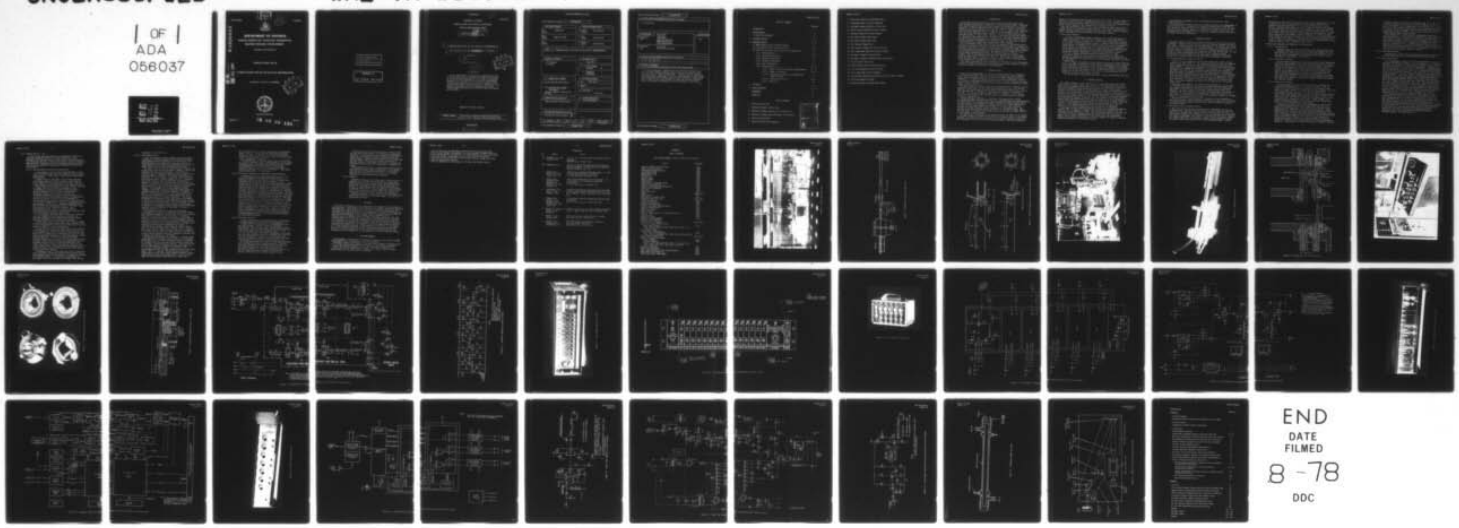
AD-A056 037 WEAPONS RESEARCH ESTABLISHMENT SALISBURY (AUSTRALIA) F/G 7/1
A VERSATILE SHOCK TUBE AND ITS ANALYTICAL INSTRUMENTATION.(U)
MAY 77 S W HISCOCK, D KILPIN, L J DRUMMOND

UNCLASSIFIED WRE-TR-1819(W) NL

| OF |
ADA
056037



END
DATE
FILMED
8-78
DDC

WRE-TR-1819(W)

AR-000-569

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS RESEARCH ESTABLISHMENT

SALISBURY, SOUTH AUSTRALIA

TECHNICAL REPORT 1819 (W)

A VERSATILE SHOCK TUBE AND ITS ANALYTICAL INSTRUMENTATION

S.W. HISCOCK, D. KILPIN and L.J. DRUMMOND

Approved for Public Release

COPY No. 27

MAY 1977

UNCLASSIFIED

AR-000-569

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS RESEARCH ESTABLISHMENT

TECHNICAL REPORT WRE-TR-1819 (W)

A VERSATILE SHOCK TUBE AND ITS ANALYTICAL INSTRUMENTATION,

S.W. Hiscock, D. Kilpin and (in part) L.J. Drummond

May 77

51 p.

SUMMARY

A fully instrumented, hydraulically operated shock tube of 6.3 cm bore, in which chemical reactions can be studied at reflected shock pressures of up to 5 MPa, is described. Apparatus for the detection and concentration measurement of species not detectable by conventional ultraviolet and visible spectroscopy has been developed. Systems for these methods of dye laser intracavity quenching, dye laser excited Raman spectroscopy and quadrupole mass spectrometry are described.

Approved for Public Release

POSTAL ADDRESS: The Director, Weapons Research Establishment, Box 2151, G.P.O., Adelaide, South Australia, 5001.

UNCLASSIFIED

DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1 DOCUMENT NUMBERS	
AR Number:	AR-000-569
Report Number:	WRE-TR-1819(W)
Other Numbers:	

2 SECURITY CLASSIFICATION	
a. Complete Document:	Unclassified
b. Title in Isolation:	Unclassified
c. Summary in Isolation:	Unclassified

3 TITLE: A VERSATILE SHOCK TUBE AND ITS ANALYTICAL INSTRUMENTATION

4 PERSONAL AUTHOR(S):

S.W. Hiscock
D. Kilpin

5 DOCUMENT DATE: May 1977

6 6.1 TOTAL NUMBER OF PAGES: 56

6.2 NUMBER OF REFERENCES: 8

7 7.1 CORPORATE AUTHOR(S):

Weapons Research Establishment

7.2 DOCUMENT (WING) SERIES AND NUMBER

Weapons Research & Development
TR-1819

8 REFERENCE NUMBERS

a. Task: DST 76/123

b. Sponsoring Agency:

9 COST CODE: 330211/333

10 IMPRINT (Publishing establishment):

Weapons Research Establishment

11 COMPUTER PROGRAM(S) (Title(s) and language(s))

12 RELEASE LIMITATIONS (of the document):

Approved for Public Release

78 07 03

12.0	OVERSEAS	NO		P.R.	1	A		B		C		D		E	

151

Security classification of this page: UNCLASSIFIED

Security classification of this page: UNCLASSIFIED

13 ANNOUNCEMENT LIMITATIONS (of the information on these pages):

No limitation

14 DESCRIPTORS:		15 COSATI CODES:
a. EJC Thesaurus Terms	Shock tubes analyzing instruments chemical reactions RAMAN spectroscopy mass spectroscopy	1402
b. Non-Thesaurus Terms	Dye lasers intracavity quenching	

16 LIBRARY LOCATION CODES (for libraries listed in the distribution):

SW SR SD AACA NL

17 SUMMARY OR ABSTRACT:
(if this is security classified, the announcement of this report will be similarly classified)

A fully instrumented, hydraulically operated shock tube of 6.3 cm bore, in which chemical reactions can be studied at reflected shock pressures of up to 5 MPa, is described. Apparatus for the detection and concentration measurement of species not detectable by conventional ultraviolet and visible spectroscopy has been developed. Systems for these methods of dye laser intracavity quenching, dye laser excited Raman spectroscopy and quadrupole mass spectrometry are described.

Security classification of this page: UNCLASSIFIED

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

Shock tubes have been extensively used in the past twenty years for the study of gaseous reactions at temperatures between 1000 and 4000°K. Most shock tubes used in physico-chemical studies are such that observations are made at pressures of 1 kPa or less behind the incident shock or between 1 and 8 kPa behind the reflected shock(refs.1(a) and (b), 2 and 3). Shock tubes generating reflected shock pressures of up to 10 MPa are used in Germany(ref.4). The basic shock tube described herein (figures 1 and 2) provides reflected shock pressures between 0.1 and 5.0 MPa. There is a choice of end sections (figure 3) for terminating the driven part of the shock tube. When high pressures are to be used the end portion attached has mountings for the installation of timing devices, pressure transducer and two sets of windows. An end plug is used so that the end plate is very close to the centre line of windows.

For low pressure studies the alternative end portion of the driven section terminates in either an end plug or a large flange which supports a pinhole and provides a connection to a large ballast chamber and associated pumps (figure 4). This end portion has mountings for timing devices, pressure transducer, windows for absorption/emission spectroscopy and another pair of windows for laser-excited Raman spectroscopic studies. In addition there is a device (figures 5 and 6) which permits sealing of the pinhole until a few seconds before a shock arrives at the end of the tube. The pinhole, ballast chamber and pumps permit gas at a pressure of about 100 kPa to enter a quadrupole mass filter operating at a pressure of less than 10^{-5} Pa.

This report describes the various sections of the shock tube, the principles involved in design and operation of these sections and also a number of items of ancillary equipment used in shock tube experiments.

2. DRIVER SECTION

This is of stainless steel, is 196.0 cm in length and 6.3 cm in diameter. Wall thickness is 0.95 cm and the interior surface has been honed so that a piston may move smoothly along 0.4 of the total length, thereby raising the pressure to 1.67 times the original value to rupture the diaphragm. A choice of thickness of diaphragm provides separate levels of shock intensity and finer control of shock strength is available by setting driver gas composition between He/N_2 = 100/0 and 0/100.

The small piston has three O-rings set in grooves along its length to prevent by-pass of driver gas. In order that driver pressures of up to 5.52 MPa are available the small piston is coupled with a large piston which moves in a mild steel cylinder and is activated by compressed air from a reservoir held at 690 kPa. The large cylinder (length = 93.47 cm, diameter = 30.08 cm) has been honed and the piston has two cup-rings of reinforced plastic to prevent by-pass of compressed air.

A damping device is attached to the rear of the large piston, thereby minimising additional forward travel when the diaphragm bursts and also smoothing reverse travel induced by pressure pulses subsequently generated downstream of the small piston. In principle, the damper consists of a dummy piston with a by-pass line and control valve which allows oil to flow in the direction required to occupy the space created by movement of the dummy piston. The setting of the valve and the backing pressure of oil within the damper govern the time taken to intensify the pressure of gas in the driver section. This is usually between 7 and 8 seconds.

Just beyond the mid-position of the driver section, and unable to be reached by the small piston, is a manifold of portholes leading to lines to vent excess pressure, to purge with air, to evacuate, to fill and to measure the pressure of filling gas. The end of the driver section remote to the large cylinder is

thicker in construction than the main portion of the driver. It has a gauge to read driver pressure prior to diaphragm rupture and an inner stainless steel sleeve which may be advanced under hydraulic action so that the diaphragm holder may be firmly clamped to the reactant section (figures 8 and 9).

When the large piston lies at the "start" position the small piston lies in a guide channel just inside the large cylinder. This cylinder is mounted on rollers and may be easily disconnected from the driver tube. Thus, if need be, "lost" diaphragm petals can be removed from the driver section.

2.1 Ancillary equipment

A series of experiments usually commences with a driver gas mixture of high helium content. The mixture is prepared in a large high pressure vessel which houses an electric motor (373W) with stirrer blades attached to its shaft. During the mixing of gases, a thermal conductivity detector (catharometer) is checked with a sample of pure helium and, if necessary, a bridge circuit is adjusted to give full deflection on a millivoltmeter. Then a sample of driver gas mixture is passed through the catharometer and the helium content read from the calibrated millivoltmeter. The use of driver gas of known composition allows accurate prediction of shock velocity in reactant mixtures containing large amounts of argon.

A console (figure 7), set alongside the driver section, permits the operator to prepare the driver section conveniently for an experiment once the diaphragm has been installed and also to "let down" the shock tube after an experiment.

The air supply is carefully filtered before it enters the large reservoir. This air is used to activate the large piston compressing the driver gas and also in hydraulic intensifiers used to clamp the diaphragm section between driver and reactant sections, to clamp the end-plug assembly to the reactant section and to activate similar devices permitting evacuation, filling and purging of the reactant section. An oil-mist is introduced into the air before it is used in these various devices.

The driver section can be evacuated with a vacuum pump (Edwards ISC 150B).

3. DIAPHRAGM SECTION

The holder (figures 8 and 9) consists of two stainless steel parts loosely held together by spring clips. An O-ring set in each mating face provides a seal for the diaphragm held between these faces. The mountings of the spring clips are extended to provide locating points which serve both to align correctly the scribed marks on the diaphragm and to offer consistently the same portions of mating faces to the driver and reactant sections. The internal sections of the faces remote to the diaphragm exactly match the internal diameters of driver and reactant sections. The internal sections of the faces alongside the diaphragm are squares of side 6.77 cm. The surfaces of the circular-to-square transition regions have been carefully ground so as to allow smooth flow of expanding driver gas and also to permit the four petals of metal, created on rupture of the diaphragm, to bend firstly forward and then in the reverse direction. The clamping edges are carefully rounded to minimise the possibility of a petal being severed from the bulk of the diaphragm.

Diaphragms for high bursting pressures are made from aluminium purchased to specification. Octagons are stamped from sheet and are provided with two locating slots as referred to above. Each diaphragm is placed on an anvil and a cruciform scriber is applied hydraulically with end stops being used to ensure that a constant thickness of metal remains below the scribe-mark. Samples of each batch of material are tested to measure the range of bursting pressures determined by the scribing process.

Unscored Mylar diaphragms of various thicknesses are used for lower bursting pressures.

The diaphragm holder sits loosely in a recess provided at the commencement of the reaction section. O-rings seal the inner and outer holder faces when an inner sleeve of the driver section is hydraulically advanced to hold the three sections tightly together (figure 9). Quick action safety clamps secure the diaphragm and prevent pressure loss if hydraulic clamping pressure fails while the driver section is pressurised.

4. REACTANT SECTION

The major portion (250 cm) is of stainless steel, 0.45 cm thick and 6.20 cm in diameter. Either of two end-portions may be attached to complete the 300 cm tube length. A thicker section at the commencement of the reactant tube allows entry of a protruding portion of the diaphragm section. At a distance of 20 cm from this end, a 2 cm diameter wall plug can be withdrawn hydraulically to provide the means of evacuating and filling the tube with reactant gas. O-rings are used to obtain vacuum-tight seals when the wall plug is replaced. Disturbance to shock and gas flow over this area is negligible since final honing of the interior of the tube was done with this section in position.

4.1 High pressure end of reactant section

This is 69 cm in length but the end plug reduces the overall internal length of the tube to 300 cm. The interior was bored to match the diameter of the longer part of the tube and the final honing was done with both parts attached. The thicker construction (1.85 cm) of this portion permits installation of a number of attachments. At a distance of 10 cm from the end plug a valve with a wall-contoured interior face can be withdrawn to allow the tube to be purged with air at the completion of an experiment. Pairs of windows are available for spectroscopic studies. In the horizontal path they are of quartz, diameter tapering to 0.8 cm, thickness = 0.48 cm; in the vertical path they are of barium fluoride or sapphire and of the same dimensions. The centre lines of these paths are 5 mm from the end plug. A pressure transducer is mounted in the same plane as the optical centre line.

Three gold film detectors are stationed at distances of 1.0, 16.0 and 31.0 cm from the end plug. They were constructed by melting glass around two tungsten electrodes and grinding a shoulder on the cold cylindrical glass mount so that it could be set into a stainless steel mount with adhesive. The front surface of this mount exactly matches the interior of the shock tube and the glass and tungsten were ground to conform to the same contour. A 1mm wide gold strip was then evaporated between the tungsten leads to a resistance of about 15 ohm.

The end plug (22 cm) is long due to the presence of an intensifier at the end of the tube. This allows the end plug to be firmly held in the tube by a hydraulically activated pressure plate after the plug is inserted in breechlike fashion.

4.2 Low pressure end of reactant section

When used with an end plug this section is a replacement for the one described above. The only basic differences relate to the facts that the second set of windows are inclined at 45° to the horizontal and that an end plate pinhole sealing valve (figures 5 and 6) can be hydraulically advanced and sealed or withdrawn. This device is used when the end plug is replaced by a large flange which incorporates a central 0.005 cm diameter pinhole, and which connects the shock tube to a large pumping assembly. During

evacuation and filling of the tube this valve body is advanced into the tube by means of an arm. This arm carries a rubber grommet which can be hydraulically advanced normal to the arm to encircle and seal off the pinhole. Several seconds before a shock is sent down the tube the grommet is retracted within the arm and the arm withdrawn to restore the interior of the tube. The control for the pinhole valve is mounted behind the shock tube control panel (see figure 7) and incorporates an accurate one second delay between the two pneumatic operations (figure 10). Within seconds after firing the sealing of the pinhole is again effected by manual switching of the pinhole valve control. The pinhole and large pumping assembly thus allows a stream of unshocked gas followed by gas that has been heated by the reflected shock to enter a quadrupole mass filter.

4.3 Ancillary Equipment and Analytical Instrumentation

4.3.1 Pumping System

Reactive gases and reaction products in the reactant section can be roughed down with a cold trap and backing pump (Edwards ISP 30). With another cold trap, diffusion and backing pumps (Edwards 4 inch and ISC 450 B respectively) the complete reactant section can be evacuated to better than 1.33×10^{-5} Pa.

4.3.2 Shock Front Detection

The resistance change of thin gold films caused by the temperature rise due to the passage of the shock front over the films is used to detect the arrival of the shock wave at several points. The output of each gold bolometer is amplified and the required circuitry (figure 11) is housed in a cylinder attached to the flange on the rear of the bolometer mount. The outputs of these detectors are used to trigger submicrosecond timers, an oscilloscope and/or a delay unit for synchronising analytical instrumentation at a known time after shock arrival. The use of flip-flop circuits allows the same bolometer detectors to measure the speeds of both the incident and reflected shocks.

4.3.3 Timing and Recording

The measurement of one or two time intervals is normally made using Hewlett Packard 5325B 0.1 μs resolution timers. When the timing of more than two events is required, a ten channel eight digit or a twenty channel four digit timer is used (figures 12 and 13). Both timers have 0.1 μs (or up to one ms) resolution and a sequentially switched LED display of the time from a common starting point. Since the trigger signal required to stop the counter is a fixed TTL level, five channel trigger units (figures 14 and 15) are normally used in conjunction with a timer. These trigger units permit the separate selection of polarity, slope and voltage level (0-10 V, 0.01 V resolution) for each channel.

Instrumentation data from pressure transducers or photoelectric detectors are usually recorded by photographing the trace of an oscilloscope (Tektronix 555, 585 or 7904) with a Polaroid camera (Tektronix C27). Most detector signals are recorded in a linear fashion where the recorded signal is directly proportional to the light intensity. However logarithmic response is sometimes desirable for a wider dynamic range or simplification of kinetic interpretation. A dual log amplifier (figure 15) is used for these purposes or differentially with a double beam, two wavelength, two detector system for compensation of lamp instability and varying background absorption. When greatest accuracy is required a transient analogue

to digital converting memory unit (figures 17 and 18) is used to convert the signal with ten bit resolution (0.1%) and store it in up to 1024 channels, each representing a time of from 1.25 to 20 μs. The unit can be triggered before the event in the usual way, or, by continuous cycling, be stopped after the event when that method of triggering is more convenient. Stored data are printed out with a Hewlett Packard 5055A digital printer.

When using either a short duration flashlamp for recording absorption spectra, the intracavity quenching of a pulsed dye laser for detection of weak absorption, or pulsed laser excited Raman spectroscopy, a delay unit is required to synchronise the analytical pulse with a specific period of reaction at a known time after arrival of the shock front. A Nagard model 5002 A double pulse generator was originally used for this purpose. Double digital delay units with switch selected delays of 0.1 μs resolution have now been developed for this purpose (figures 19 and 20).

4.3.4 Pressure Measurement

Pressures are measured with a piezo-electric pressure transducer (Kistler 603A) used with a charge amplifier (Kistler 504 M3).

4.3.5 Mass Spectrometry

The large pumping complex for the mass spectrometer consists of a stainless steel ballast chamber (2.0 m in length, 0.5 m in diameter). Centrally, in the front of this horizontal cylinder, sits a flange for mating with that at the end of the shock tube. Centrally, at the rear is another flange to which is attached the quadrupole mass filter which is centred on the shock tube - pinhole axis, and whose ionizer is 12 mm from the pinhole. Near both ends and at the rear of the cylinder are vertical flanges attached to large baffle valves (Edwards H12R12). Each valve isolates a diffusion pump (Edwards E012) connected to a booster pump (Edwards 9B3) and backing manifold. A large backing pump (Edwards ISC 900) serves this common manifold. The entire complex can be offered up to the shock tube by advancing on rails in the direction of the shock tube. Once separated from the shock tube the complex can be removed on rails in a direction normal to the shock tube axis. A large refrigerated water supply is used for dissipation of the heat generated by the diffusion and booster pumps. Before opening the pinhole the pressure within the quadrupole is 1.3×10^{-5} Pa or less. Shocked reactant gas is sampled by the mass filter at pressures around 1.0×10^{-3} Pa.

The quadrupole mass filter and control unit (EAI Quad 150A) monitors the ion currents of species of different m/e values at known sensitivities for a specific emission current. Since the scan rate of the unit is too slow to permit the detection of even two adjacent peaks in the one millisecond observation time available, non scanning operation is used to measure the ion current of one selected m/e value. The output from the electron multiplier is monitored on an oscilloscope using a cable driving amplifier (figure 21), or using a sensitive oscilloscope amplifier (Tektronix 1A7A or 7A22) and probe to measure the voltage developed across a one megohm resistor.

4.3.6 Spectra 200 nm - 5 μm

In most cases the concentrations of intermediate, product or reactant species are monitored by direct absorption in the UV-Visible (200-800 nm) spectral region using a lamp continuous in both wavelength and time. However, facilities for the recording of Raman spectra, infrared emission and flashlamp absorption spectra, and the use of intracavity quenching of broadband dye lasers are also available.

4.3.6.1 Light sources for absorption spectroscopy

A one kilowatt xenon arc lamp (Osram XBO 1000) is used with a filtered current regulated supply to yield a highly stable source (< 0.2% ripple, < 0.5% noise) for absorption spectroscopy.

A small xenon arc lamp (XBO 150 W/1) with stabilised power supply yields equivalent signals at fast response times (shock tube beam widths of no more than 1 mm) and narrow spectral slitwidths because of its smaller arc size.

When a more intense signal is required, either because of low signal level in the 200-270 nm region, or the interference of emission with the absorption signal, a pulsed intensified xenon arc lamp, as described in reference 5 (figure 22), is used. Although the intensified emission from this lamp requires nearly 3 ms to stabilise, the intensification factors (at maximum) of from 20x at 500-350 nm to 50x at 220 nm represent a valuable gain for monitoring species such as CH_3 and HO_2 at 214 and 245 nm respectively. This unit is triggered from an accelerometer, mounted on the diaphragm clamping section, which detects the diaphragm burst some 2-3 ms before shock front arrival at the observation windows. The accelerometer output is used to trigger a several millisecond wide pulse from a pulse generator (Advance PG54) via an intermediate amplifier (figure 23).

A 100 W mercury lamp (Wotan HBO 100 W/2) with extremely small arc dimensions permits precise collimation for multipass absorption and a usable signal at very narrow spectral slitwidths for fine absorption features.

A water cooled deuterium arc lamp (Cary 1000D) is useful in the 200-250 nm range, particularly where scattered light of longer wavelengths from other lamps might distort the real signal or require a double monochromator.

In some cases line emission sources may be more suitable for absorption work because the high intensity of the line and the specificity of the effectively narrow spectral slit width yield an improvement in the signal to noise ratio and simplify wavelength adjustment of the monochromator. Hollow cathode lamps (e.g. Pb 217 nm for CH_3) and microwave discharge lamps (e.g. Bi 307 nm for OH) may be used for such purposes. However their extended source dimensions render collimation more difficult for narrow beams (fast time resolution) and may require large spectral slitwidths for usable signal levels. Unless the required emission line is intense and well separated from nearby lines these sources do not yield better signals.

Flashlamps of about 2 μs duration and 50-100 J energy are used to provide a background continuum from 220-700 nm on a spectrographic plate for the detection of absorption features in a reaction system. A continuous glow discharge is maintained in the lamp to reduce the trigger delay (series

thyratron) to less than 3 μs.

4.3.6.2 Raman Spectroscopy

Since the intensity of Raman spectra of gases is weak, a sensitive and efficient combination of exciting source and spectrograph has been developed for the shock tube. This system consists of a pulsed laser exciting source and a large aperture double dispersion spectrograph fitted with an image intensifier tube for photographing the spectra.

The laser source is still in the development stage and its precise final form not yet determined. However, a few of its essential features can be described. It consists of a collinear pair of flashlamp pumped dye lasers similar to the system of Maeda et al(ref.6). A low power narrowed line oscillator is used to excite a high power forced oscillator. Both sections employ integral coaxial dye cell - flashlamp structures similar to that of Morrow and Price(ref.7). However, a re-entrant dye solution flow is used (figure 24) since it provides both a distortion free active lasing window area and a flow of dye with no dead volume in the active region. The flashlamps are fired by separated series triggers (trigatrons) to produce fast rise light pulses for exciting an ethanolic solution of Coumarin 102 (Eastman Kodak). This dye was selected for its high efficiency and the close correspondence of its lasing wavelength to the maximum sensitivity of the image intensifier. The natural broadband (4 nm) spectrum of the first section is narrowed by air spaced, dielectric coated Fabry Perot etalons similar to those of Bradley et al(ref.8). The second stage is forced to oscillate on the narrow injected line by simultaneous firing of the flashlamps to yield several joules of radiation near 470 nm with a bandwidth of less than 0.1 nm and a duration of about 3 μs.

The dispersive and rejective optics of the Raman spectrograph are housed in a light-tight baffled box fitted with recording systems for the spectral output, and collection and calibration optics for the slit input. A rotating selector, on which are mounted fixed slits of from 0.025 to 0.81 mm is fitted to the front of the spectrograph housing. Ahead of the selector is an efficient sphero-cylindrical lens (f/2) which images a 25 cm distant point as an ellipse, and a focussed vertical beam as a broadened slit shape. A calibration lamp housing, offset from the entrance optics axis, is fitted with Oriel Neon or Mercury lamps, a shutter, and several neutral density filters. The light is imaged by a 5 cm lens onto the upper and lower sections of the slit by a pair of small prisms to provide a calibration spectrum with no image plane movement of the detector.

The spectrograph (figure 25) consists of a primary single prism disperser at the focal plane of which is an adjustable knife-edged mirror to reject wavelengths longer (or shorter, if reversed) than that selected before radiation enters the second higher dispersion grating section. Light entering the slit is collimated by L_1 (figure 25, Schneider Xenar, 1:2, f = 100 mm), dispersed by prism P (12.5 cm base, 60°, Schott glass No. SF.5) and then focussed by lens L_2 (Schneider Xenar, 1:3.5, f = 300 mm). Mirrors M_1 and M_2 fold the optical path with the focal plane between them where a knife edged mirror mounted on a micrometer arm is used to divert light of the excitation wavelength into a light trap.

The transmitted light is again collimated by L_3 (Schneider Xenar, 1:4.5, f = 420 mm) before dispersion by grating G (Bausch and Lomb, 15 x 20 cm, 1200 lines per mm, 500 nm blaze) to lens L_4 (Schreider Xenar, 1:4.5, f = 300 mm) which forms the spectrum at plane S.

The spectrum can be recorded directly on film (Polaroid or 127 x 101 mm sheet film) or glass plates, or via an image intensifier tube. The gated tube (English Electric P829A) is synchronised with the laser pulse to yield light amplifications of up to 10^4. The intensified image is recorded on Polaroid film using a Tektronix C12 high speed camera fitted with a 1:1 f/1.4 lens.

4.3.6.3 Intracavity Quenching of Broadband Dye Laser Emission

Photomultiplier-monochromator detection is not a very sensitive technique with most light sources when an absorption feature is very narrow or weak. A considerable enhancement of the sensitivity of detection of such absorption can be achieved with the absorbing species inside a laser cavity, where a decrease of the broadband emission envelope occurs at wavelengths where absorption reduces the laser gain and output. Relatively low power (10 mJ) pulsed, broadband dye lasers (of several nm bandwidth) are suitable for most applications (400-800 nm, resolving power < 100,000). For shock tube use a flashlamp pumped dye laser of moderately short duration (2 μs) was constructed so that the shock tube observation section is within its optical cavity. The laser is essentially the same as those of the Raman source, except that this unit fits in the central tubular hole of a coaxial capacitor on the optical bar. Complete coverage of the visible region is possible by selecting one of about fifteen dyes and adjusting the concentration to match a required centre wavelength with a bandwidth of from 4 to 15 nm. The several milliradian divergent output beam can be tightly focussed with a cylindrical lens onto the entrance slit of a spectrograph enabling the use of very narrow slitwidths and high resolving powers.

4.3.6.4 Wavelength Selection

Several monochromators, spectrographs and non-dispersive wavelength selectors are available for spectroscopy.

A Hilger H700 monochromator with interchangeable quartz and glass prisms is used most often for absorption measurements. When working in the infrared region either a Perkin Elmer model 83 sodium chloride prism monochromator or a Bausch and Lomb grating monochromator (0.8 - 1.6 or 1.6 - 3.2 μm) is used. The latter instrument is also used with two other gratings (200-400 nm, 400-800 nm) to monitor very broad absorption regions, or, in conjunction with filters to minimise the effect of internal scattered light, when working in regions where the lamp output is low.

Two prism spectrographs are used for flashlamp-absorption work and laser intracavity quenching studies. A quartz prism unit (Hilger E 498) provides adequate dispersion in its 200-800 nm coverage on a single plate for most absorption features. For fine line absorption studies, and for all laser intracavity quenching, a Littrow unit (Hilger E 478) with glass or quartz prisms is used.

Coloured glass and multilayer dielectric coated filters are also used either alone in the infrared for wavelength selection, or in conjunction with dispersive instruments to reduce the interference of scattered radiation with the desired signal. Emission studies at fairly broad bandwidths are also usually made with well blocked filters and a detector because of the simple optical set up required and the large apertures which can be employed to increase the signal.

An adjustable Fabry Perot interferometer (Burleigh RC 40) with interchangeable mirrors covering most of the visible spectrum with a finesse exceeding 50 and a free spectral range (at 600 nm) of from 1.2×10^{-3} to 1.8 nm is also available for very narrow spectral features.

4.3.6.5 Detectors

Photomultipliers are most often used for the detection of radiation in the 200-900 nm range because of their high sensitivities and fast response times. End windowed tubes with S1 photocathodes are usually employed (EMI 9526 B). However for some applications a red sensitive photocathode is required (RCA C 31034, usable sensitivity to 900 nm) and for the far ultraviolet a "solar blind" unit (RCA C 31034, usable sensitivity in 180-320 nm region) is invaluable.

Infrared radiation is detected by a cooled photoconductive device (Optoelectronics, OTC-11-52T, PbSe, 1-5 μm) or a pyroelectric detector.

5. CONCLUSION

The shock tube described in this publication was designed for convenience of operation over a broad range of conditions with an extensive variety of analytical instrumentation. Results obtained so far have successfully demonstrated the achievement of these objectives with throughputs of up to thirty shocks per day, reflected shock pressures of up to fifty atmospheres, duplication of shocks to less than 0.5% difference of shock speeds, and the detection of low concentrations of transient species by laser intracavity quenching. The high pressure capability of the tube enables lower concentrations of intermediates to be detected, or, if strictly isothermal conditions are required, very low concentrations of reactants may be employed. From the wide range of analytical instrumentation available it is possible to monitor concentrations of species of various absorption strengths at wavelengths in the 200 nm - 5 μm region, and of non-absorbers detectable by mass spectrometry or Raman spectroscopy. Results of using the shock tube and its associated instrumentation will be described in future reports on the investigations of various chemical systems.

6. ACKNOWLEDGEMENTS

This equipment is the result of cooperative efforts from many people at WRE. Acknowledgements are particularly due to the following:

PMD Drawing Office and Workshops, especially Mr G.L. Driver and Mr O.E. Hale, for the design drawing and manufacture of most of the mechanical equipment.

Mr F.A. Rousseau who designed much of the electronic instrumentation including the ten and twenty channel timers, five channel triggers, double digital delay unit and the transient digitizer.

Mr R.A. Beech and the Electronic Workshop where the above units were constructed and several lamp supplies and other equipment designed and built.

Mr R. Nelles and Mr G.W. Brooks at the Glass Workshop for the construction of bolometer blanks, flashlamps, dye laser units and vacuum systems.

MOT Group for the production of high quality windows, prisms, dielectric mirrors and Fabry-Perot etalons.

Mr R.E. Galbreath for the design of the Raman spectrograph system.

REFERENCES

No.	Author	Title
1(a)	Drummond, L.J. and Hiscock, S.W.	"A 5 in. by 3 in. Shock Tube for Chemical Kinetic Studies" WRE-TM-CPD 45, October 1964
1(b)	Drummond, L.J.	"Results of Shock Tube Ignition of Fuel-Oxidant Mixtures relevant to Solid Propellant Combustion" WRE-TN-402(WR&D), June 1971
2	Lifshitz, A., Bauer, S.H., and Resler, E.L. Jr.	"Studies with a Single-Pulse Shock Tube. I. The Cis-Trans Isomerization of Butene-2" J. Chem. Phys. 38, 2056-2063, 1963
3	Dorko, E.A., Crossley, R.W., Grimm, U.W., Mueller, G.W. and Scheller, K.	"Shock Tube Isomerization of Cyclopropane. II. Investigation of a Vibrationally Excited Intermediate" J. Phys. Chem. 77(2), 143-148, 1973
4	Olschewski, H.A., Troe, J. and Wagner, H. Gg.	"Untersuchung unimolekularer Reaktioner bei hohen Drucken in Stosswellen: Zerfall von CS_2 and CO_2" Ber. Bunsenges. Phys. Chem. 70 (9-10), 1060-1064, 1966
5	Taylor, W.B., LeBlanc, J.C., Whillans, D.W., Herbert, M.A. and Johns, H.E.	"Intensified Ultraviolet Analyzing Lamp for Flash Photolysis" Rev. Sci. Inst. 43 (12), 1797-1799, 1972
6	Maeda, M., Uchino, O., Okada, T. and Miyazoe, Y.	"Powerful Narrow-Band Dye Laser Forced Oscillator" Japan J. Appl. Phys. 14 (12), 1975-1980, 1975
7	Morrow, T. and Price, H.T.W.	"A Simple Reliable Coaxial Dye Laser System" Opt. Comm. 10 (2), 133-136, 1974
8	Bradley, D.J., Caughey, W.G.I. and Vukusic, J.I.	"High Efficiency Interferometric Tuning of Flashlamp Pumped Dye Lasers" Opt. Comm. 4 (2), 150-153, 1971

APPENDIX I

LIST OF DRAWINGS

All Drawing Numbers, except P10379, are Prefixed PD

Title	PD Number
General assembly of shock tube	4384
Driver piston actuator	4385
Diaphragm clamping section	4386
Low pressure tube	4387
Measuring section	4388
Intensifier	4389
Control panel	4390
Mixing vessel	4405
Catharometer	4465
Intensifier - diaphragm clamp	4502
Driver calibration unit	4528
High vacuum pumping system Quad 150	4535
Line-up laser mounting	4576
Test cell	4597
Gimballed mirror	4608
Mirror	4609, 4610
Clamp block	4611
End plate (for shock tube)	4612
Blanking plate (for H.V.)	4613, 4614
Vacuum connection	4638
Laser beam director	4657
Lansing universal mount	4660
Coaxial dye laser capacitor mount	4671
Pinhole closing device	4679
Pump end fitting	4683
Mirror holder	4699
Optical system Quad 150 - high vacuum system	4703
Housing, slit	7688
Housing, filter	7726
Raman laser spectrograph (Optical Layout P10379)	7730
Pinhole valve controller	7677, 7678
Ten channel time interval meter	
Front panel layout (Also circuit drawings 7740, 7743, 7907, 8153, 8154, 8155 and 8164)	8152
Dual digital delay unit	
Functional block diagram (Also circuit drawings 7777, 8007, 8013, 8038 and 8040)	7986
Five channel trigger unit	8128, 8129
Analog to digital converter	
Block diagram	8385
General assembly (Also circuit drawings 8038, 8190, 8192, 8203, 8206, 8208, 8209, 8210, 8211, 8213, 8214 and 8384)	8187
Bolometer amplifier	8322
Cable drive amplifier	8361
Accelerometer amplifier and pulse generator	8362
Dual logarithmic amplifier	8376
Intensified Xenon lamp supply	8379

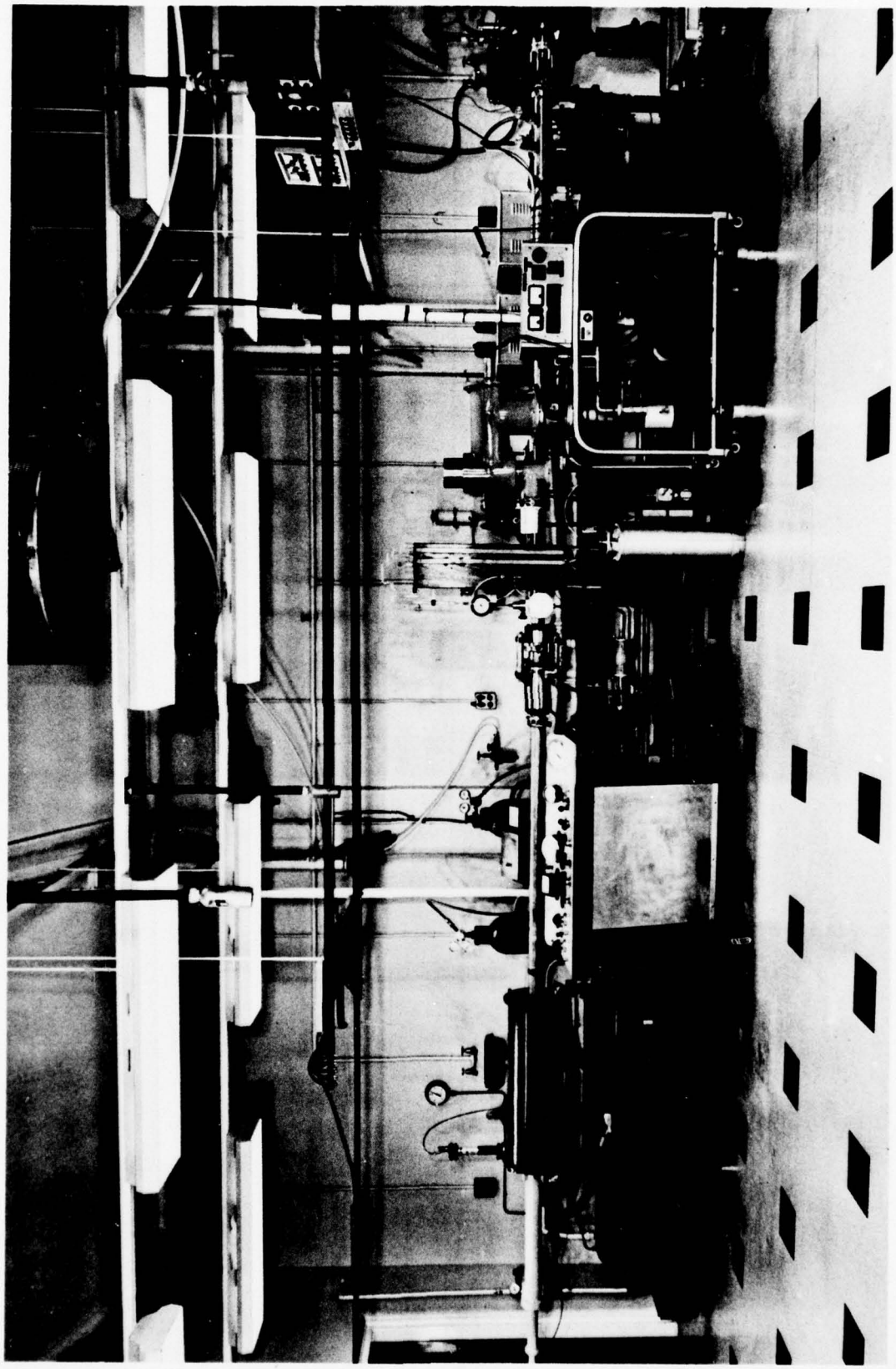


Figure 1. Shock tube side view

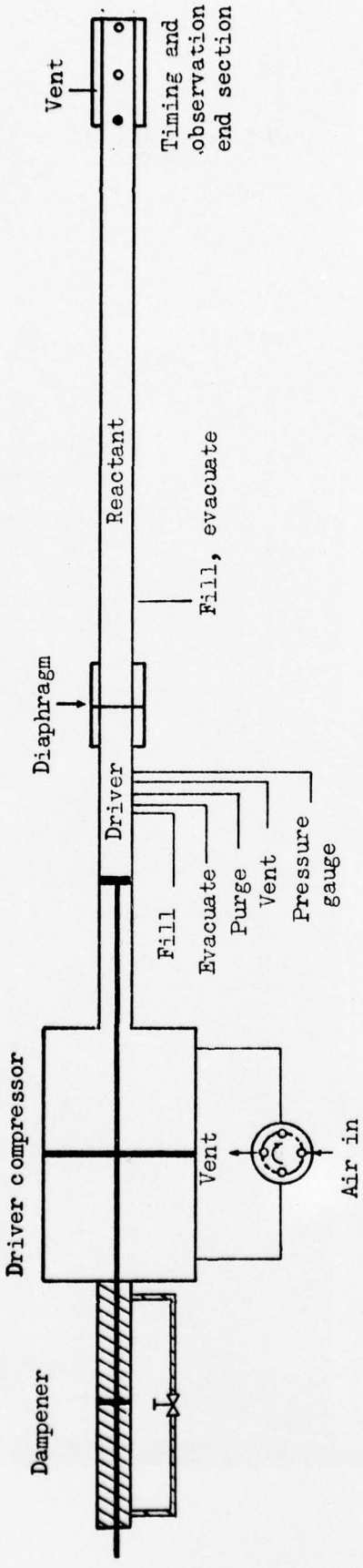


Figure 2. Schematic diagram of shock tube

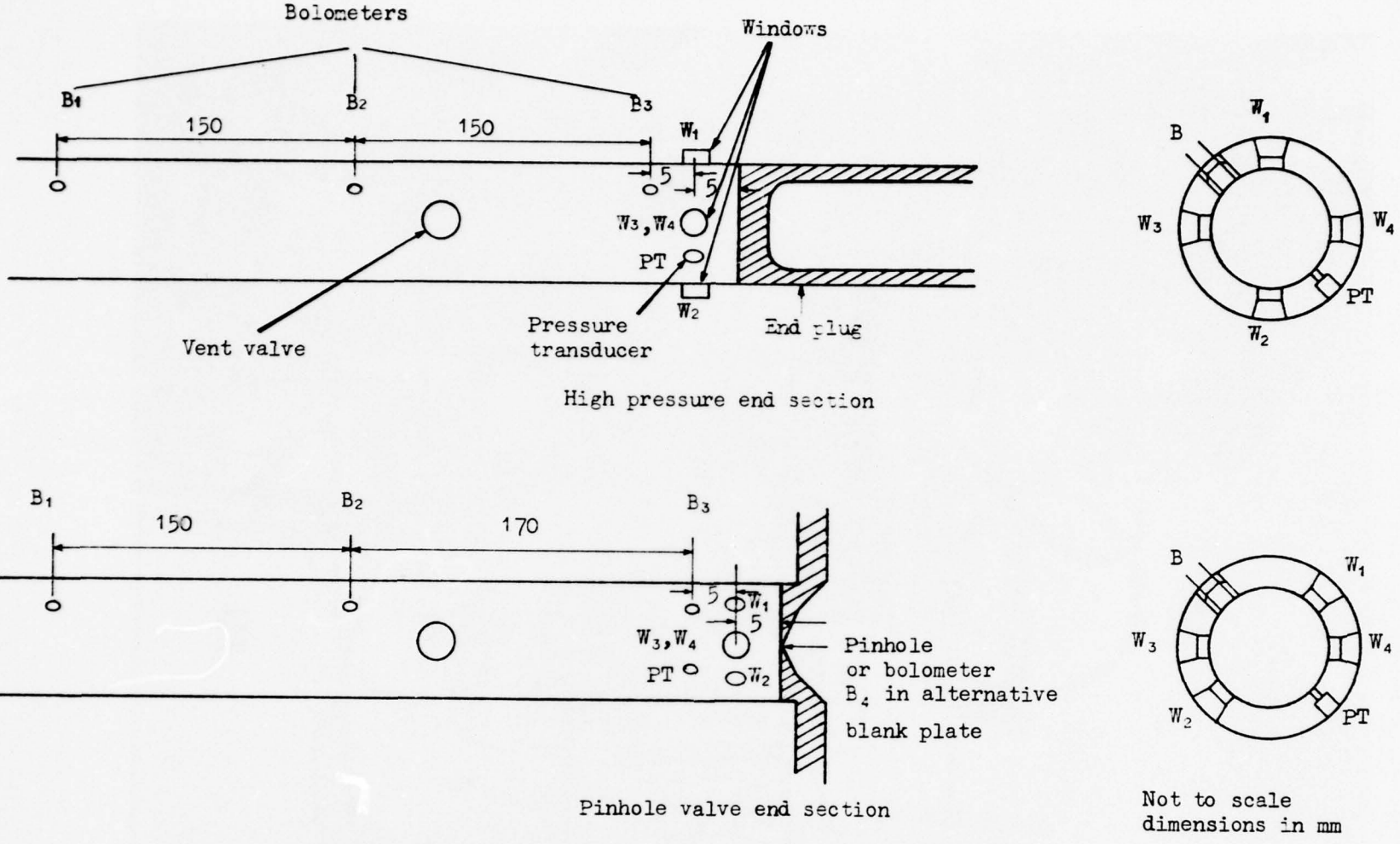


Figure 3. Schematic diagram, end sections of shock tube

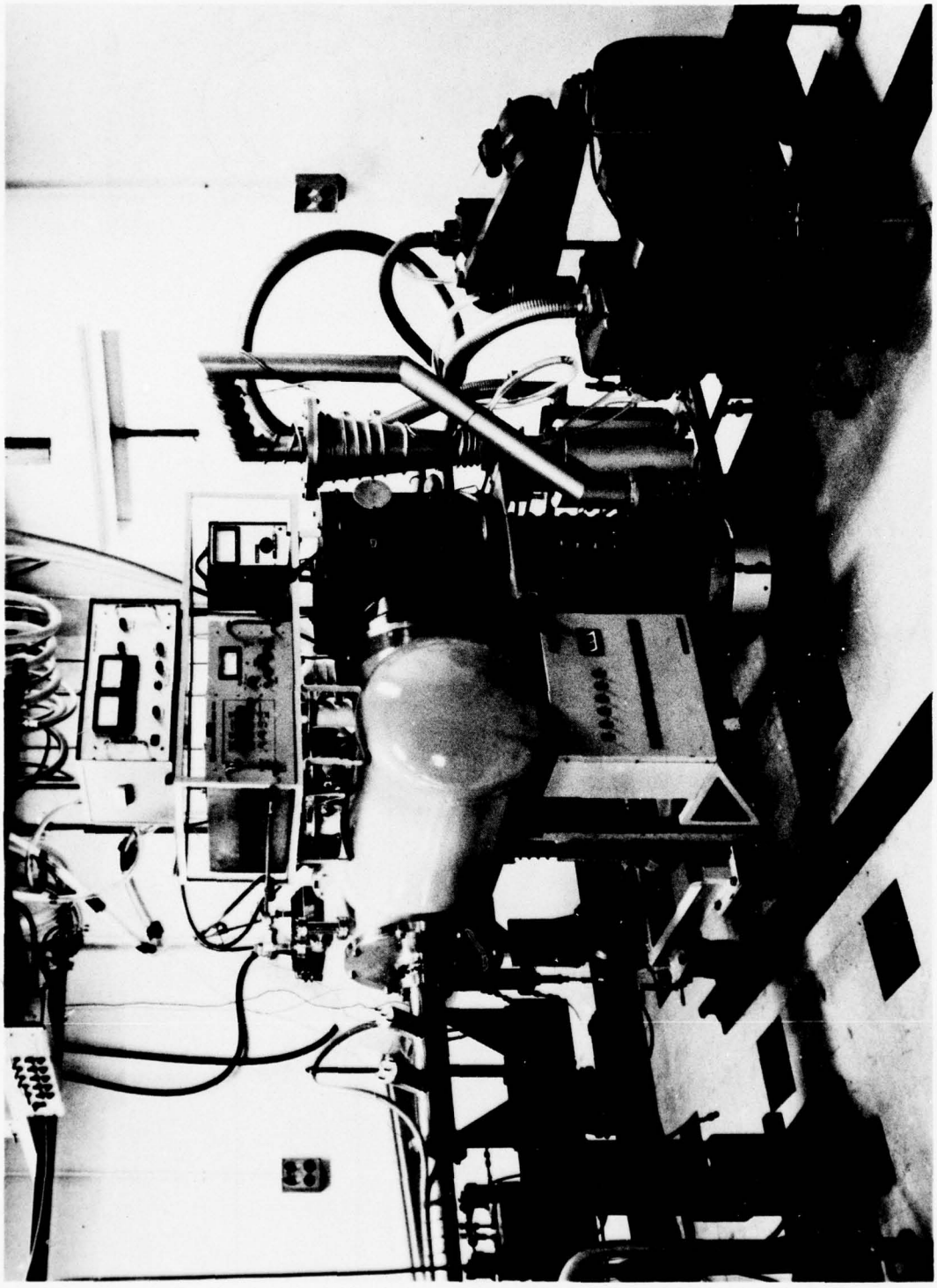


Figure 4. Quadrupole pumping system attached to shock tube

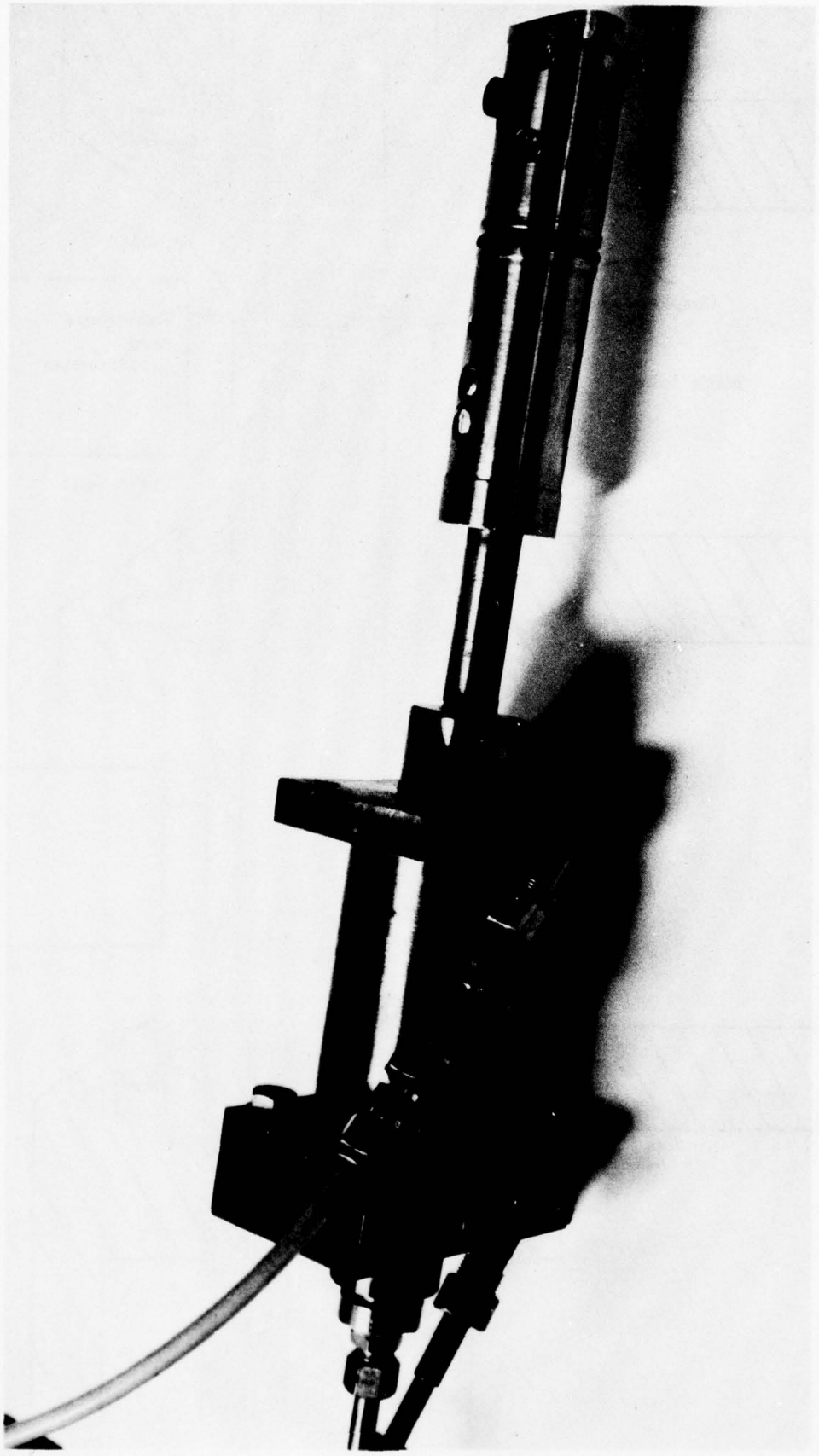
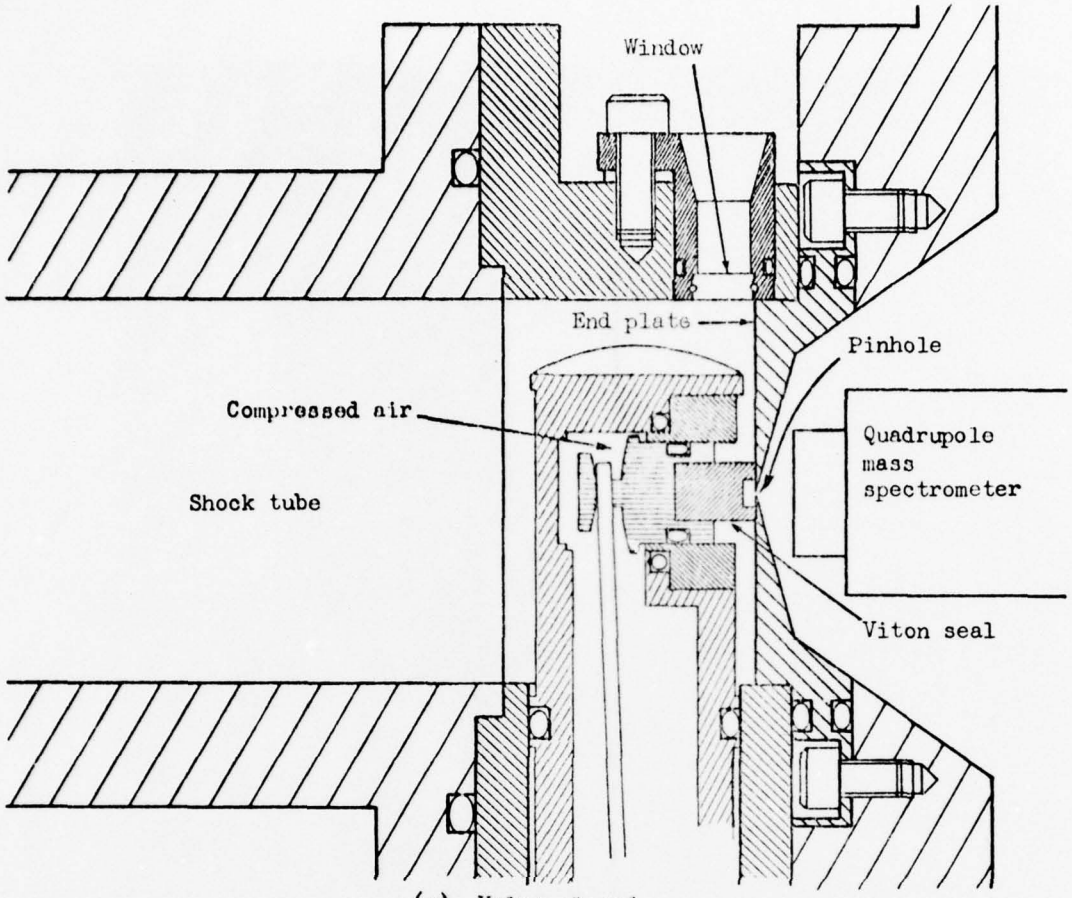
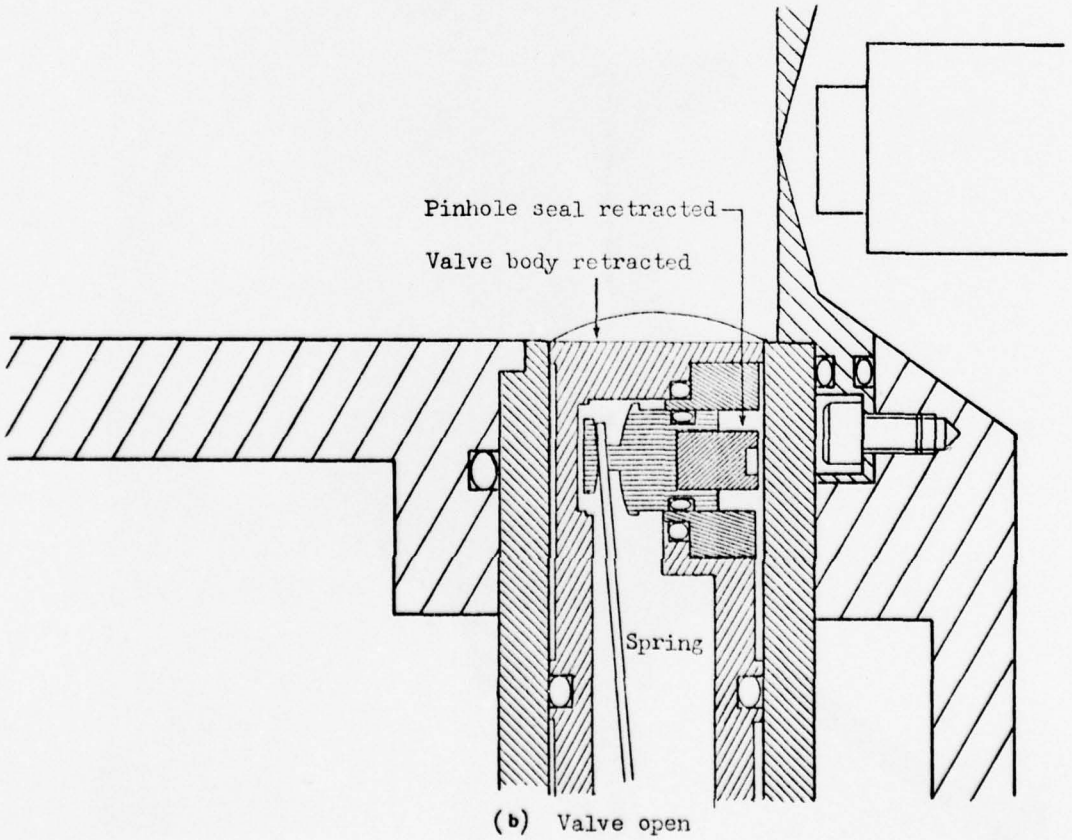


Figure 5. Pinhole sealing valve



(a) Valve closed



(b) Valve open

Figure 6. Pinhole sealing valve operation

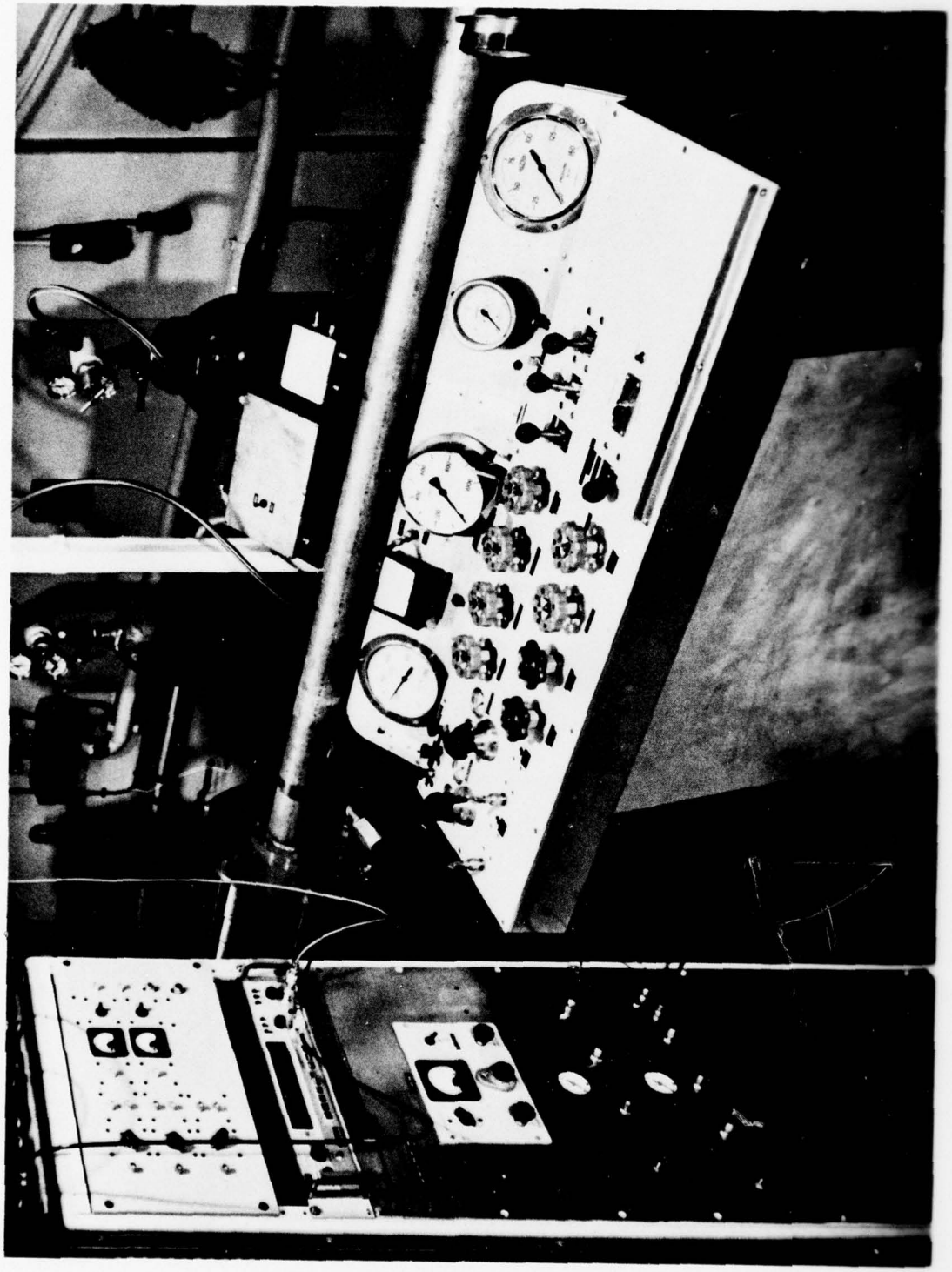


Figure 7. Shock tube console and instrumentation rack

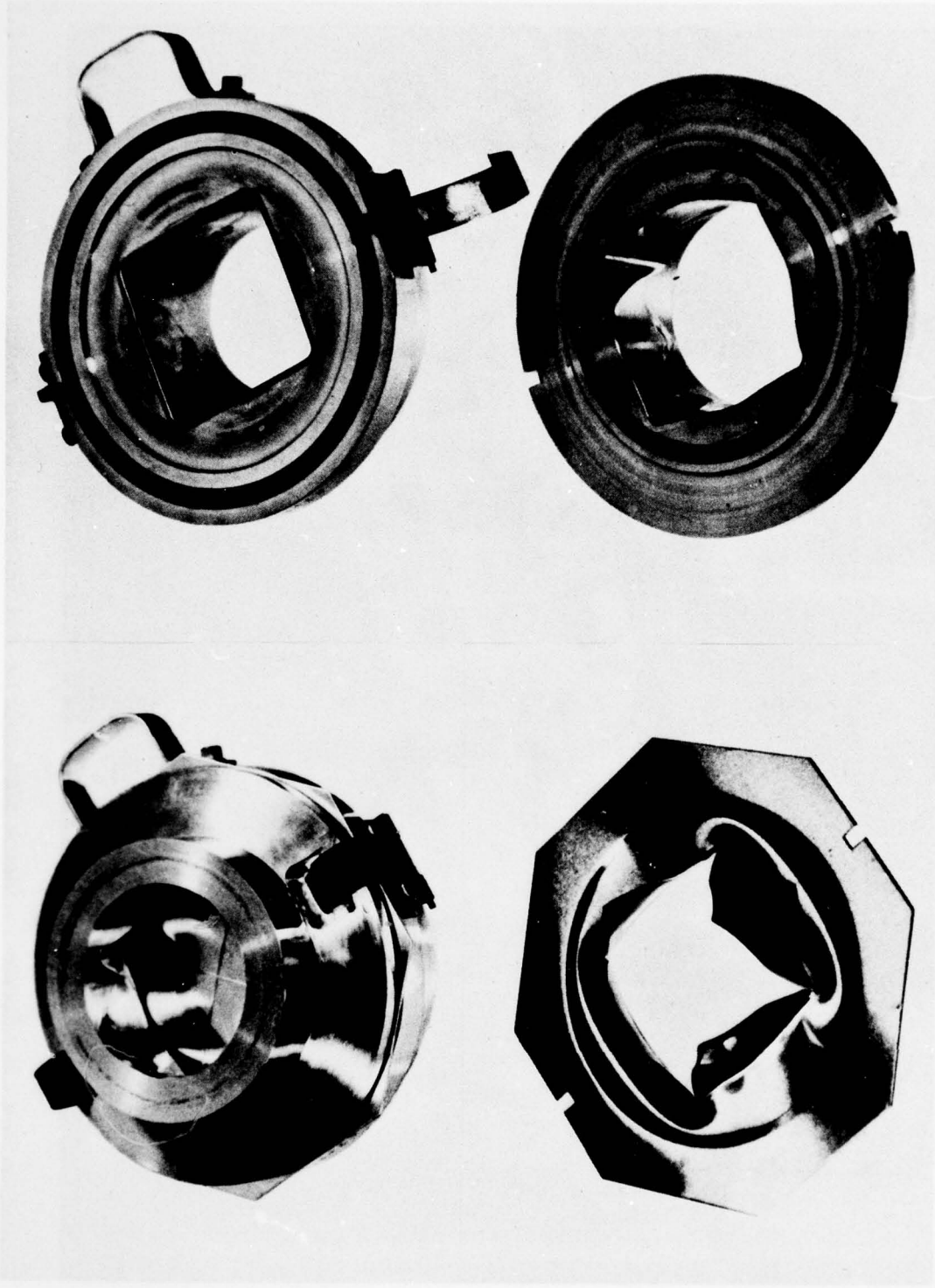


Figure 8. Diaphragm holder and burst diaphragm

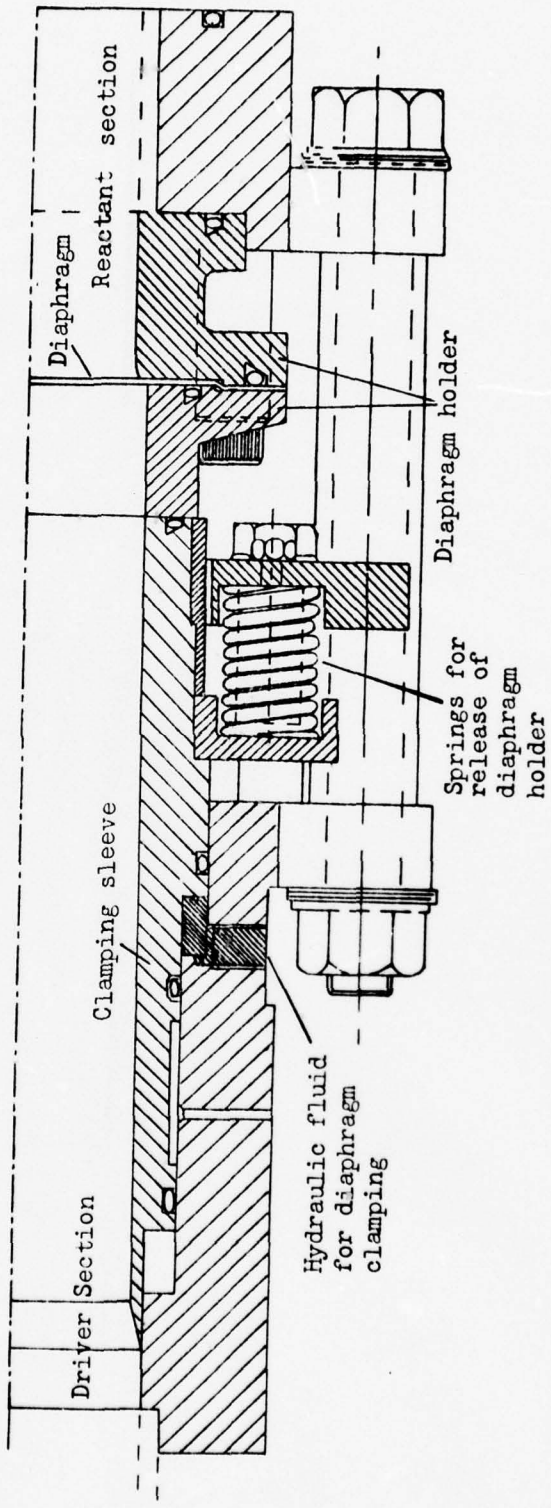


Figure 9. Diaphragm clamping section of shock tube

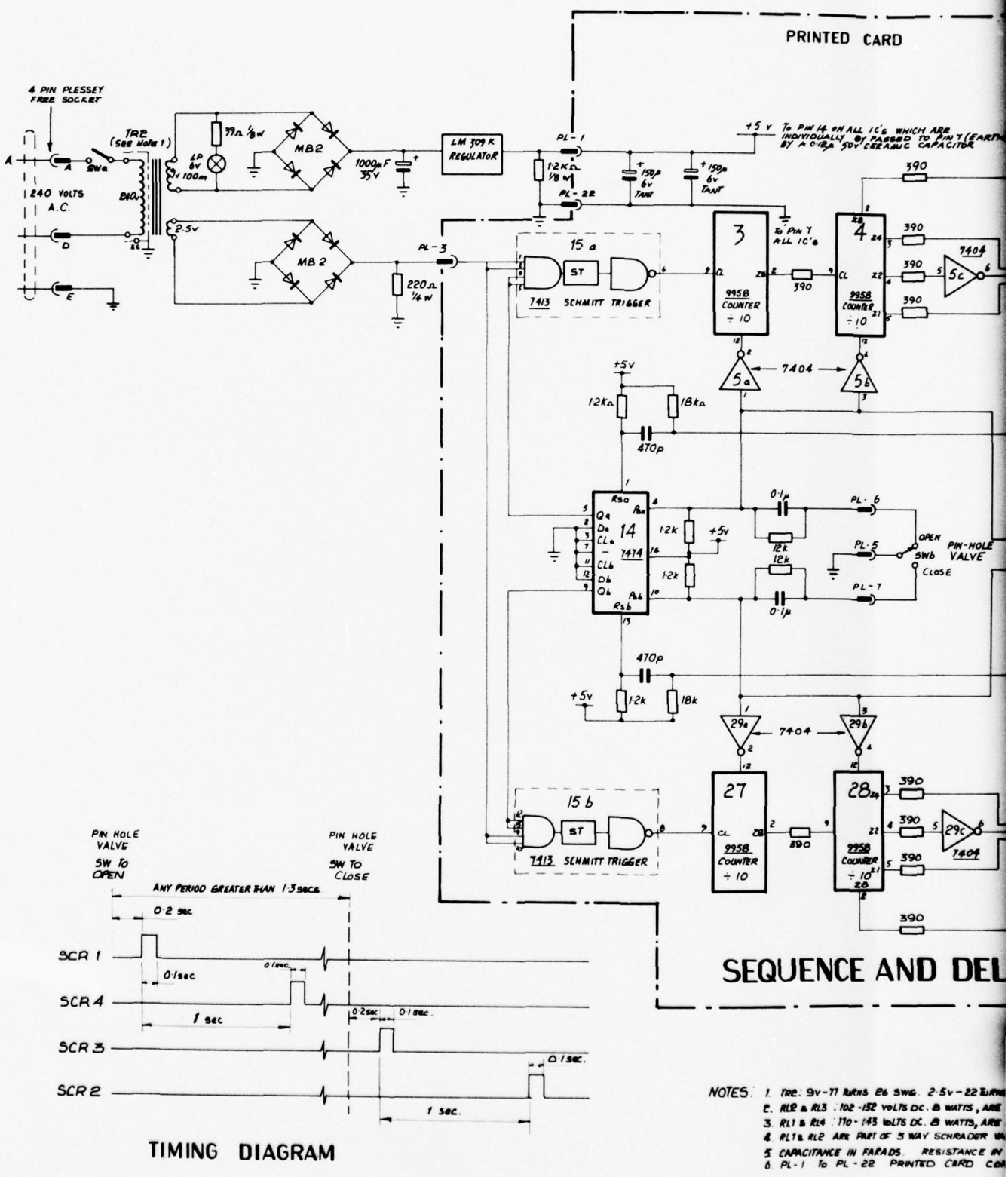
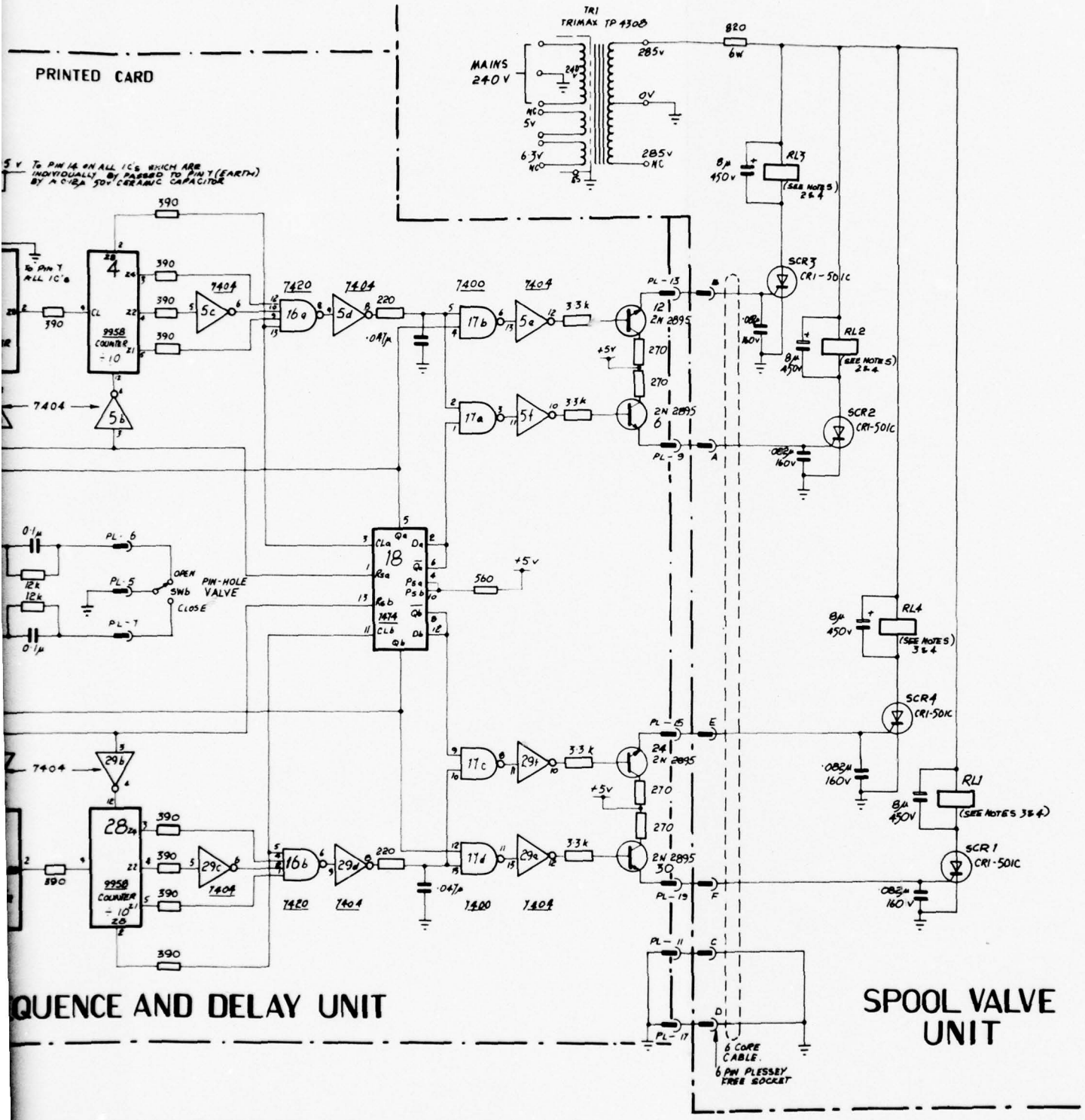
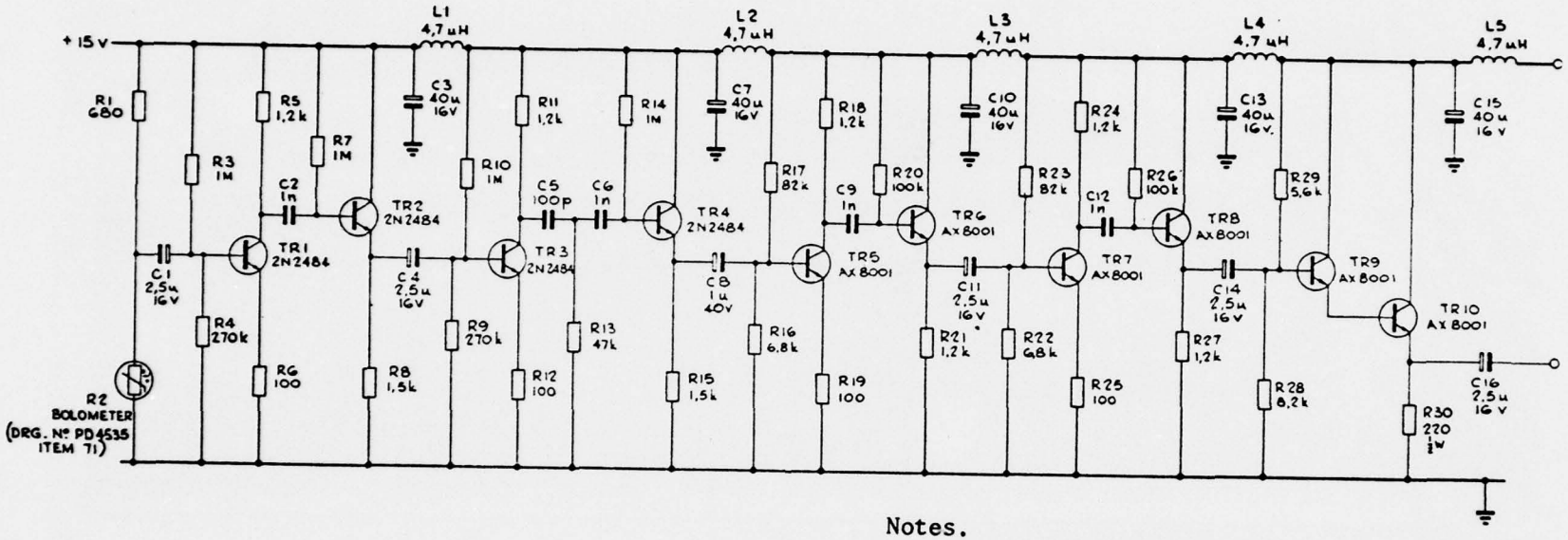


Figure 10. Pinhole valve controll



1. TR1: 9v-77 TURNS 26 SWG 2·5v-22 TURNS 26 SWG. ELECTROSTATIC SHIELD ADDED. TP4341 (MODIFIED)
2. RL2 & RL3 : 102-152 VOLTS DC. 8 WATTS, ARE SOLENOIDS WHICH SEQUENTIALLY OPERATE A PAIR OF SPOOL VALVES
3. RL1 & RL4 : 110-143 VOLTS DC. 8 WATTS, ARE SOLENOIDS WHICH SEQUENTIALLY OPERATE A SECOND PAIR OF SPOOL VALVES.
4. RL1's RL2 ARE PART OF 3 WAY SCHRADER VALVE NS 3028 SA. RL3 & RL4 ARE PART OF 4 WAY SCHRADER VALVE NS 3024 SA.
5. CAPACITANCE IN FARADS. RESISTANCE IN OHMS. RESISTORS 1/16 WATT ±5% UNLESS OTHERWISE STATED.
6. PL-1 TO PL-22 PRINTED CARD CONNECTOR.

Pinhole valve controller circuit diagram



Notes.

Resistors ¼ W unless shown otherwise.
Voltage gain > 80 db
Bandwidth 6 MHz
Output voltage into 50 Ω 4V P-P
Noise at input 4 μV RMS

Figure 11. Bolometer amplifier circuit diagram

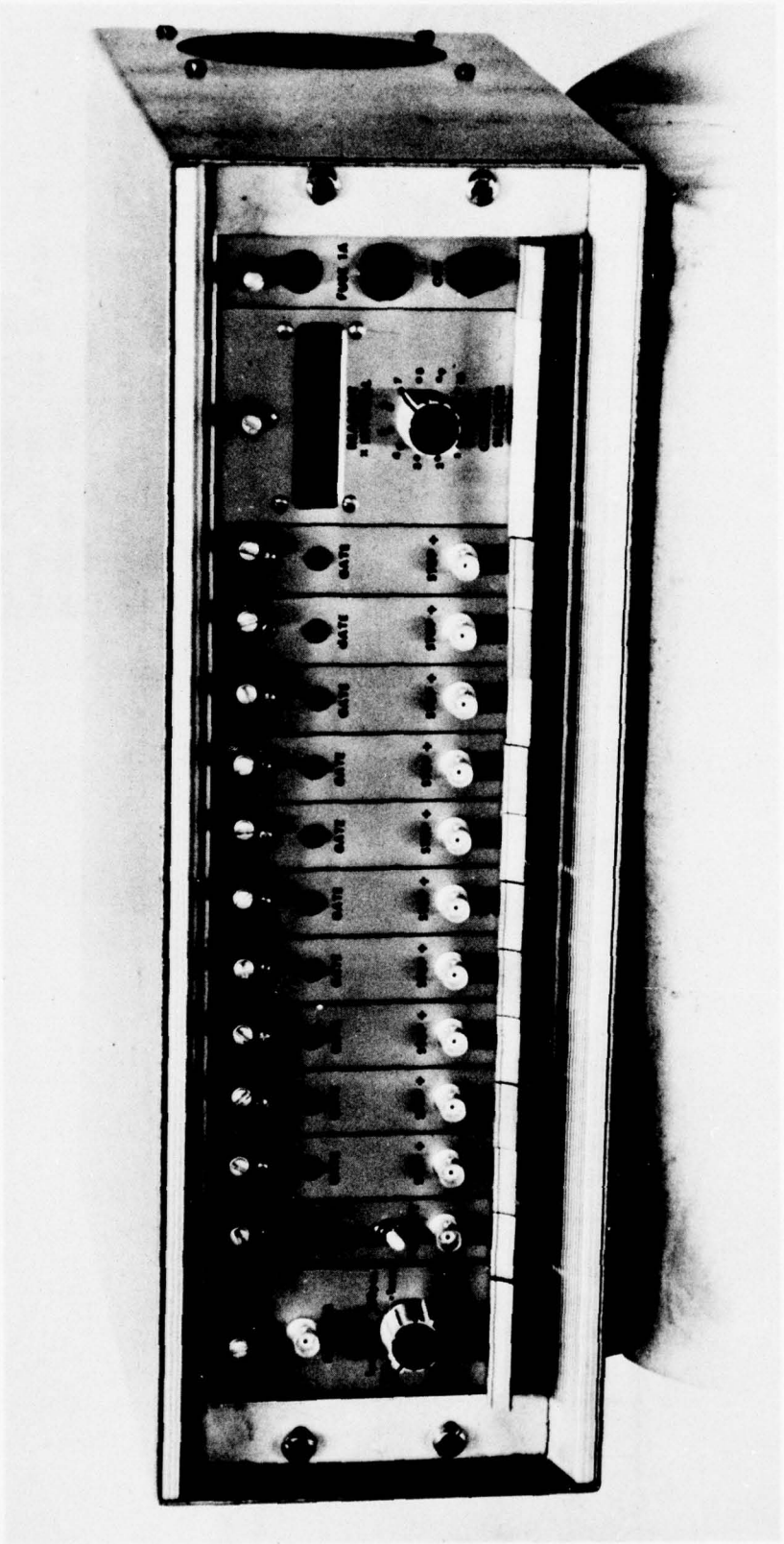


Figure 12. Ten channel eight digit timer

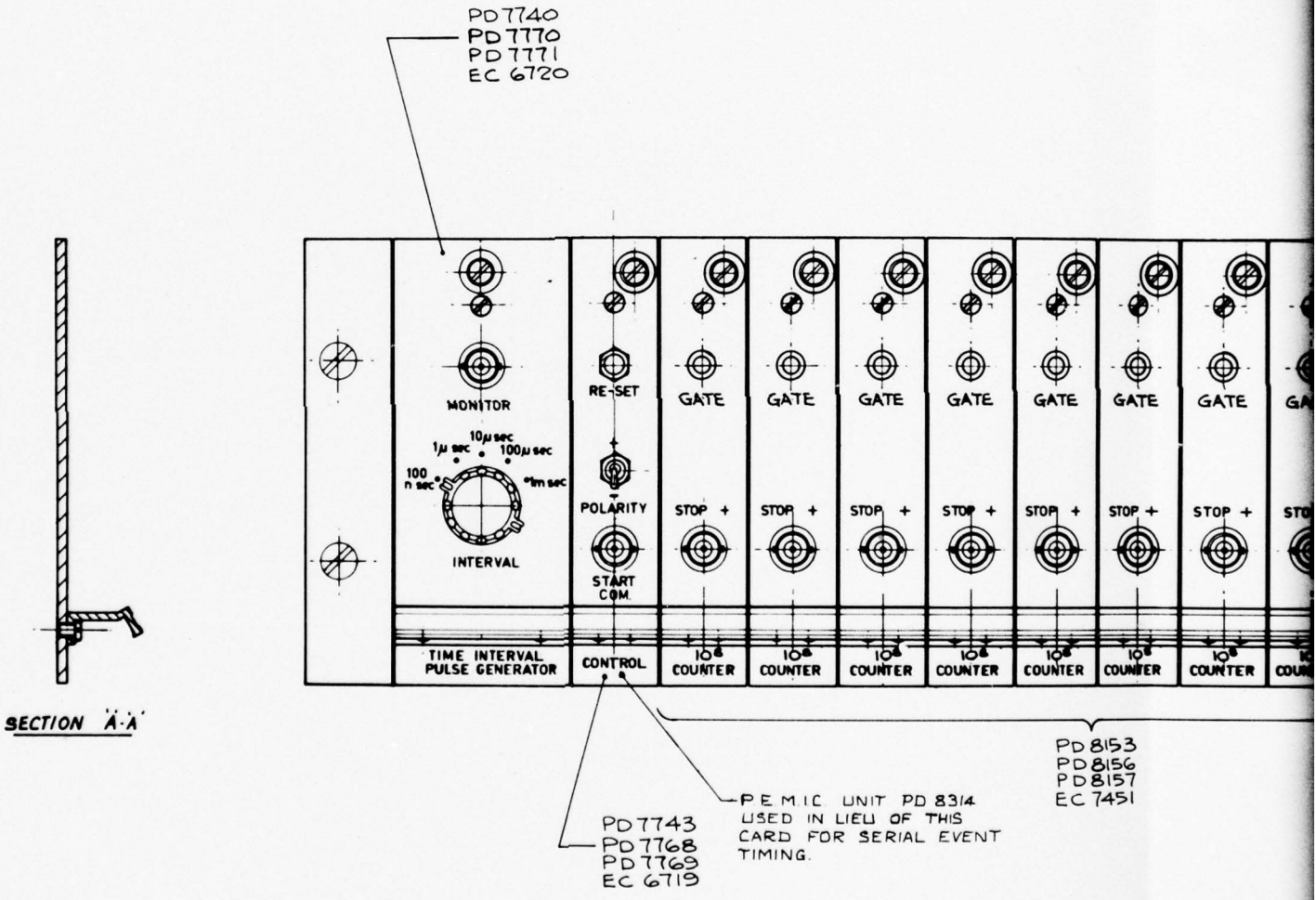
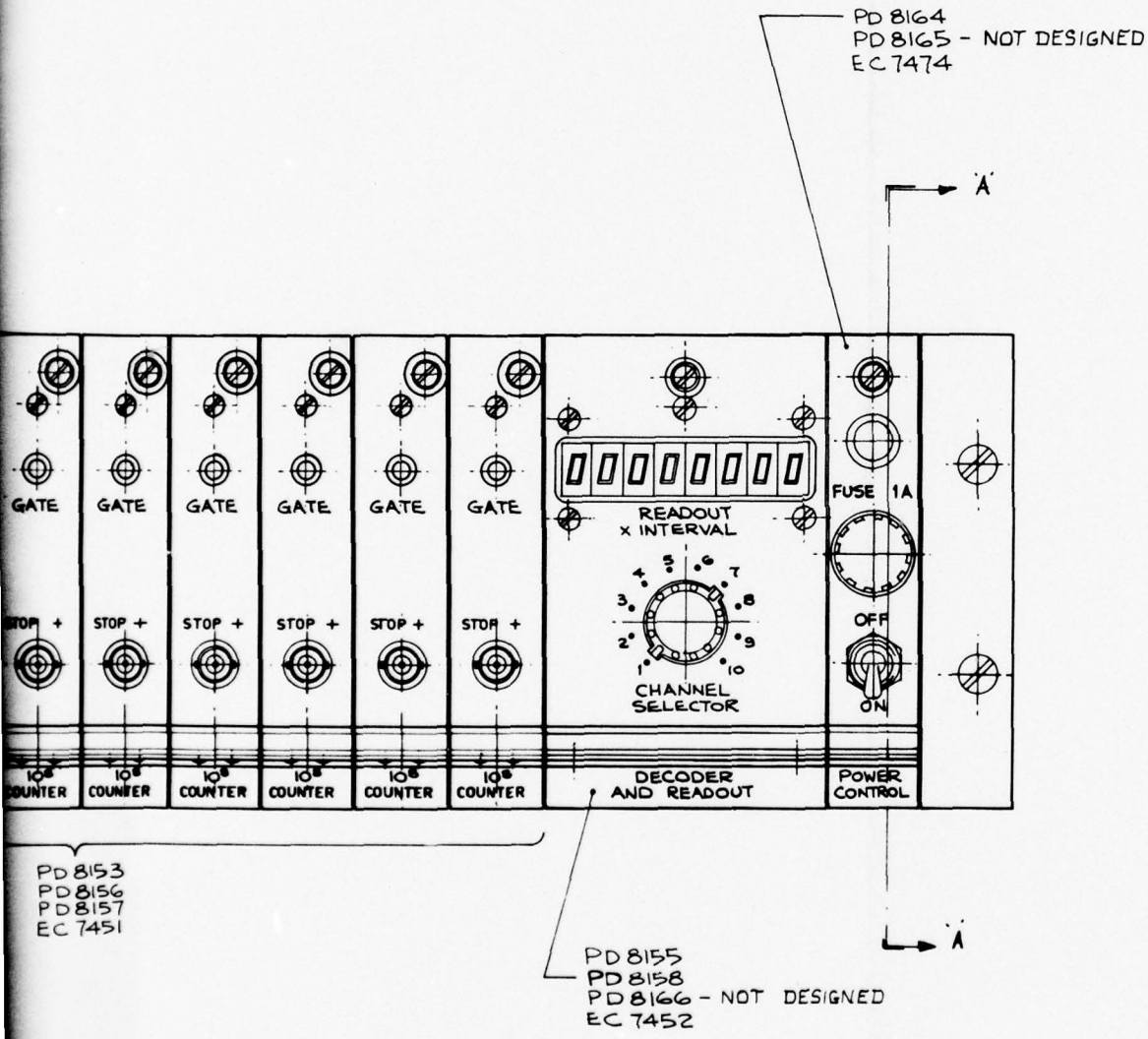


Figure 13. Ten channel eigh

NOTE:
CABINET WIRING PD 8154
POWER SUPPLY PD 7907



13. Ten channel eight digit timer

Figure 14. Five channel trigger unit

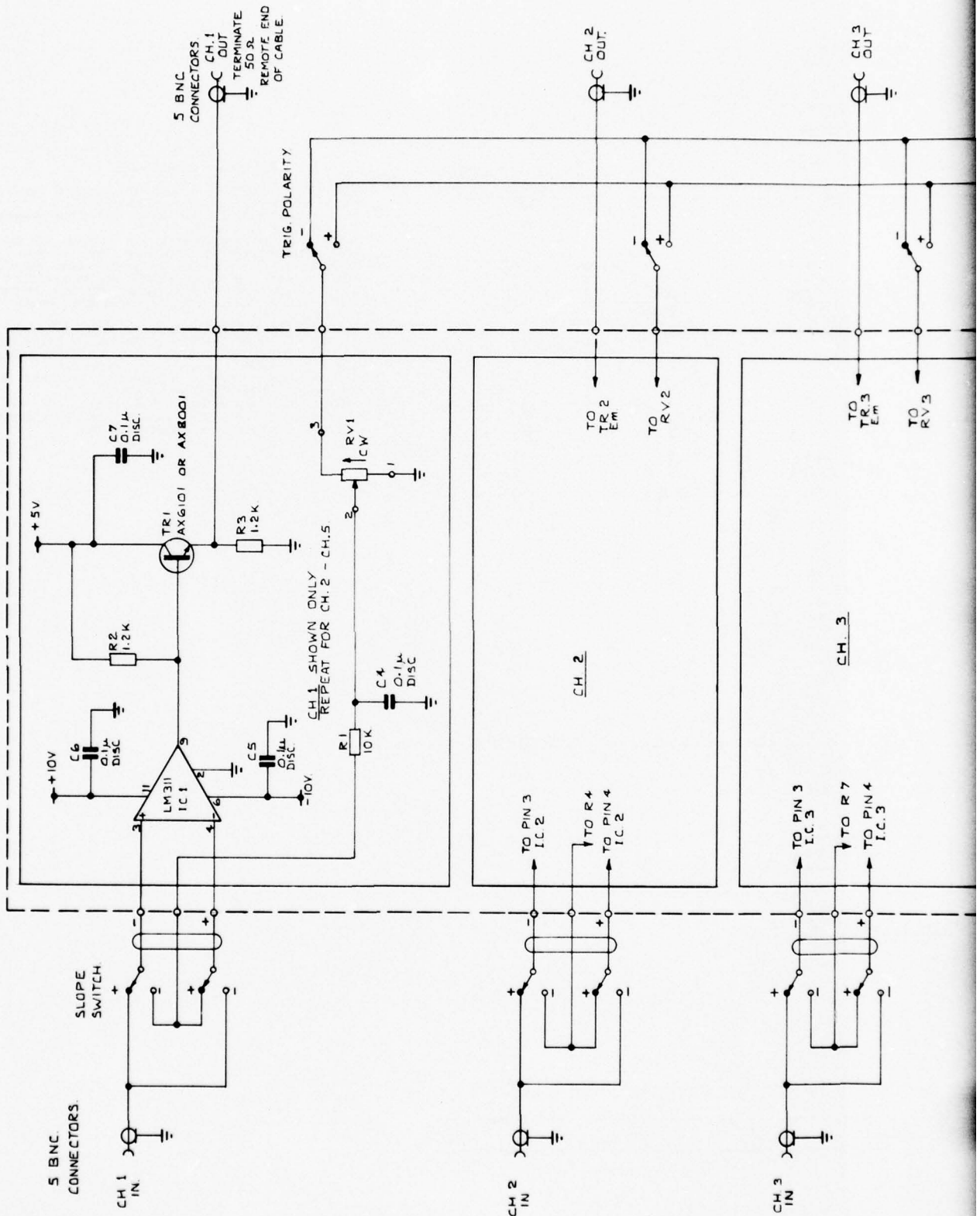
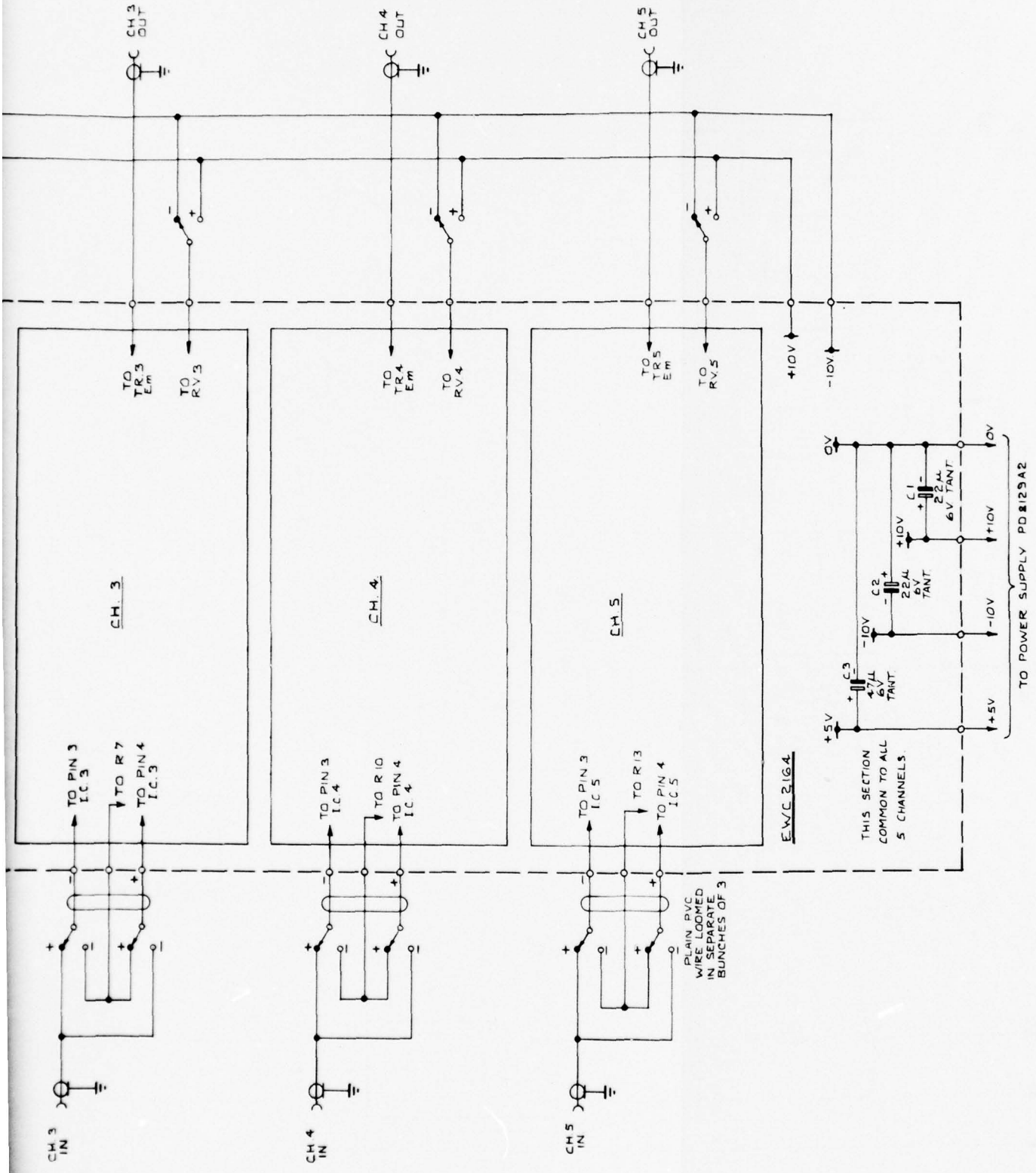


Figure 15. Five channel trigger u



Five channel trigger unit circuit diagram

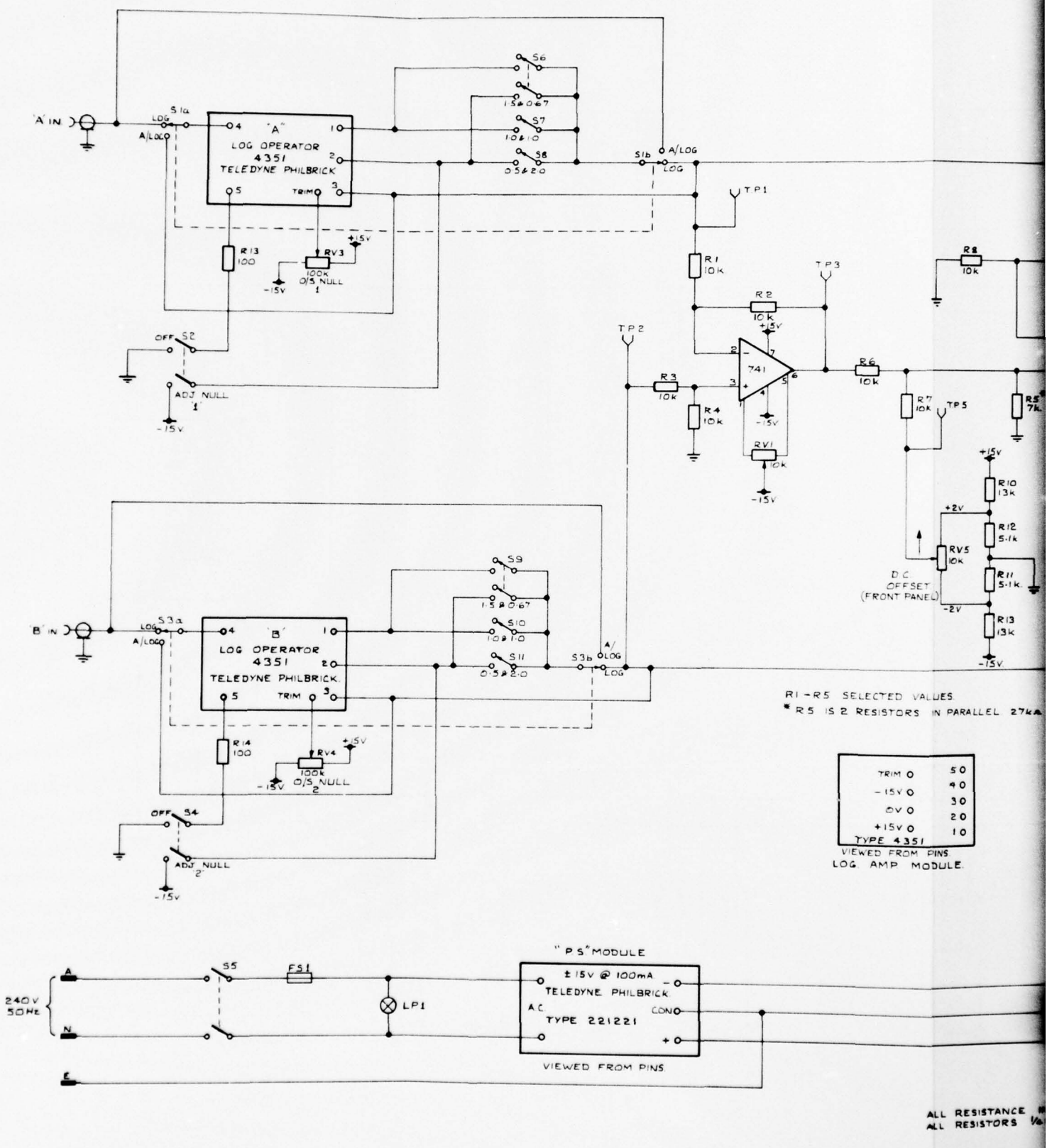
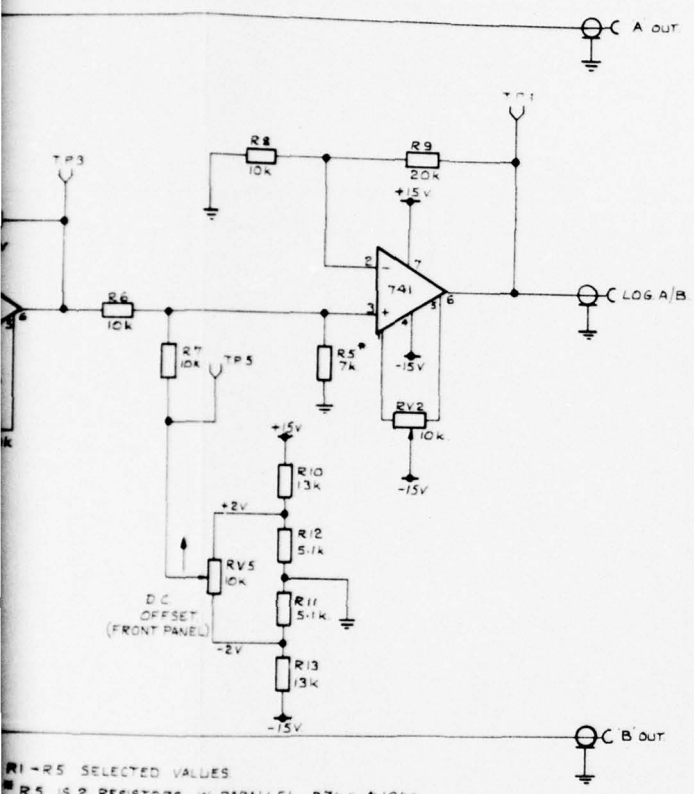


Figure 16. Dual logarithmic amplifier circui



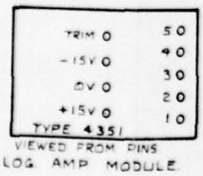
R1 - R5 SELECTED VALUES

* R5 IS 2 RESISTORS IN PARALLEL 27kΩ & 10kΩ

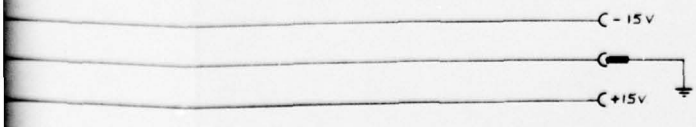
SETTING UP PROCEDURE.

NOTE -

1/ EQUIPMENT REQUIRED :- D.C. OSCILLOSCOPE OR D.C. NULL METER WITH 1.0 mV SENSITIVITY.
2/ ALL MEASUREMENTS MADE FROM THE TEST POINTS TO GROUND. (CHASSIS).
3/ SWITCH ON UNIT, DISCONNECT ALL INPUTS AND OUTPUTS AND ALLOW UNIT TO STABILIZE FOR 10 MINS.
4/ CHANNEL 'A' PUT LOG-A/LOG SWITCH (S1) IN A/LOG POSITION, SWITCH NULL '1' (S2) ON AND ADJUST NULL 1 POT (RV3) FOR MINIMUM (NULL) OUTPUT AT T.P.1. PUT NULL 1 SWITCH (S2) OFF WHEN ADJUSTMENT FINISHED.
5/ CHANNEL 'B', SAME AS FOR 'A' USING NULL SWITCH '2' (S4) AND T.P.2. USE S3 IN LIEU OF S1 FOR THIS STEP OF THE PROCEDURE.
6/ PUT SHORTING LEAD FROM T.P.1 TO T.P.2 AND ADJUST NULL POT 3 (RV1) FOR NULL AT T.P.3.
7/ ADJUST FRONT PANEL D.C. OFFSET CONTROL (RV5) CAREFULLY FOR NULL AT T.P.5.
8/ ADJUST NULL POT 4 (RV2) FOR A NULL AT T.P.4.
9/ REMOVE THE "SHORTING" LEAD FROM T.P.1 AND T.P.2. THE UNIT IS NOW READY TO USE.



VIEWED FROM PINS
LOG. AMP. MODULE.



ALL RESISTANCE IN OHMS
ALL RESISTORS 1/4 W 5%

garithmic amplifier circuit diagram

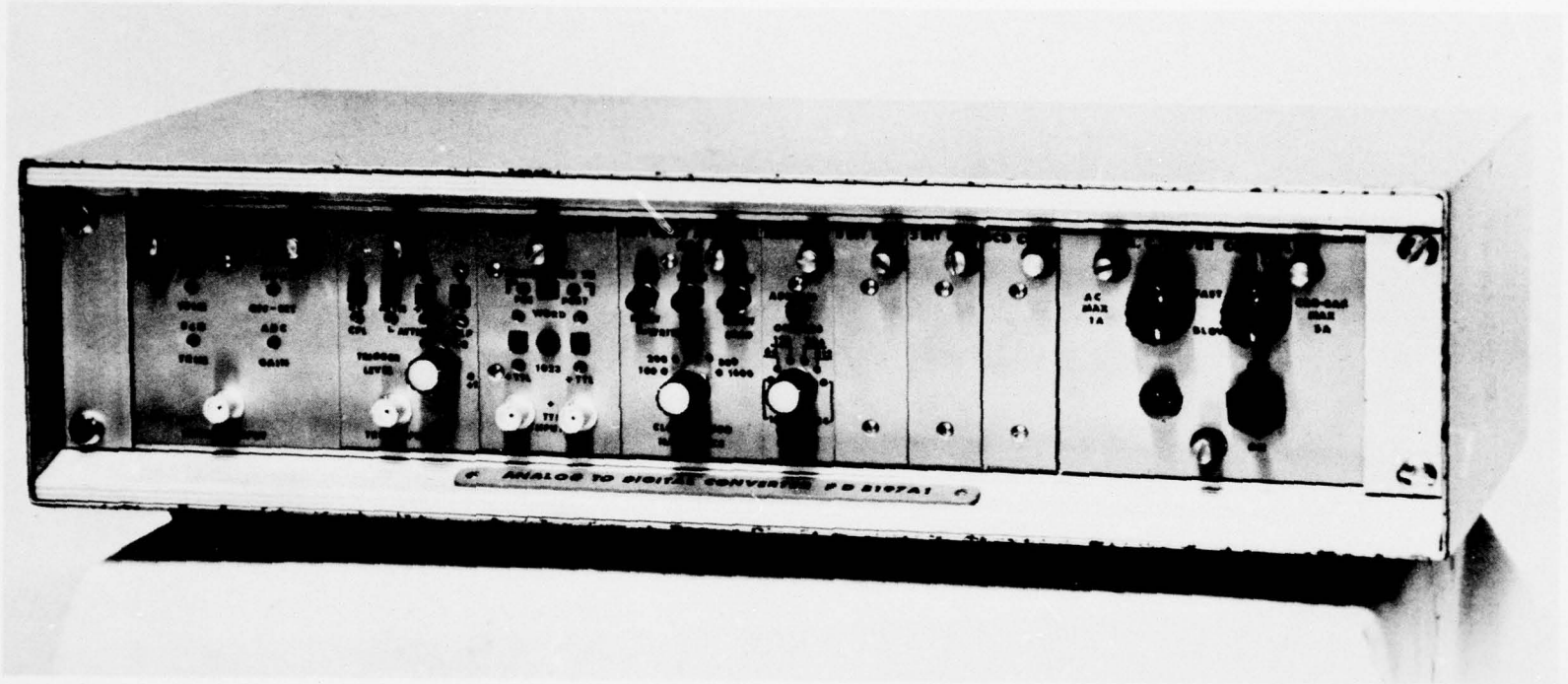


Figure 17. Analogue to digital converter unit

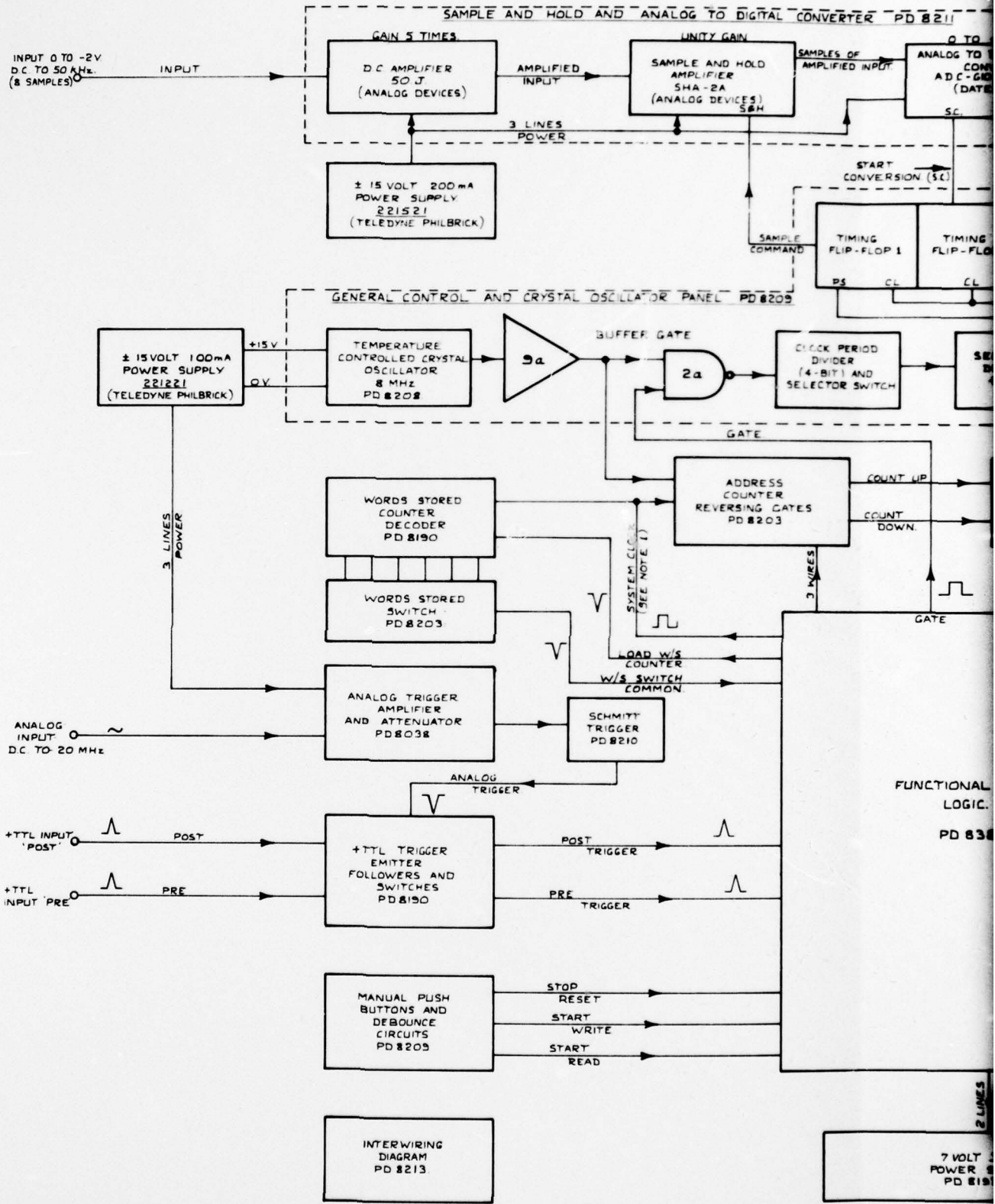
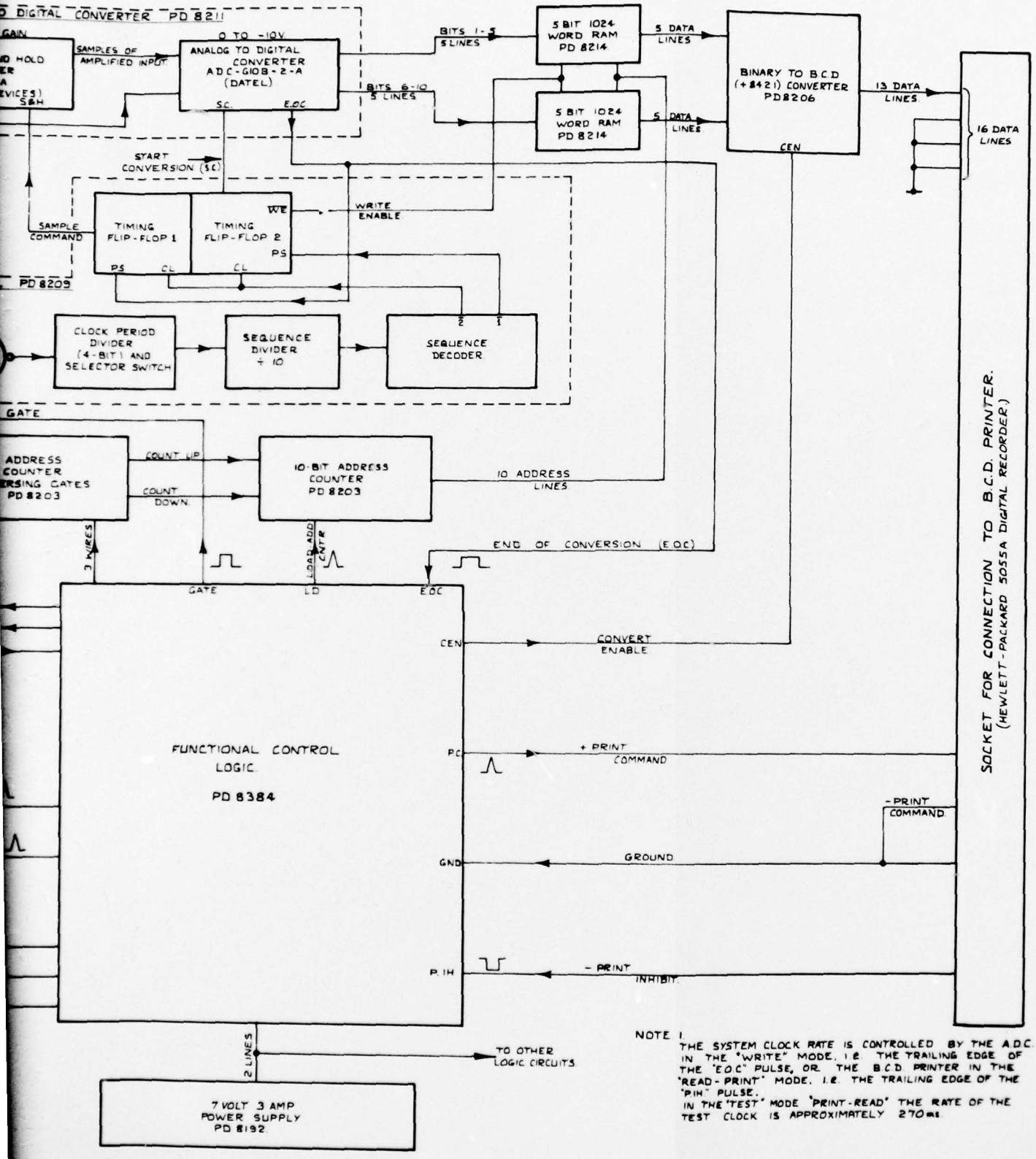


Figure 18. Analogue to digital conver



logue to digital converter unit block diagram

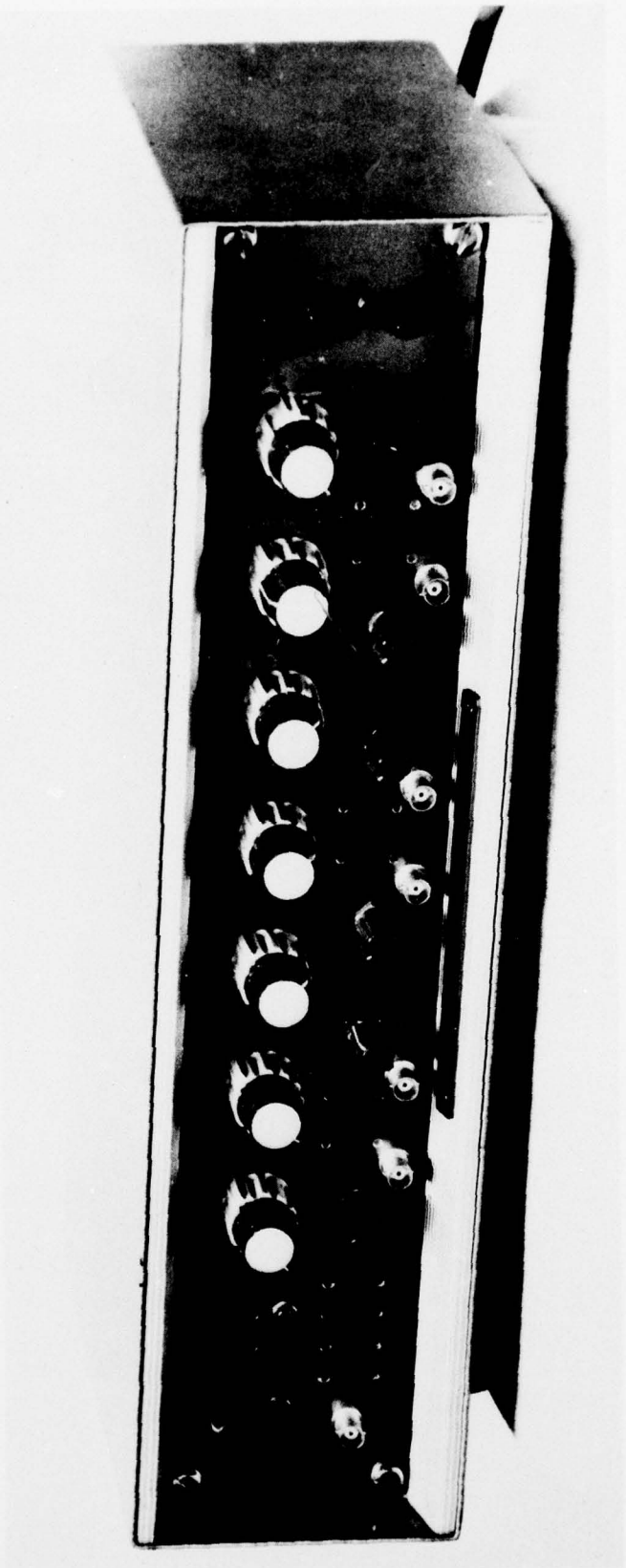


Figure 19. Double digital delay unit

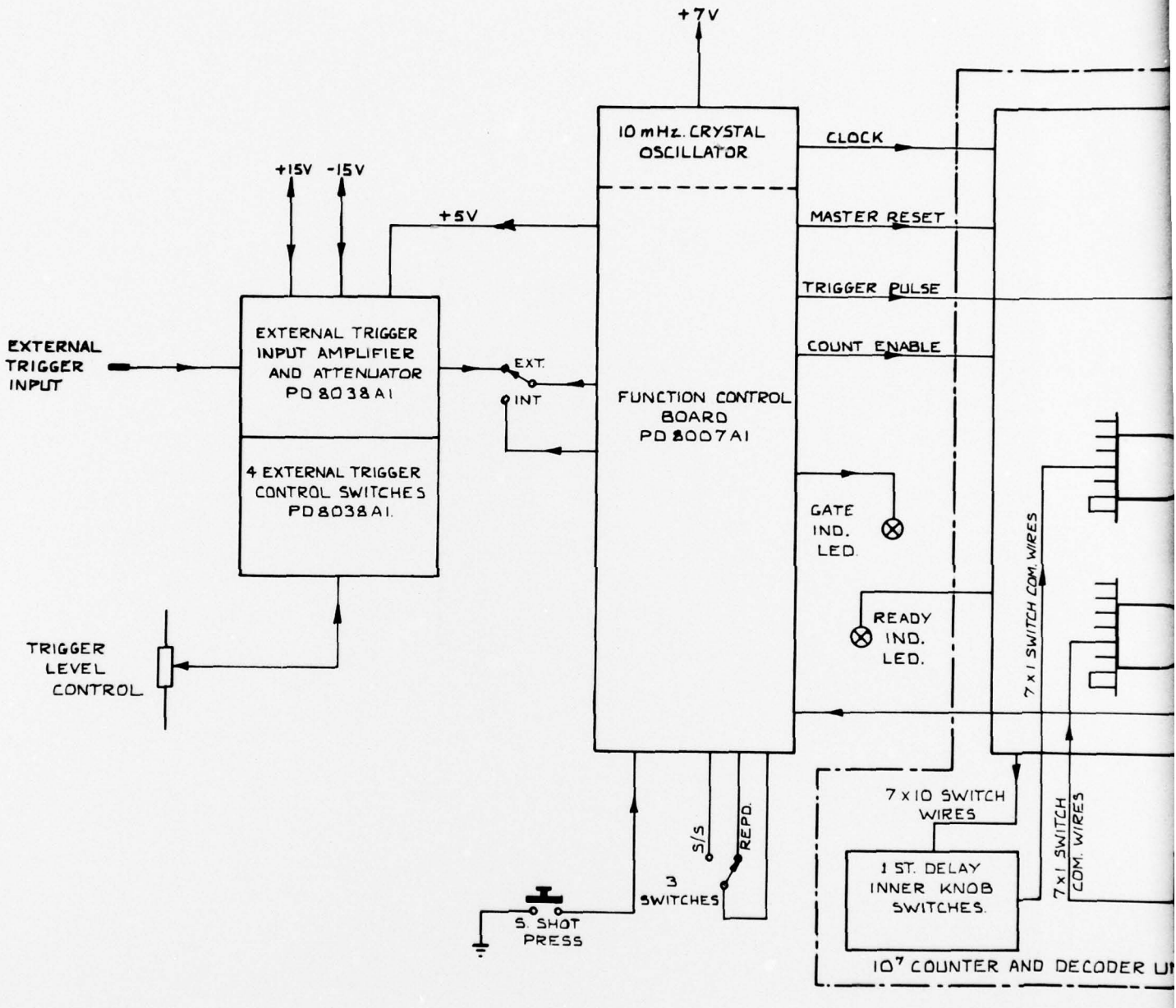
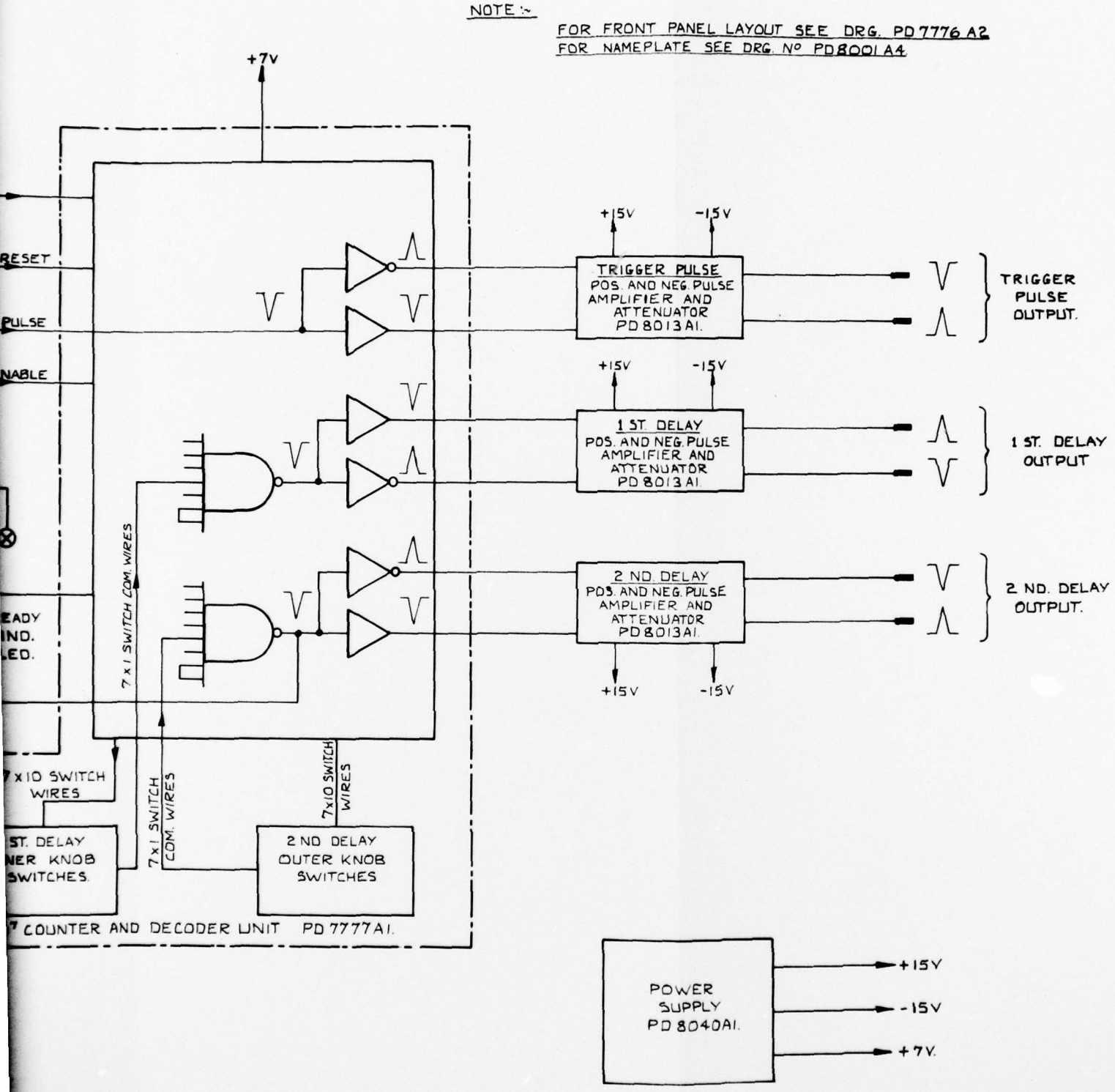
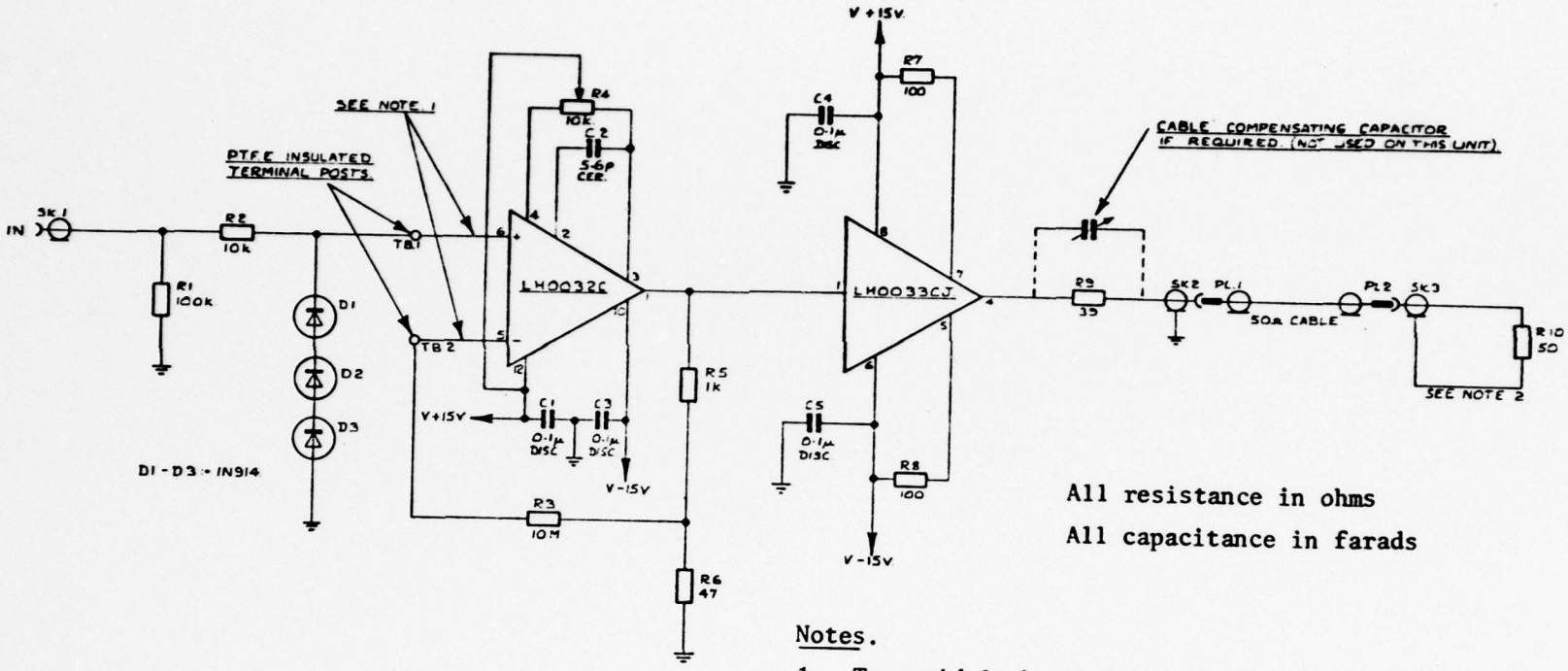


Figure 20. Double digital delay u



Double digital delay unit block diagram



All resistance in ohms

All capacitance in farads

Notes.

1. To avoid leakages to high impedance inputs the LH0032C input leads 5 & 6 are connected to P.T.F.E. insulated terminals and not to the P.C. board.
2. To avoid cable reflections terminate cable with 50 Ω termination

Figure 21. Cable drive amplifier circuit diagram

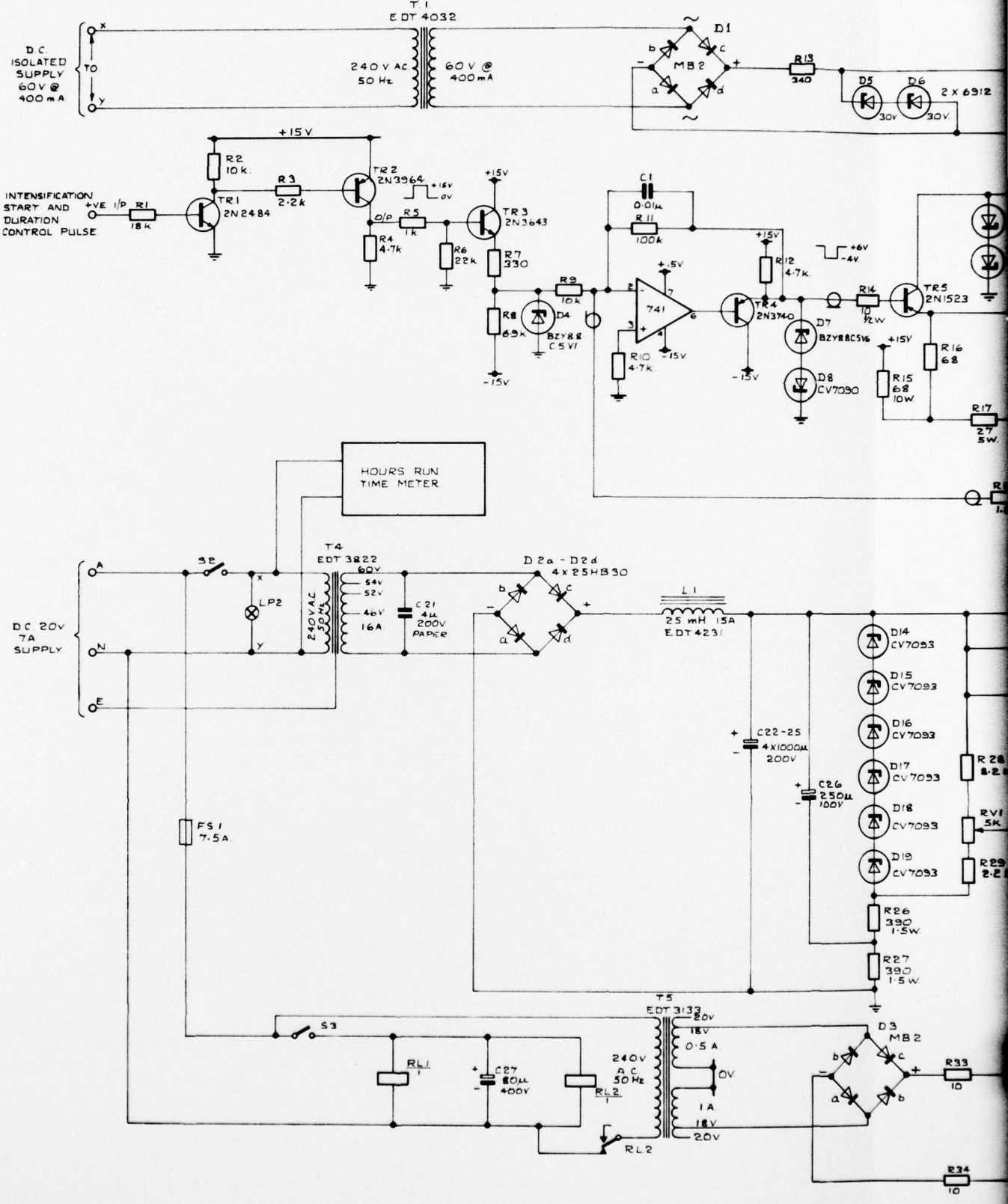
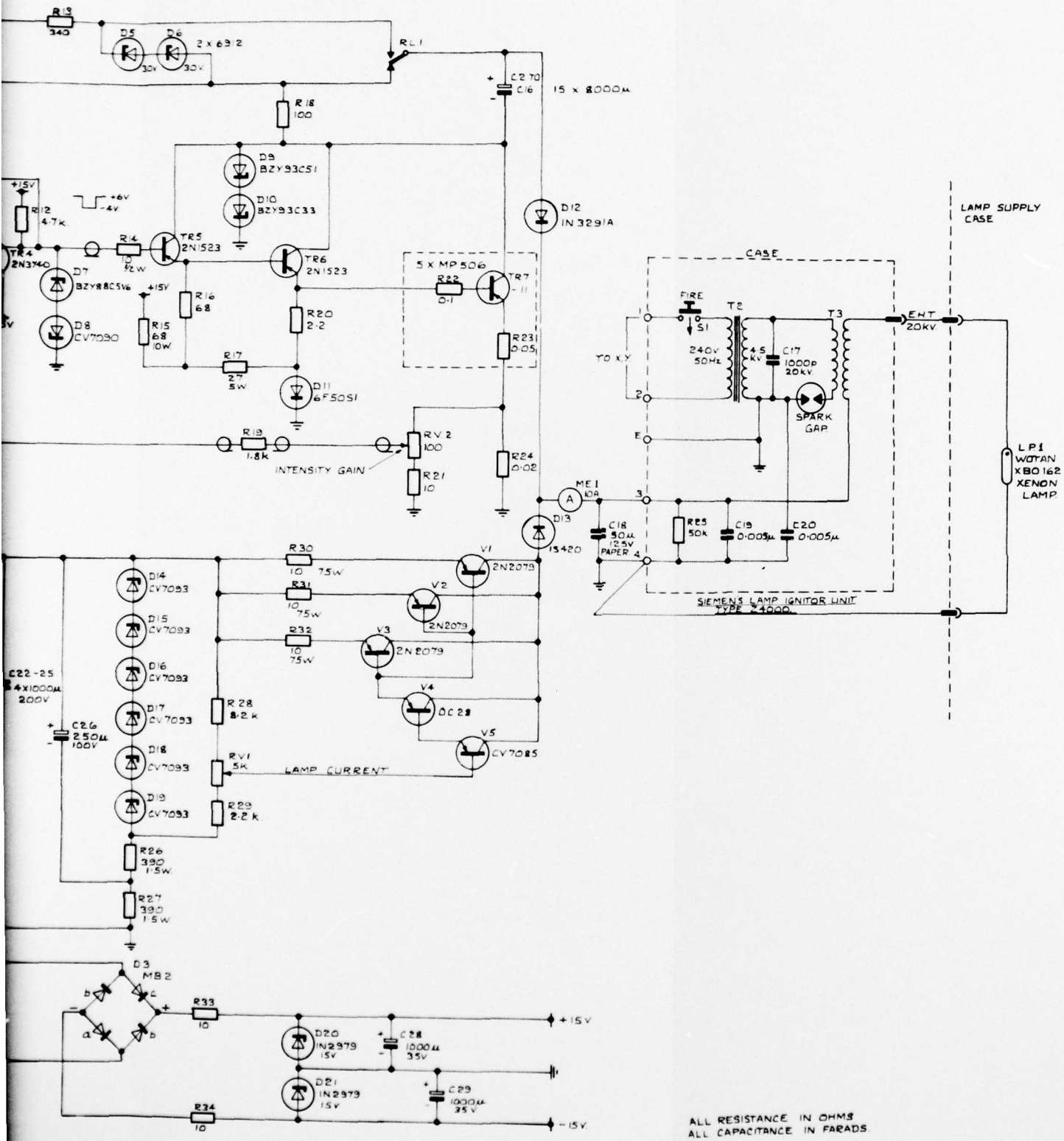
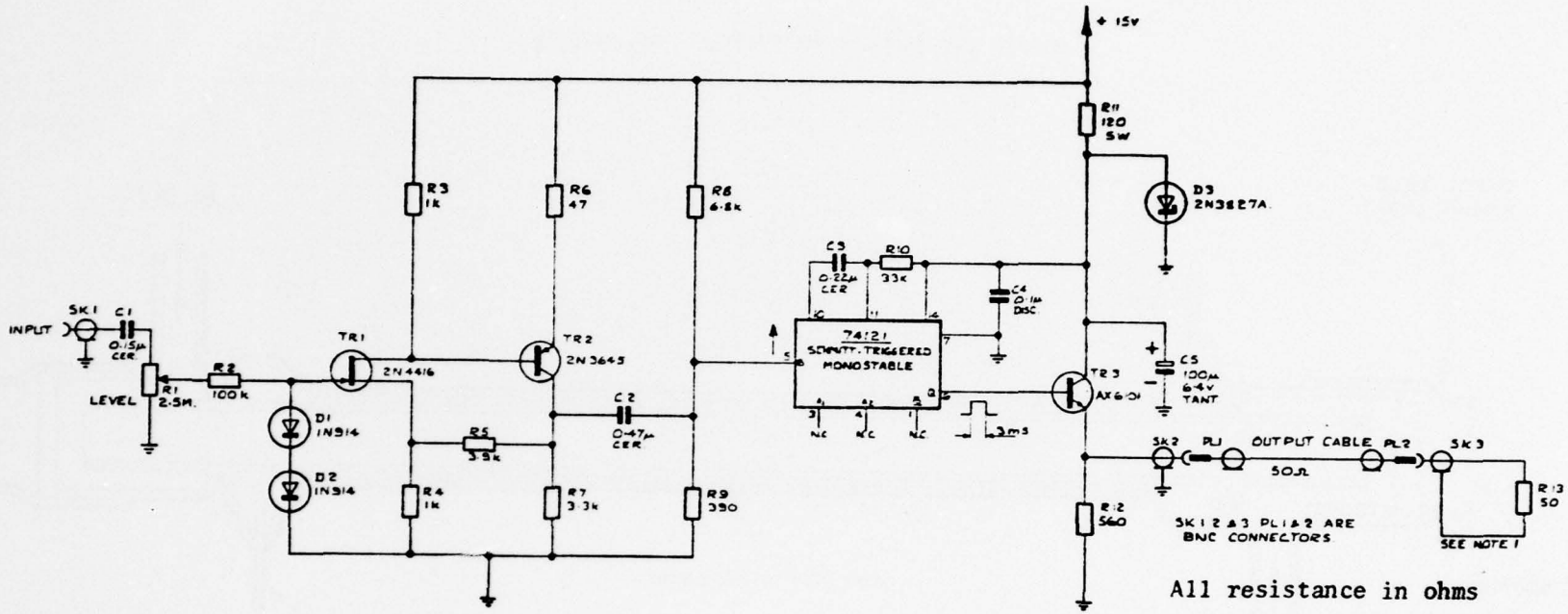


Figure 22. Xenon lamp supply



22. Xenon lamp supply circuit diagram



Notes.

1. To avoid cable reflections terminate cable with 50 Ω termination.

Figure 23. Accelerometer amplifier and pulse generator circuit diagram

WRI:-TR-1819(W)
Figure 23

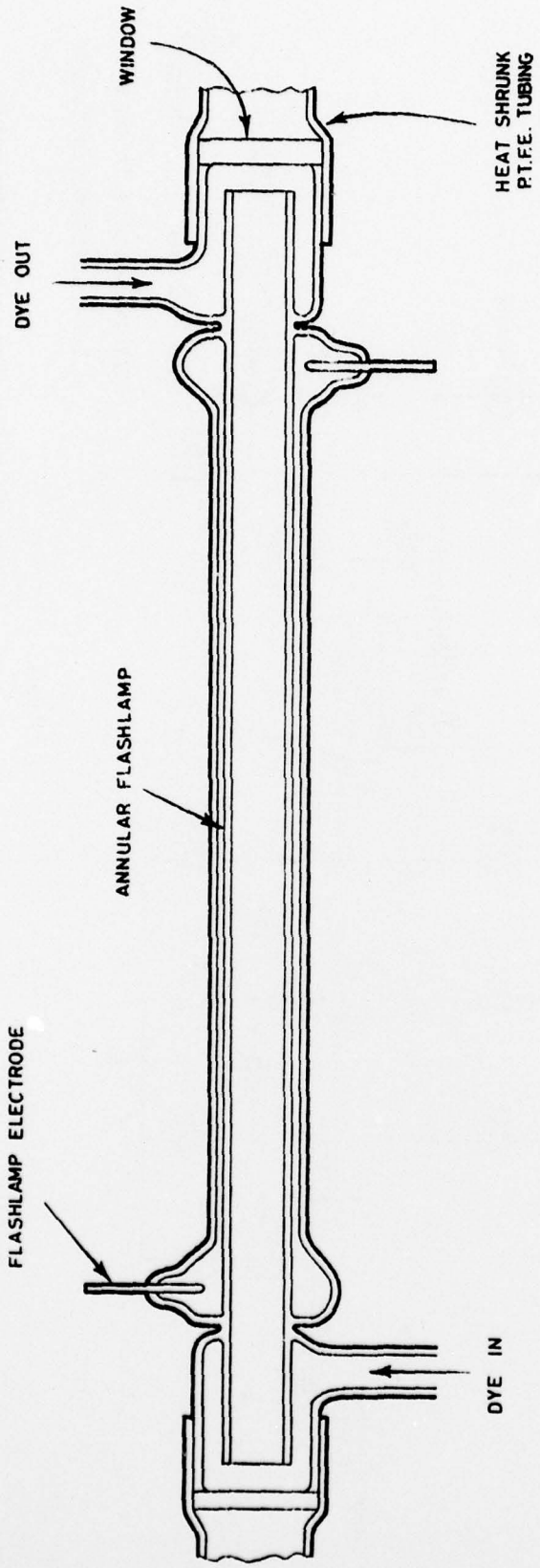


Figure 24. Flashlamp pumped dye laser

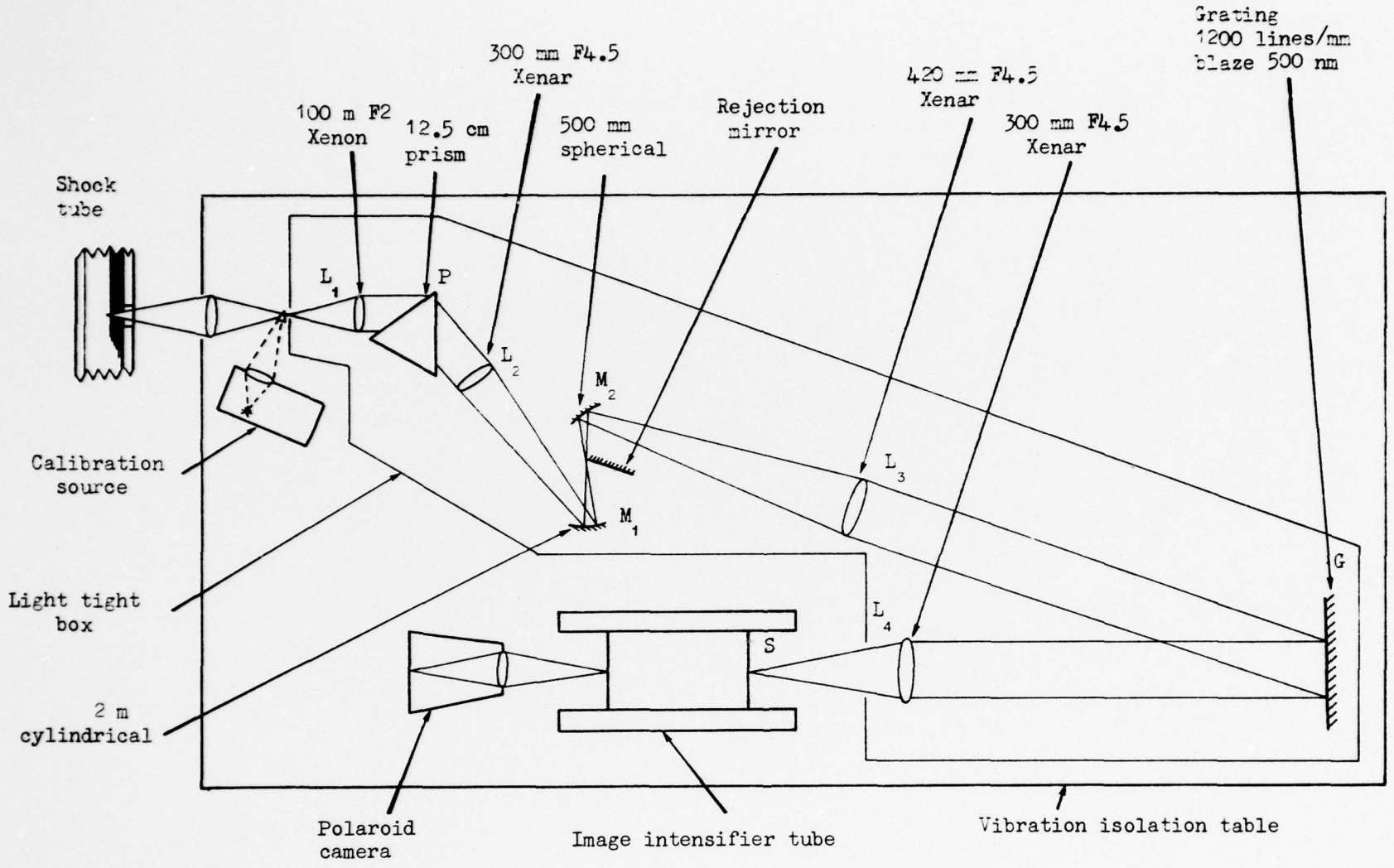


Figure 25. Schematic diagram of Raman spectrograph

DISTRIBUTION

	Copy No.
EXTERNAL	
In United Kingdom	
Defence Scientific and Technical Representative, London	1
In United States	
Counsellor, Defence Science, Washington	2
In Australia	
Chief Defence Scientist	3
Controller, Programme Planning and Policy Division	4 - 5
Executive Controller, Australian Defence Scientific Service	6
Superintendent, Defence Science Administration Division	7
Defence Information Services Branch (for microfilming)	8
Defence Library, Campbell Park	9
Library, Aeronautical Research Laboratories	10
Library, Materials Research Laboratories	11
Director, Joint Intelligence Organisation (DDSTI)	12
Chief Superintendent, Aeronautical Research Laboratories	13
Chief Superintendent, Materials Research Laboratories	14
Defence Information Services Branch for:	
United Kingdom, Ministry of Defence, Defence Research Information Centre (DRIC)	15
United States, Department of Defense, Defense Documentation Center	16 - 27
Canada, Department of National Defence, Defence Science Information Service	28
New Zealand, Department of Defence	29
Australian National Library	30
INTERNAL	
Director	31
Chief Superintendent, Weapons Research and Development Wing	32
Superintendent, Propulsion and Marine Physics Division	33
Senior Principal Research Scientist, Propulsion Composite	34
Principal Officer, Propellants and Polymers Group	35
Principal Officer, Rocket Propulsion Group	36
Mr R.H. Weldon, Combustion and Explosives Group	37
Mr P.E. Rogasch, Combustion and Explosives Group	38
Dr A.R. Rye, Combustion and Explosives Group	39
Authors	40 - 42
Library, W.R.E.	43 - 44
Library, P.M.D.	45 - 46
Spares	47 - 53