW for an output of 8kW. The required sound output power level is achieved by adjusting the modulating anode potential and by either broad or narrow-banding the amplitude/frequency response of the klystron.

## THE COOLING SYSTEM

The cooling requirements of the klystron fall into three distinct categories:

- (i) Air
- (ii) Water
- (iii) Steam

The klystron gun assemblies are cooled by jets of high velocity filtered air supplied by a fan mounted in the centre cabinet.

The focussing assemblies and the bodies of the klystrons are water cooled and the collectors steam cooled. The cooling circuit is shown in figure 5.

To achieve stability of the focussing current and to reduce the effects of temperature drift upon the klystron, the cooling water supplied to the magnet and klystron body is maintained at a temperature of  $60^\circ\text{C}$ . Water is pumped from the reservoir to a mixing valve where the flow is divided. A proportion passes through the coils of a secondary water cooling circuit in the heat exchanger, the remainder flowing through the mixing valve to mix with the water from the heat exchanger. The valve automatically adjusts the flows to maintain the correct temperature in the delivery line. A temperature alarm ensures that the maximum permitted inlet temperature is not exceeded.

The flow from the klystron bodies is returned to the reservoir. The magnet flow is divided, a controllable proportion flowing to the collector via a flow meter, the remainder being returned to the reservoir. The temperature of the water at the collector is raised to boiling point by the collector dissipation. Some of the boiling water is converted



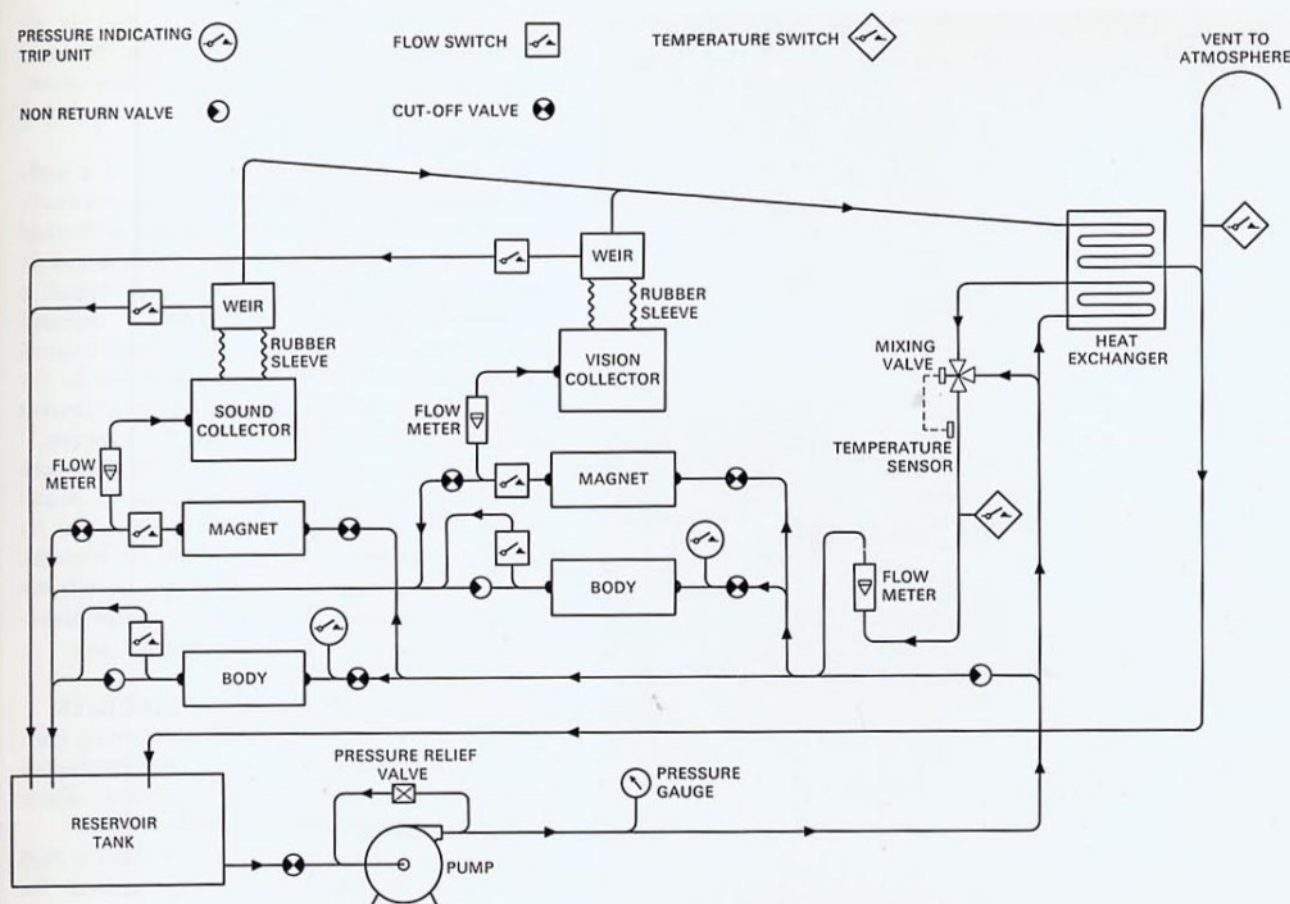


Fig.5 The cooling circuit.

to steam, the latent heat required for the change of state being drawn from the collector which is cooled as a result.

An emulsion of steam and boiling water rises from the collector via a flexible rubber sleeve to a weir where the steam and boiling water separate; the steam passes to the heat exchanger where it is condensed and returned to the reservoir. The excess water flowing over the weir passes through a minimum flow switch before being returned to the tank to ensure that a surplus of water is present whilst the h.t. is on.

Protection against loss of cooling water flow is provided by minimum flow switches in the outlet lines of each circuit branch. Protection against excess pressure on the body inlets is provided by pressure indicating trip units.

When the pump is switched off, the cooling circuit drains completely to the tank, non-return valves ensuring that the flow meter loops drain completely.

As a further protection, a hermetically sealed Chromel-Alumel thermocouple is attached to the collector to guard against thermal runaway. The thermocouple drives a trip unit which removes the h.t. when a predetermined temperature is reached. The trip fails to safety should the thermocouple become open-circuited. A photo-cell arc detector equipped with a test lamp is fitted at the output window to remove the h.t. should an internal flash-over occur.

## THE DRIVER AND POWER SUPPLIES UNIT

This unit is the centre of the three cabinets and contains two sections suitable for mounting standard 19in rack units. The left-hand section houses the solid-state driver units previously described.

The right-hand section houses the solid-state control unit containing the status and overload indicating circuits. The protection devices, which are circuit breakers (fuse links are not used in the equipment), are mounted below the control unit, while space is provided above for an oscilloscope for monitoring video waveforms and also a v.s.b demodulator if required.

Access to the rear of the unit is via the enclosure where removal of a single panel gives access to the inside of the cabinet, which contains the solid-state low voltage power supplies. The 24V regulated modular power supply energizes the control circuit modules, and provides a 24V source for external logic facilities.

The h.t. contactors, which are driven from the solid-state control circuits through a relay interface, require a 50V d.c supply and this is obtained from a three-phase full-wave silicon bridge rectifier circuit, with in-built transient suppression to give long and reliable operation.

A single three-phase cooling fan is mounted in the rear of this unit to provide filtered cooling air at low velocity to the heat sinks of the solid-state





*Fig.6 The modular control and overload circuits.*

driver units, and general cabinet cooling; it also supplies the high velocity jets of air for the klystron gun assemblies in the r.f. cabinets. The air filters are washable and are mounted in a convenient position within the roof area, accessible from the front of the equipment, permitting cleaning to be carried out without interruption of transmission.

All external connections to the transmitter, with the exception of the mains input terminals, are conveniently grouped in one area at the rear of the unit and external wiring is carried away via a single cable duct above the enclosure roof.

### THE ENCLOSURE

The three cabinets form one side of an enclosure housing the klystron h.t. beam supply which is common to both the sound and vision klystrons. This supply can easily be adjusted in approximately 500V steps from 20–25kV to give optimum performance over the klystron life span.

There are two versions of the h.t. transformer; one is for mains supplies of 380V or 415V at 50Hz and the other for 440V, 460V or 480V at 60Hz. Delta/star or delta/delta winding configurations are available to increase the number, and reduce the amplitude of the current pulses drawn from the mains supply, an arrangement advantageous on multi-equipment installations. Suppressors are fitted on the transformer primary to limit injurious

mains-borne transients. The transformer is air cooled and is energized in two stages. Resistors limit the initial starting surges and are then short-circuited by a second power contactor during normal running.

The silicon rectifier is an extension of a well-established design, conservatively rated and incorporating surge suppression across each individual silicon diode. The diode stacks are mounted in modular form, one per phase, and their output is immediately fed to a commutation transient suppression circuit, followed by a conventional smoothing filter. The resultant d.c. is fed to the individual klystron cathodes via a resistor to prevent excessive fault currents flowing in the klystrons.

The rectifiers are protected by monitoring both the transformer primary current and the d.c. output current. Should either become excessive the h.t. transformer mains supply is automatically removed. Under fault conditions, all protection circuits are themselves protected against over-voltage breakdown by the inclusion of a vacuum spark gap.

### CONTROL AND OVERLOAD CIRCUITS

With the exception of the power switching contactors and the interface relays, the transmitter control and overload circuits employ silicon devices and are constructed in modular form.

The circuits have been designed to have a high noise immunity and are therefore suitable for operation in areas where high radio-frequency fields are encountered, such as high-power broadcast transmitters operating in the m.f. and h.f. bands.

The modules are mounted in a single compact unit. The front panel, on which the status and overload indicating lamps are mounted, can be lowered to give access to the logic modules themselves (Fig.6).

Each module incorporates a selection of test points for rapid fault detection. Application of the auxiliary mains supply results in the 'Control' indicator becoming illuminated, and if the overload and protection circuits are functioning correctly all the overload indicating lamps also become illuminated.

Operation of the 'Standby' button on the meter panel initiates an automatic sequence of events which brings the transmitter to the standby condition.

Immediately 'Standby' is selected the upper part of the push-button is illuminated and the fan and water pump start. When the air pressure is correct the heater delay starts and the 'Air' and 'Heater Delay' status lamps are illuminated. The sound and vision klystron focus supplies are energized once the water pressure and flow are correct, indicated by the 'Water', 'Sound Focus' and 'Vision Focus' lamps. If any of these functions fails to operate correctly the run-up sequence is halted and the appropriate status lamp remains unilluminated.

When the heater delay is complete and the focus supplies are within their predetermined limits the lower half of the 'Standby' button becomes illuminated, giving a 'Standby Ready' indication.

The transmitter is finally made operational with the h.t push-button. The upper half is illuminated immediately and when the h.t starting sequence is completed, the lower half also becomes illuminated indicating 'H.T On'.

The cooling systems automatically remain running for five minutes after the normal shut-down sequence has been initiated.

A heater delay over-ride circuit reapplies h.t immediately in the event of a mains failure of up to 15 seconds duration.

The equipment is suitable for remote unattended operation; a single closing contact will initiate the transmitter automatic starting sequence.

Outputs suitable for processing all essential information for remote telemetering are included as standard features.

### OPERATING SYSTEMS

The equipment may be operated as a single transmitter, or as a paralleled installation, or in the multiplex system.<sup>4</sup>

Parallel operation offers the advantage that in the event of failure of one half of the transmitter the programme is continued on the other half without interruption, though the output power is reduced to a quarter of its pre-fault value.

The advantages offered by the multiplex system are that only two klystrons are required thereby reducing running costs. In the event of a fault in one klystron, the programme continues on the other at one fifth of the pre-fault output power.

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