THE CONTROL AND AUXILIARY EQUIPMENT OF THE NATIONAL ACCELERATOR CENTRE PRECISION 1,5m SCATTERING CHAMBER.

by

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SUMMARY

A variable-energy separated-sector cyclotron with a K value of 200 MeV as well as an 8 MeV solid pole injector cyclotron has been completed at the National Accelerator Centre complex at Faure. These accelerators will produce both light-ion and heavy-ion beams for Nuclear Physics, Radiotherapy and Isotope production.

The Scattering Chamber can be defined as follows:-

In many nuclear experiments a beam of high energy ions strikes a target. Some of the ions are scattered elastically from the target, others cause nuclear reactions. The scattered ions and/or reaction products must be detected by instruments at a distance from the target. The target and detection instruments must be in a vacuum enclosure and the angle between the incoming beam and the detector must be precisely determined. The vacuum enclosure containing the target and detectors together with their support mechanism is called a Scattering Chamber.

Four movements have to be controlled on the NAC 1,5m Scattering Chamber, namely:-

The Upper and Lower arms, on which the detectors are mounted. These arms had to be controlled to an accuracy of 0,01°.
The Target Angle. This angle can change to plus and minus 90° with respect to the incoming beam, with an accuracy of 0,1°.
The Target Height has an accuracy of 0,01". Up to five targets can be mounted in the target holder and moved in front of the beam.
An Out of Plane Angle movement has been planned and will be built if it is needed for an experiment.

Modular stepper motor controls were built for the various movements. With these controls it is possible to change the angles or height in three modes, namely: continuously, with a preset angle or height, or in single steps of the stepper motors. The speed of the motors can be changed and use was made of a buffered clock to minimize steps lost or gained because of drag or inertia.

Determining the angles and the height to the stated accuracies gave the most problems. Shaft encoders were used and in the case of the two arms a hybrid shaft encoder with a 36000 point resolution was used. Use was also made

of anti-backlash gears. In the case of the Target Angle and Target Height pin contact shaft encoders were used. These encoders are radiation resistant.

As the Experimental Area can be radioactive if the beam is on, the readouts and controls had to be remotely placed in the Data Area. A remote control box is situated at the Scattering Chamber. This control will typically be used to ensure that the equipment and cables inside the chamber do not foul each other before the lid is replaced. Great care had to be taken with earthing problems as very small signals emerge from the detectors and the environment is electrically very noisy. As the Scattering Chamber is an experimental facility the possibility of later modifications and changes had to be kept in mind. Everything was thus built as modular as possible.

In order to prevent unwanted nuclear reactions with gas molecules and to minimize losses after reactions on the targets have occurred, a vacuum system had to be designed which could pump the chamber down to the 10^{-7} mbar range.

Some smaller instruments like a Pre-amp power supply, Remote switching, H.T. Vacuum protection and Detector temperature displays also had to be built. These instruments form an integral part of the Scattering Chamber.

SCOPE

To describe the design and development of a display and control system as well as the auxiliary equipment for the National Accelerator Centre 1,5m precision Scattering Chamber.

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1. INTRODUCTION

A variable-energy separated-sector cyclotron with a K value of 200 MeV as well as an 8 MeV solid pole injector cyclotron has been completed at the National Accelerator Centre complex at Faure. These accelerators will produce both light-ion and heavy-ion beams for Nuclear Physics, Radiotherapy and Isotope production. [1]

1.1 Definition of a Scattering Chamber

In many nuclear experiments a beam of high energy ions strikes a target. Some of the ions are scattered elastically from the target, others cause nuclear reactions. The scattered ions and/or reaction products must be detected by instruments at a distance from the target.

The target and detection instruments must be in a vacuum enclosure and the angle between the incoming beam and the detector must be precisely determined. The vacuum enclosure containing the target and detectors together with their support mechanism is called a scattering chamber. [2]

1.2 The precision 1,5m Scattering Chamber

The NAC was fortunate to acquire one of the two 1,5 m Scattering Chambers (S.C.) from the University of Maryland's Cyclotron Laboratory after their facility shut down. See figs 1.1 - 1.3

This is a high precision S.C. which can accommodate a wide variety of experiments, its precision and flexibility being mainly due to the fact that the mechanisms which carry the target and detectors, are supported independently from the vacuum chamber. The two independently movable arms can be positioned to any angle with respect to the target. These arms can support complex detector systems. See fig 1.2.

Provision has also been made for flexible lines to carry liquid nitrogen to cool certain types of detectors.

The target mechanism makes provision for 5 targets which can move vertically so that any one of the different targets can be positioned in front of the beam.

The target mechanism can also be moved to an angle with respect to the beam.

A detector support table for measurements out of the median plane has still to be be constructed if needed.

1.3 Problems with the Maryland Scattering Chamber

The following changes and modifications had to be made.

1.3.1 The control and measurement system

- * The measurement system consisted of two potentiometers, one for coarse and one for fine measurements. Two digital volt meters were used to display the angle. The two readings had to be added and the fine potentiometer gave a wrong reading once per revolution when this was in its inactive region.
- * The system often had to be calibrated.
- * The control and display was multiplexed and only one function could be displayed or moved at a time.
- * It was old and obsolete parts were not readily available. The control and readout section alone used seven 480 mm racks and used 95 relays to do the multiplexing.
- * The electronics worked from 110V, 60Hz .
- * Some parts were missing.

1.3.2 The vacuum system

- * The whole system had to bedesigned from scratch in order to incorporate a new oil free technology and consequently none of the old parts could be used.
- * Leaks on the chamber and seals had to be repaired.
- * Vacuum tight feedthroughs for BNC and detector H.T. cables as well as for the stepper motors and shaft encoders had to be made.

1.3.3 Mechanical

- Some damage occurred during transport.
- New fittings to accommodate the new shaft encoders and stepper motors had to be designed and made.
- The S.C. had to be aligned within 0,1 mm with respect to the beam.
- A new stand had to be made for the S.C.

1.4 Design considerations

As this instrument is used for a wide variety of experiments it had to be made as modular as possible. It also had to be made easy to operate as people from external organizations will be making use of it.

The Experimental Area is situated about 80m from the Data Area in an electrically noisy environment. The signals emerging from the detectors are very small and earthing can be very critical. High repeatable accuracies also had to be met. When the beam is on personnel cannot enter the Experimental Area because of radiation danger.

The instrumentation in the S.C. should be able to withstand radiation damage and operation in a vacuum environment.

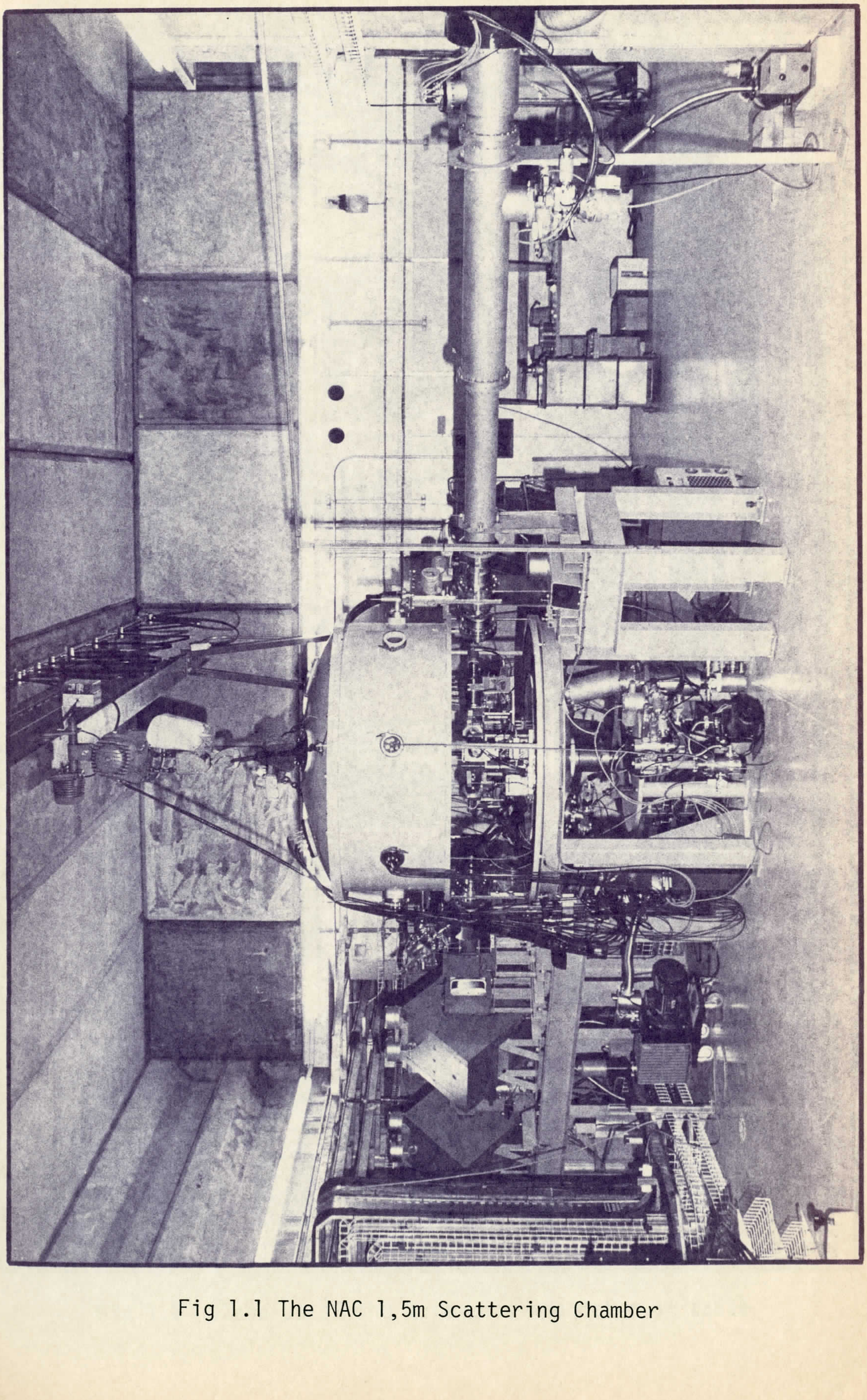

Fig 1.1 The NAC 1,5m Scattering Chamber

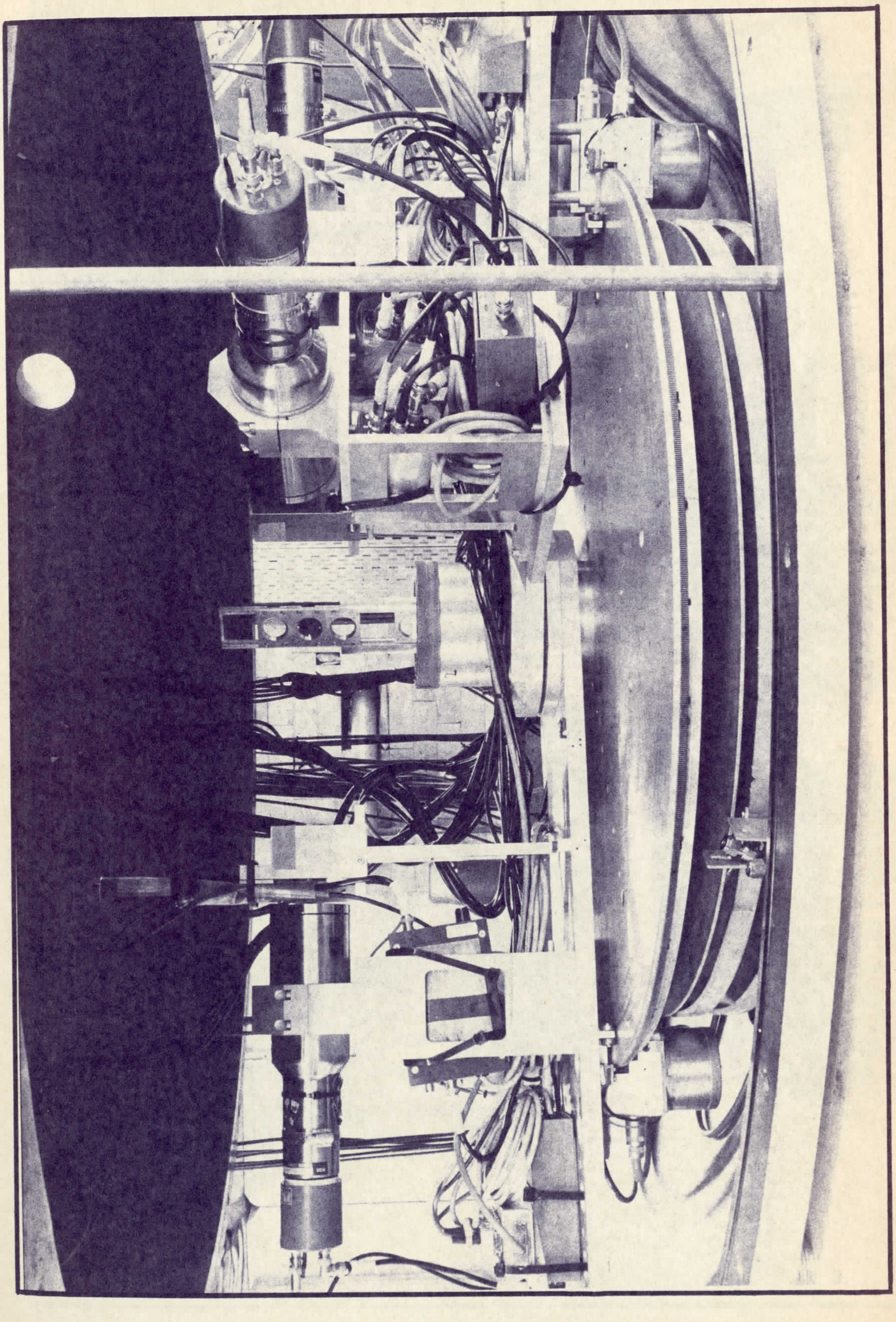

Fig 1.2 Close up of the movements and detector table

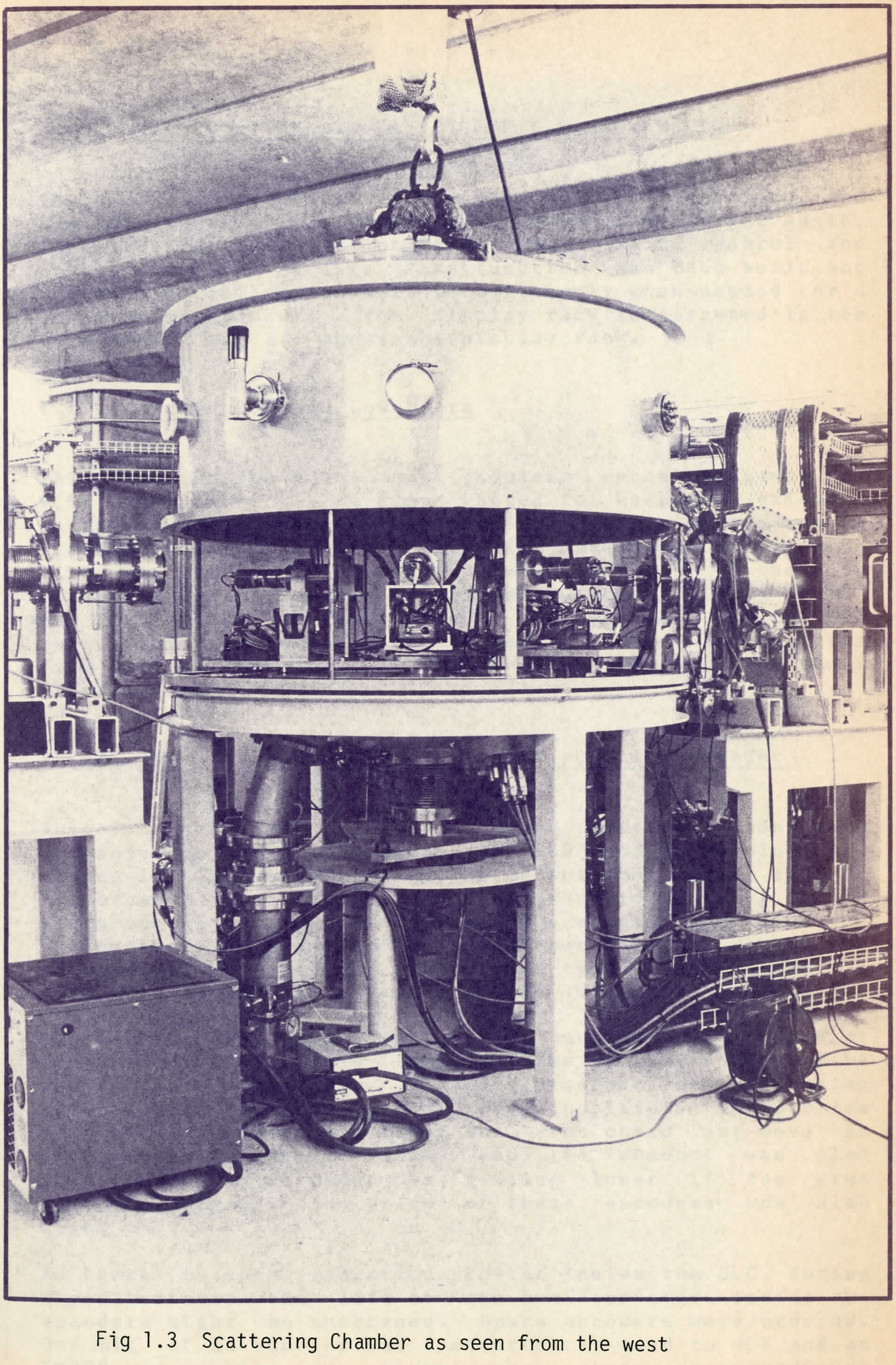

Fig 1.3 Scattering Chamber as seen from the west

2. THE POSITION DISPLAY OF THE S.C. MOVEMENTS

There were 5 movements that had to be controlled and monitored namely the Upper Arm, Lower Arm, Target Angle, Target Height and Out of Plane Angle. The control and display section of this last function has been built but the mechanical section will be built only when needed for a specific experiment. The display rack is situated in the Data Area. Fig 2.1 shows the display rack.

2.1 The Upper and Lower Arm

This function gave the most problems as an accuracy of 0,01° was needed. We also wanted to keep the existing gears as their accuracy was proven, by experiments done at the Maryland University. The ring gear on the detector table had 1800 teeth and the anti-backlash gear on the fine potentiometer of the old system had 50 teeth, giving it 10° per revolution. We thus needed a shaft encoder giving 1000 counts per revolution with 36 revolutions. An American firm was willing to modify a shaft encoder out of their existing range.

2.1.1 The Litton SBD43-363H31 shaft position encoder

This is a whole word (absolute) shaft position encoder with a resolution of a 1000 counts per 360° and 36 revolutions, giving it 36000 positions. The output code format is 8-4-2-1 binary coded decimal. It is a hybrid system i.e. the "high-speed" section producing 1000 counts per 360° is photo electric and the "low speed" section that counts the 36 revolutions is of the pin contact type. This encoder is also able to work in a vacuum of the 10^{-7} mbar range.

There were also some problems in mounting these encoders; because of their size (125mm x 107mm Ø) they could not be mounted below the arms. The only alternative was mounting them next to the arms in an inverted position. The problem with this position was that the arms could not move as close together as previously and the readout was also inverted i.e. the count was getting lower if the arms turned clockwise. The price of these encoders was also high.

As there is some radiation present inside the S.C. during experimentation the life of the semiconductors inside the encoders might be shortened. Spare encoders were ordered. One bit of an encoder was inadvertently tied to +5V and an LM339 comparator was blown; the potting compound was

The electronics of the readout section was straight forward, the BCD bits were fed directly to five VK00-46b modules.These modules contain the 7 segment display drivers as well as the displays and the the current limiting resistors. The third decimal point is always on.

The encoders drew 750mA each, consequently the voltage drop over the 80m line was excessive. Sense lines were tried but this did not work too well because of the noise problem. An OLV 30-5 5V, 3A power supply was then placed in the preamplifier power supply box situated in the vacuum control rack. This rack is situated a few meters from the S.C. The mains switch for the encoders is situated behind the preamplifier power supply.

Note should be taken that the Lemo vacuum feedthroughs can take a male plug on each side, there are no numbers printed on the feedthrough but one side is a mirror image of the other. The 2m section of cable inside the S.C. must thus not be bypassed.

2.1.2 Aligning the arms

When an arm has been mechanically set at the 0° position by a surveyor, the display must also be zero. If this is not the case the angle readout can be adjusted as follows: Somebody must be present to observe and communicate the angle reading in the Data Area as the angle can not be seen from the S.C. In the case of a small error the angle can be set by loosening the encoder body and turning it slightly until it gives a zero reading. This is a tedious task, because the slightest movement will make a substantial change.

If the error is large or if the encoder has been removed completely for any reason, the following has to be done: Loosen the bolts keeping the encoder holder on the arms and disengage the gears by moving the holder away from the ringgear. The shaft of the encoder can now be moved by hand. Get the reading as close as possible to zero by turning the shaft. Tension the anti-backlash gear with thumb and forefinger and mesh the teeth with the ring-gear making sure the shaft does not turn. Repeat the procedure described in the first paragraph.

2.2 Target Angle

An accuracy of 0,1° was needed here. The gearing of the fine potentiometer had a ratio of 72:5 indirectly via the motor gear. This gave a reading of 10° per revolution. It was decided to use the Litton BVD11-362P6 shaft encoder. This encoder has a resolution of 100 counts per revolution and a capacity of 36 turns. It is a pin-contact encoder with a block V-scan BCD output. See section 2.5 for description of block V-scan. Some decoding electronics were needed to change the block V-scan BCD to BCD. The angle of the target is defined as the normal to the target with respect to the beam. Limit switches were inserted to keep the targets from moving more then 90° cw or ccw.

2.2.1 Aligning the Target Angle

When the 0° position had been determined by the surveyor, small changes in the actual readout may be made by loosening the allen screws holding the encoder and turning the encoder body until the 0° position is displayed. If more than one revolution has to be made the detector must be removed from its holder and the shaft turned by hand so as not to wind up the cables.

2.3 Target Height

A Litton BVD11-102P3 shaft encoder was used to indicate the height. This shaft encoder has a capacity of 100 counts per revolution and can do 10 revolutions, giving it a capacity of a 1000 counts. The existing thread and gear ratio gave a 1" height difference on the target per revolution of the encoder. This ratio was not metricated because the target holders were 1½" square. The readings are thus in hundredths of inches, 000 being the centre of the lowest target, 150 the centre of the second target, up to 600 for the fifth target.

The BVD11-103P3 shaft encoder works on the same principles as the one used in the Target Angle. The V-scan BCD to BCD decoder circuit board can be used here and is fully interchangeable. The two most significant bits are not used in this case, and can be left open. Limit switches are also used to prevent damage. Alignment can be done in the same way as with the Target Angle.

2.4 The Out of Plane Angle

This function will move detectors out of the horizontal plane and will be fixed to one of the arms. The mechanical section will be done when needed for an experiment, as was mentioned before.

It is envisaged that a vacuum version of the BVD11-102P3 will be used. Provision has been made for the display.

2.5 Description of V-scan

V-scan is used to remove ambiguity from a code such as BCD where more than one bit changes at a time. V-scan requires two lines for each bit except for the LSB. With external electronics either of the lines will be "read" in the middle section of either logic "1" or logic "0" therefore no lines are "read" during a transition. The LSB is used to control the next lower bit.

V-scan allows for increased tolerances within the encoder, since each lower bit increases the "read" section. Therefore, V-scan will remove any ambiguity which may occur through backlash in the gear train between the code disks.

2.6 Description of the Block V-scan BCD to BCD decoder circuit board NAV D3. (See fig. 2.2)

As there is an 80 meter distance between the S.C. and the Data area in an electrically noisy environment some care had to be taken with the decoding. A lowpass filter was incorporated on the input lines to filter out 50 hz ripple. 5C914 Schmidt trigger inverters were also used on the input. These i.c.'s have the added advantage that they can tolerate 12V on a 5V supply line. +12V was used to supply the encoder and a 330Ω resistor was put in series to prevent the pin contacts from burning in the case of an accidental short to earth.

The decoding is done by 74LS38 NAND gates. For logic equations see next page. The bits printed in bold are "read" in the middle section of either logic "1" or logic "0". On the schematic diagrams fig. 2.3.1 and fig. 2.3.2 these bits are circled. The LSB (2^0) is used to control the next higher bit (2^1). The decoded output of any used bit controls the next higher bit. The "cont." bit is used as a control signal from the high-speed section (0-99 counts per revolution) to the low-speed section (0-36 revolutions). The gates are all open collectors and pull up resistors were used.

The output of the board is BCD and the VK00-46b modules were used to display the angle.

2.7 Logic equations of the BVD11-362P6 and BVD11-102P3 shaft encoders

BCD output '1' = $\overline{\overline{\mathbf{1}}}$

" '2' = $(1)\overline{(2)} + \overline{(1)}\,\overline{(\mathbf{2})}$

" '4' = $(1)\overline{(4)} + \overline{(1)}\,\overline{(\mathbf{4})}$

" '8' = $(1)\overline{(8)} + \overline{(1)}\,\overline{(\mathbf{8})}$

" '10' = $(1)\overline{(10)} + \overline{(1)}\,\overline{(\mathbf{10})}$

" '20' = $(10)\overline{(20)} + \overline{(10)}\,\overline{(\mathbf{20})}$

" '40' = $(10)\overline{(40)} + \overline{(10)}\,\overline{(\mathbf{40})}$

" '80' = $(10)\overline{(80)} + \overline{(10)}\,\overline{(\mathbf{80})}$

Low speed control 'cont' = $(1)\overline{(\mathrm{cont})} + \overline{(1)}\ \overline{(\mathbf{cont})}$

BCD output '100' = $(\mathrm{cont})\overline{(100)} + \overline{(\mathrm{cont})}\,\overline{(\mathbf{100})}$

" '200' = $(100)\overline{(200)} + \overline{(100)}\,\overline{(\mathbf{200})}$

" '400' = $(100)\overline{(400)} + \overline{(100)}\,\overline{(\mathbf{400})}$

" '800' = $(100)\overline{(800)} + \overline{(100)}\,\overline{(\mathbf{800})}$

" '1000' = $(100)\overline{(1000)} + \overline{(100)}\,\overline{(\mathbf{1000})}$

" '2000' = $(100)\overline{(2000)} + \overline{(100)}\,\overline{(\mathbf{2000})}$

The '1000' and '2000' bits are not used on the BVD11-102P3 encoder.

2.7 Logic equations of the BVD11-362P6 and BVD11-102P3 shaft encoders

BCD output '1' = $\overline{\overline{\mathbf{1}}}$

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" '8' = $(1)\overline{(8)} + \overline{(1)}\overline{(\mathbf{8})}$

" '10' = $(1)\overline{(10)} + \overline{(1)}\overline{(\mathbf{10})}$

" '20' = $(10)\overline{(20)} + \overline{(10)}\overline{(\mathbf{20})}$

" '40' = $(10)\overline{(40)} + \overline{(10)}\overline{(\mathbf{40})}$

" '80' = $(10)\overline{(80)} + \overline{(10)}\overline{(\mathbf{80})}$

Low speed control 'cont' = $(1)\overline{(\text{cont})} + \overline{(1)}\ \overline{(\textbf{cont})}$

BCD output '100' = $(\text{cont})\overline{(100)} + \overline{(\text{cont})}\overline{(\mathbf{100})}$

" '200' = $(100)\overline{(200)} + \overline{(100)}\overline{(\mathbf{200})}$

" '400' = $(100)\overline{(400)} + \overline{(100)}\overline{(\mathbf{400})}$

" '800' = $(100)\overline{(800)} + \overline{(100)}\overline{(\mathbf{800})}$

" '1000' = $(100)\overline{(1000)} + \overline{(100)}\overline{(\mathbf{1000})}$

" '2000' = $(100)\overline{(2000)} + \overline{(100)}\overline{(\mathbf{2000})}$

The '1000' and '2000' bits are not used on the BVD11-102P3 encoder.

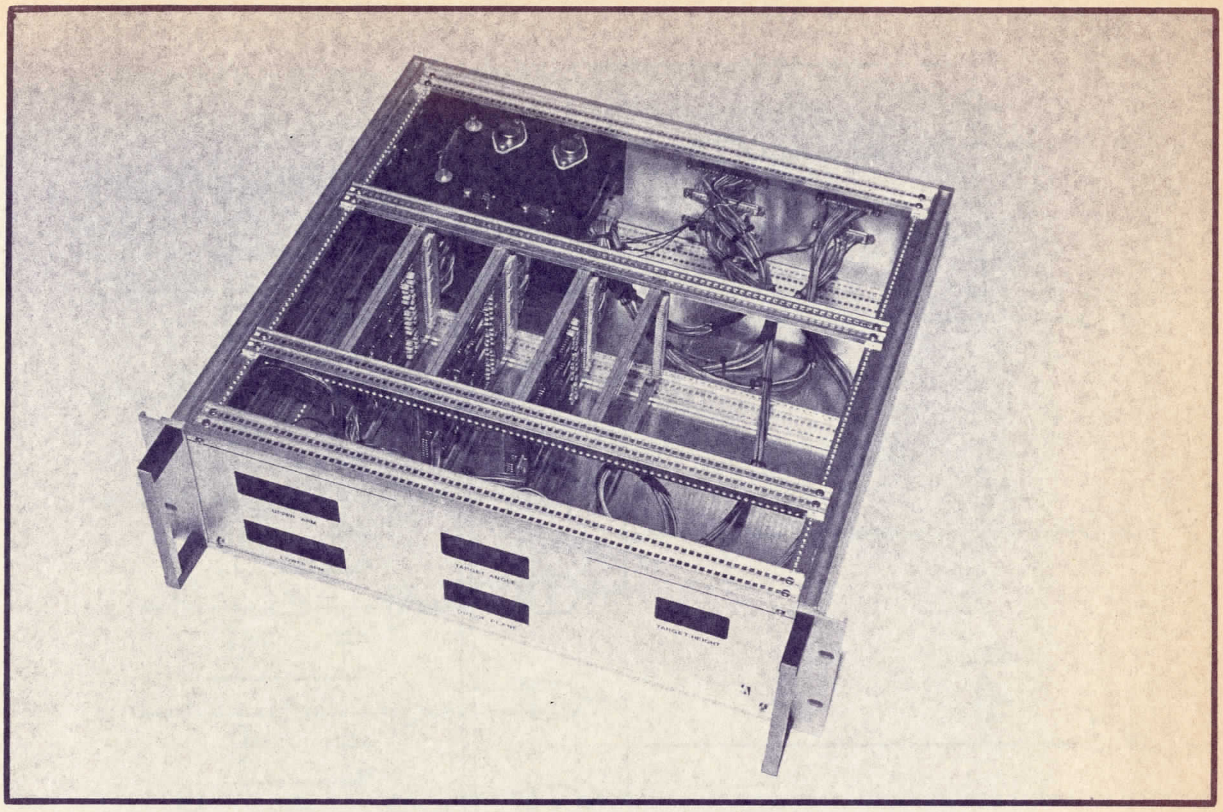


Fig 2.1 Shaft encoder display rack

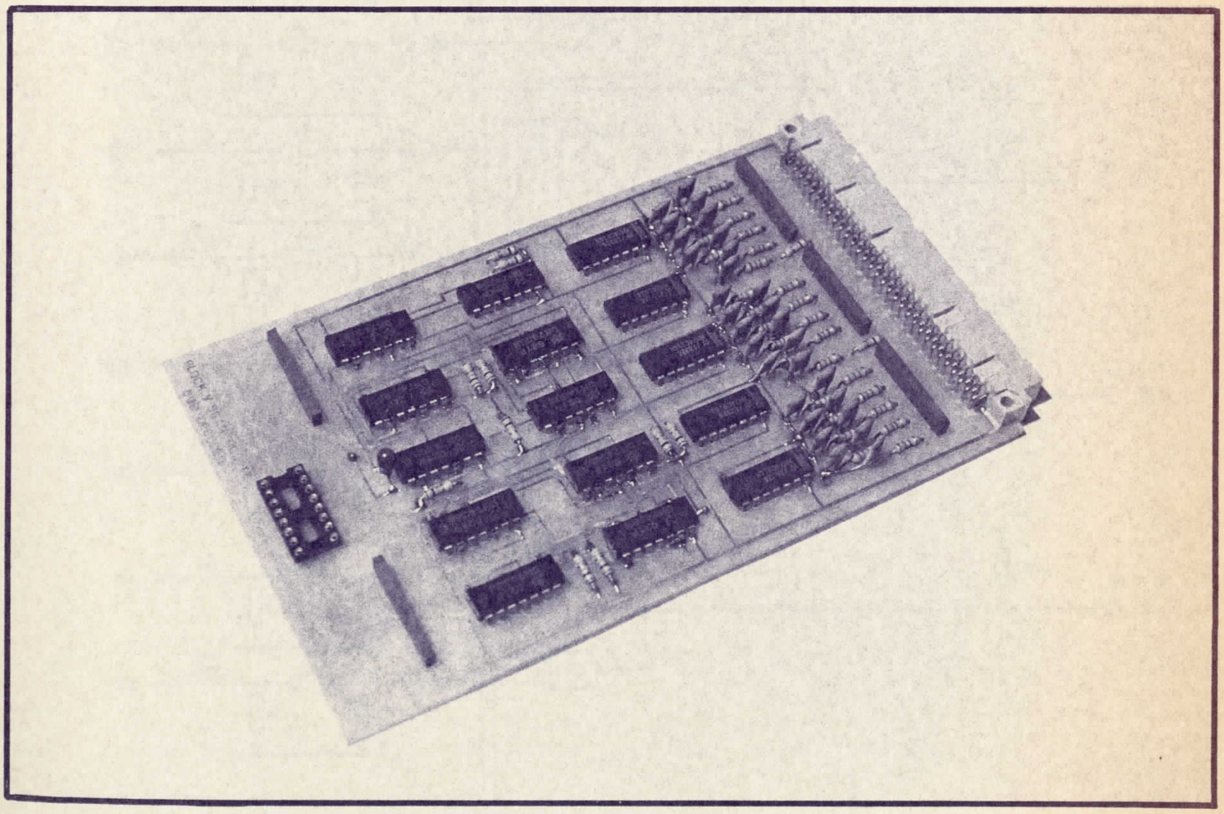


Fig 2.2 Block V-scan BCD to BCD decoder circuit board NAV D3

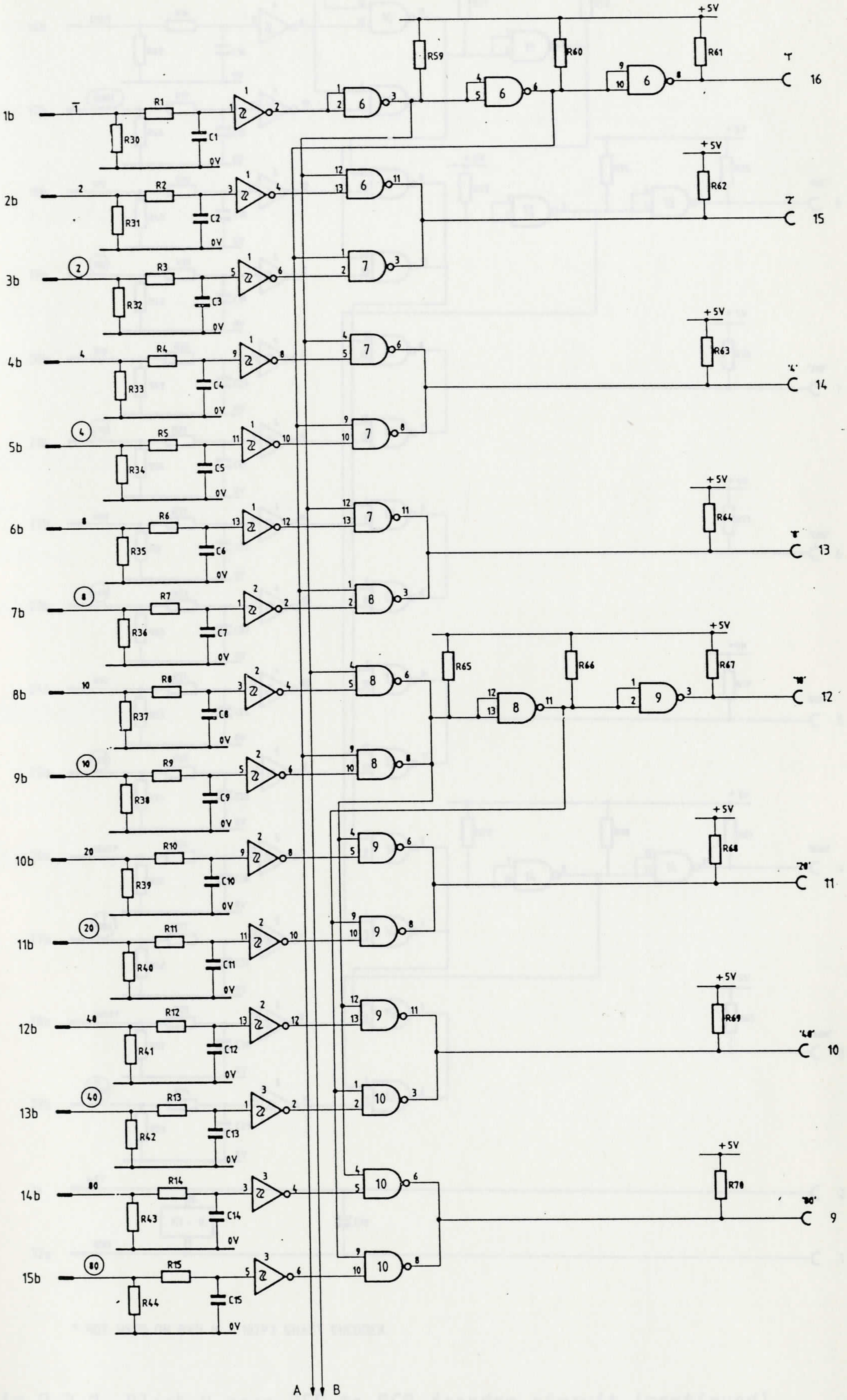
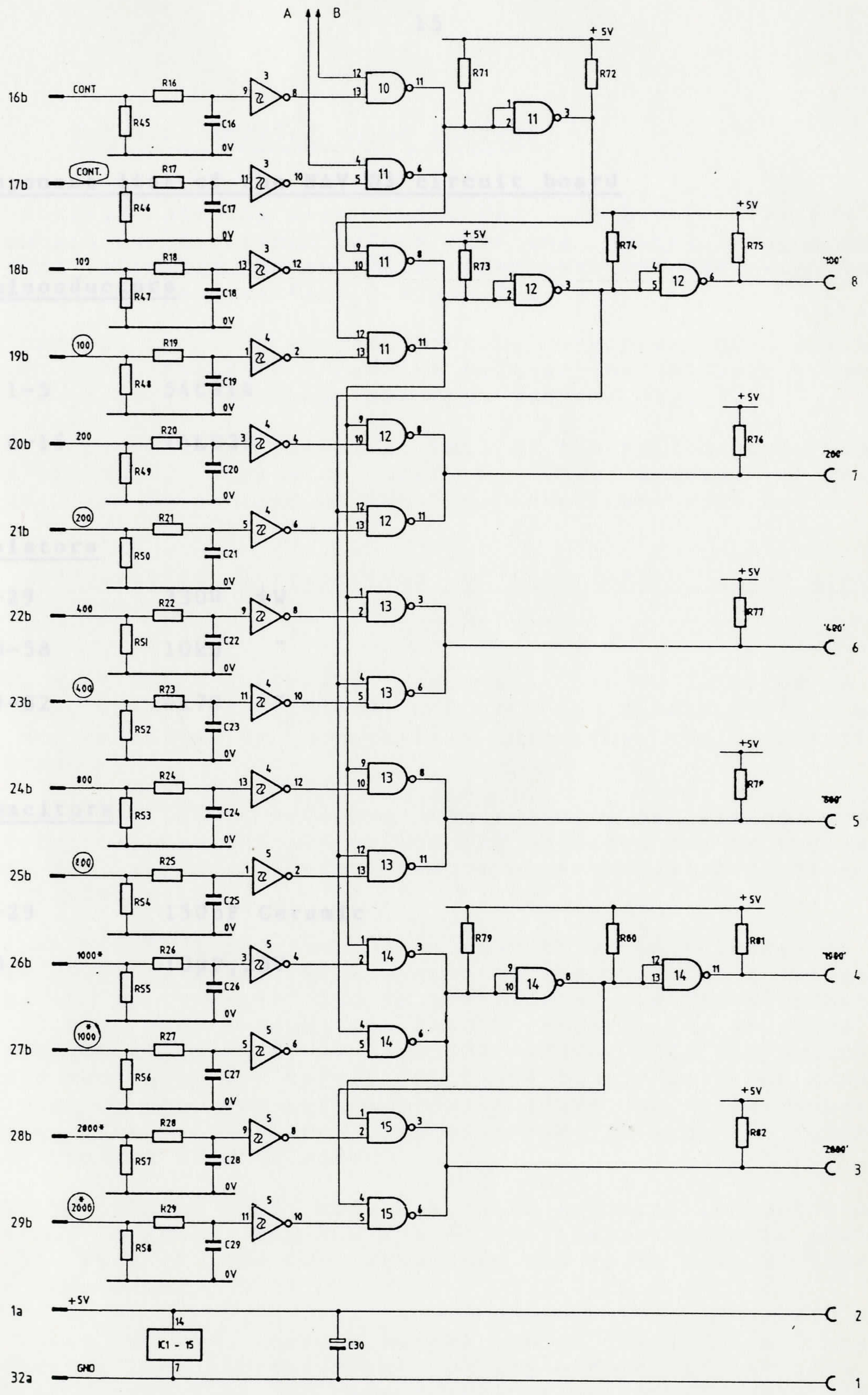


Fig 2.3.1 Block V-scan BCD to BCD decoder circuit



* NOT USED ON BVD 11 - 102P3 SHAFT ENCODER.

Fig 2.3.2 Block V-scan BCD to BCD decoder circuit (continued)

Component list of the NAV D3 circuit board

Semiconductors

IC 1-5	54C914
IC 6-15	74LS38

Resistors

R1-29	330Ω	$\frac{1}{3}$W
R30-58	10kΩ	"
R59-82	4k7Ω	"

Capacitors

C1-29	150nF Ceramic
C30	10μF,25V

3. THE S.C. STEPPER MOTOR CONTROL

Six control modules were built for the S.C., five for the movements as described before and one spare. These modules are all situated in the Data Area cabinet and are fully interchangeable, see fig. 3.2 and fig. 3.3.

The control modules consist of the Digiplan BC7 buffered clock card, the NAVD 2 card as well as the relevant switches and thumb wheel switches, see fig. 3.4 and fig. 3.5.

CD20 stepper motor drives as well as the PM1200 power supply from Digiplan, were also used in this system. A remote control box to be used at the S.C. itself was also built.

3.1 Operating instructions of the stepper motor control module.

There are three different modes that can be selected on the modules, namely CONTINUOUS, DISCRETE and SINGLE STEP. A mode can be selected by momentarily pressing the appropriate switch.

When the CONTINUOUS mode has been selected the stepper motors will run if the POS RUN or NEG RUN switches are kept pressed down. The angles or height can be observed as they change on the display unit.

In the DISCRETE mode a value must first be selected on the thumb wheel switches: in the case of the two arms a change in value of up to 99,99° and in the case of the TARGET ANGLE up to 99,9°; the change in TARGET HEIGHT is selected in hundredths of inches. If the POS RUN or NEG RUN switch is pushed the arms or target will move by the selected amount. The pos or neg run switches will light up if the motor is running. The stop button can be pushed to stop the movement while running in this mode.

When the SINGLE STEP mode has been selected the motor will move one step if the POS RUN or NEG RUN switches is pushed. In the case of the two arms this has to be done 8 times to move them 0.01°.

The speed of the stepper motors can be changed continuously by varying the potentiometer on the module. If the arms run into each other or if target height or target angle limits have been reached, the limit LED's will light up and the motors will stop. Only the opposite direction can now be selected or in the case of the arms, the opposing arm can also be moved out of the way.

3.1.1 The remote control box.

This box is situated at the S.C. It will typically be used when an experiment is set up to ensure that the detectors and cables do not foul each other.

One of the five movements can be selected with a rotary switch. If the POS RUN or NEG RUN switch is pushed the control module will automatically revert back to the CONTINUOUS mode. The motor speed can also be set. The rotary switch must be left in the off position when not in use, otherwise it will override the speed selector at the control in the Data Area.

3.2 Description of the stepper motor control system

The stepper motor control can be described in the following blocks. See fig.3.6.

* CD 20 Stepper motor drive.

* PM 1200 Power supply module.

* BC7 Buffered clock card.

* NAVD 2 Stepper motor control card.

3.2.1 CD20 Stepper motor drive.

These drives from Digiplan have been used extensively throughout the NAC. They are bipolar chopper-regulated and fully short-circuit protected. The rated output is 4A/phase.

The inputs and outputs of the stepper motor drive which are used are as follows:

* Motor phases 1A, 1B, 2A, 2B: These four terminals are used for the connections to the motor windings.

* +24V: This is required for the logic and the pre-driver section.

* Motor Supply: This voltage can be between 24V and 85V depending on the speed and load.

* Direction: Taking this output low will reverse the direction of the motor rotation.

* Clock: A low-going transition on this input advances the motor one step.

- * The link to de-energise at standstill was inserted as noise was induced on adjacent coaxial cables by the drive even when the motors were not running. Due to the high gear ratio the arms cannot move of their own accord.

- * The 400 step per revolution step link was inserted on the two arms to give higher accuracy.

- * The unit contains error indicator LED's, namely Overload, Supply failure and Over temperature. If these LED's light up the drive will switch off.
[3]

3.2.2 The CD20 current levels

The current levels had to be set by changing R55 and R59. On the Upper and Lower arm stepper motors (M081-FC034V) the current levels have been set to 1,6A, which is a bit lower than the rated current of the motors. Although these motors are especially made for vacuum conditions they can not lose heat by convection. The Target Angle motor (M091-FD03P2) was also set to 1,6A. The Target height motor (M111-FD-327) was set to 3,5A. A vacuum type stepper motor (M061-FC024V) was purchased for the Out of Plane function. This current was set for 1A. The motors mentioned above are all SLO-SYN stepper motors from Superior Electric.
[3]

3.2.3 The PM 1200 Power supply

This power supply from Digiplan delivers 85V, 15A for the motor supplies and 24V, 2A for the logic supplies. Although the current of all the motors together does not exceed 15A, two units were purchased and mounted in the cabinet. This was done to facilitate later expansion. A 600VA transformer with 61VAC and 20VAC outputs is situated in the lowest rack in the cabinet, along with the mains sockets and switch.

3.2.4 The BC7 Buffered clock card

This card from Digiplan stores the incoming pulses and delivers a re-timed pulse sequence. This sequence will contain the same number of pulses, but the rate is controlled in such a way that the required motor movement is accomplished without loss of synchronism. See fig. 3.1.

A separate oscillator is included on the card which permits operation at preset speeds from DC logic inputs or manual switches. A directional limit switch facility to protect against over-travel is also present.

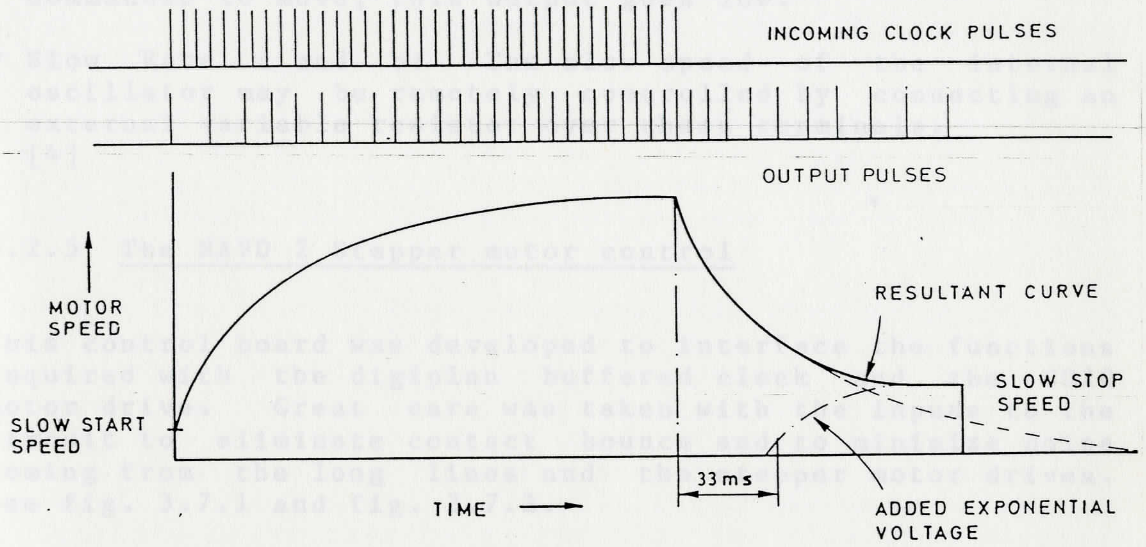


Fig. 3.1 Buffered clock characteristics.

The input and output signals that are used on the buffered clock are as follows.

- * Motor Clock: This is a negative going output pulse from the Buffered Clock and goes to the CD20. A link must be made from the Internal Clock to the Buffered Clock In.
- * Pos Limit and Neg Limit: These are directional limit switches which inhibit motion in one direction only. When the input is tied to earth it disables the clock and normal deceleration to stop will occur. The direction request must then be changed before the motion can be restored.
- * Direction Request: This is the input which is used to call up the required direction of travel, it determines the direction of the next motor step provided motion is not present. If it is changed when motion is present, it will initiate deceleration to stop before the motor is reversed.
- * Allow Clock: This negative going signal is an override input which allows the internal oscillator to run. If it is taken high when running on the internal oscillator a normal deceleration to stop will occur.

- * Motion: When the motor is actually moving or has been commanded to move, this output goes low.
- * Slow Rate a and b: The slow speed of the internal oscillator may be remotely controlled by connecting an external variable resistor over these terminals. [4]

3.2.5 The NAVD 2 Stepper motor control

This control board was developed to interface the functions required with the digiplan buffered clock and the CD20 motor drive. Great care was taken with the inputs to the circuit to eliminate contact bounce and to minimize noise coming from the long lines and the stepper motor drives. See fig. 3.7.1 and fig. 3.7.2.

- * Continuous Mode: When the CONTINUOUS (SW1) switch is pressed RL1 latches over its own contacts and the indicator light goes on. If the POS RUN switch (SW4) is now pushed RL4 is also latched over its own contacts and the Direction Request line is tied low through SW4b. The Pos run light will go on and the Allow Clock will be pulled low by SW4b. The motor now runs in a positive direction as long as the POS RUN switch is held down.

  If the NEG RUN switch (SW5) is pushed power is taken away from RL4 and it drops out. The Direction Request is now kept high by a pull up resistor on the Buff. Clock Card. The Allow Clock is now tied low through SW5b. The motor will run in a negative direction as long as the NEG RUN switch is held down.

- * Discrete mode: When the DISCRETE switch (SW2) is pushed RL2 will latch and if any of the other modes were selected their relays will drop out. The desired angle or height movement must now be selected on the BCD thumb wheel switches. This value gets loaded in the CD4510 BCD up down counters (IC 1 - 4). If the POS RUN switch is now pushed RL4 will latch and the pos run indicator light will go on. The Flip Flop (IC6) will also be set, Q then goes high and gets inverted by IC8. The Allow Clock now goes low producing clock signals from the Buffered clock ard, bar Q enables the counters.

  The clock from the Buffered clock card gets divided by IC5, in the case of the arms by 8 and in the case of the other functions by 4. This division lets the angle and heights correspond to the actual value dialed on the BCD thumb wheel switches. If the selected amount of clock pulses are counted the Carry Out of IC4 goes low and resets the Flip Flop. This lets the Allow Clock revert back to its high position.

If the NEG RUN switch is pushed the action described above repeats itself except for the fact that RL4 drops out and Direction Request goes high. The direction indication then also changes.

If the discrete movement has to be stopped for any reason the stop switch (SW6) can be pushed, which resets the Flip Flop. The Flip Flop also resets when the SINGLE STEP function is selected while the motor is still running.

* Single Step mode: When this mode has been selected RL3 latches and the relays of any other mode selected will drop out. When the POS RUN is pushed the Direction Request is pulled low. The trigger on the Monostable (IC9) is made high and a pulse of about 10µs is put on the CD2Q's clock input, the stepper motor now moves one step. If the POS RUN switch is pushed the same action as described above repeats except that the Direction Request goes high and the direction indication changes.

* Pos and Neg Limits: When one of these limits are reached power is put on RL6 or RL7. The Limit LED's on the front panel will light up and the Pos Limit or Neg Limit on the Buff. Clock card will go low, stopping the motor.

* Remote functions: If the POS RUN or NEG RUN switch is pushed on the remote box and the appropriate movement has been selected on the rotary switch, RL8 or RL9 will get power. See Fig 3.8. RL1 will latch and the other modes will fall out if they were selected. The CONTINUOUS mode will thus always be selected from the remote box. The speed can be changed from the remote box as RL10 is also selected from the rotary switch. The potentiometer in the remote box effectively replaces the one in the stepper motor control module.

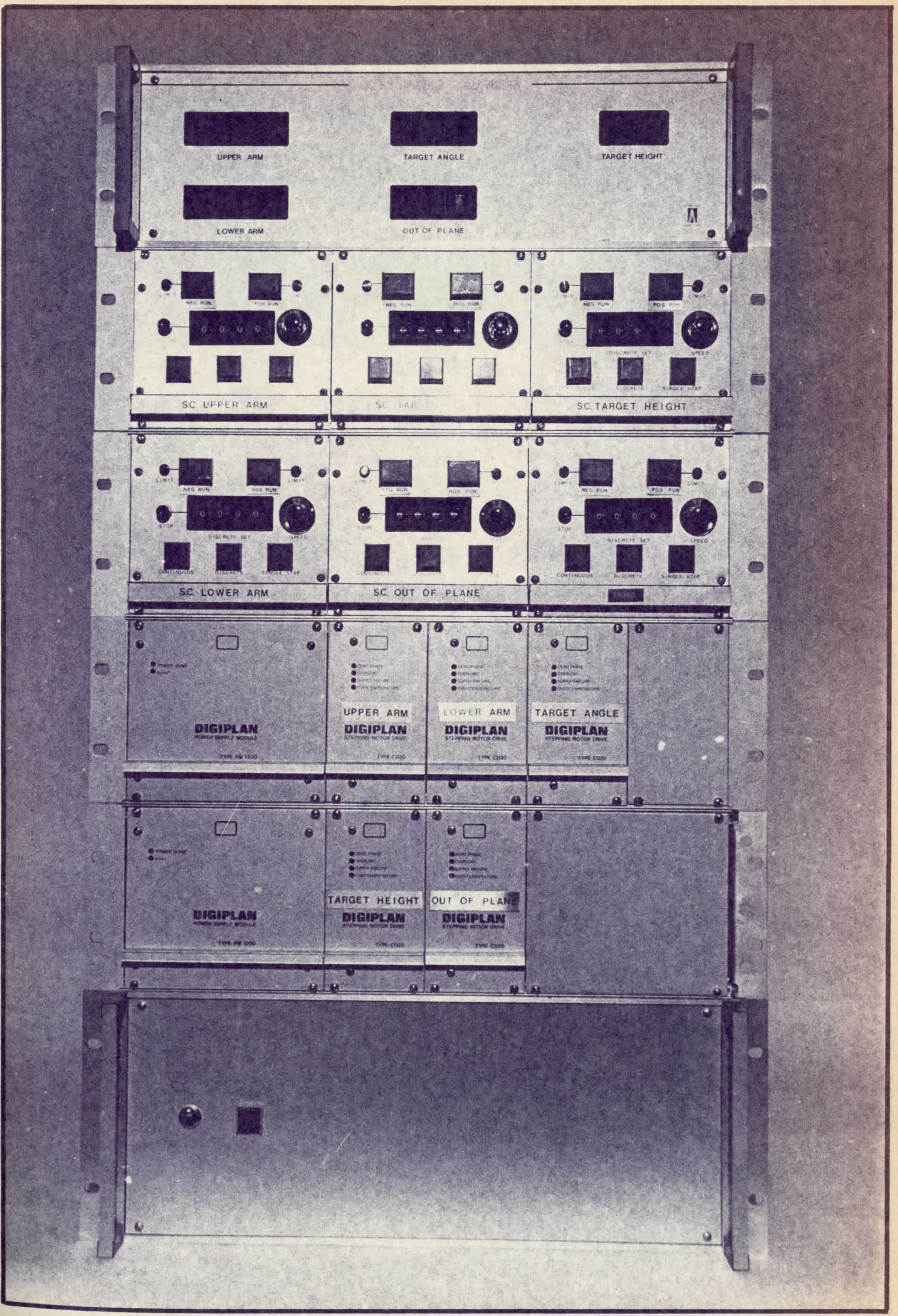


Fig 3.2 Scattering Chamber control system

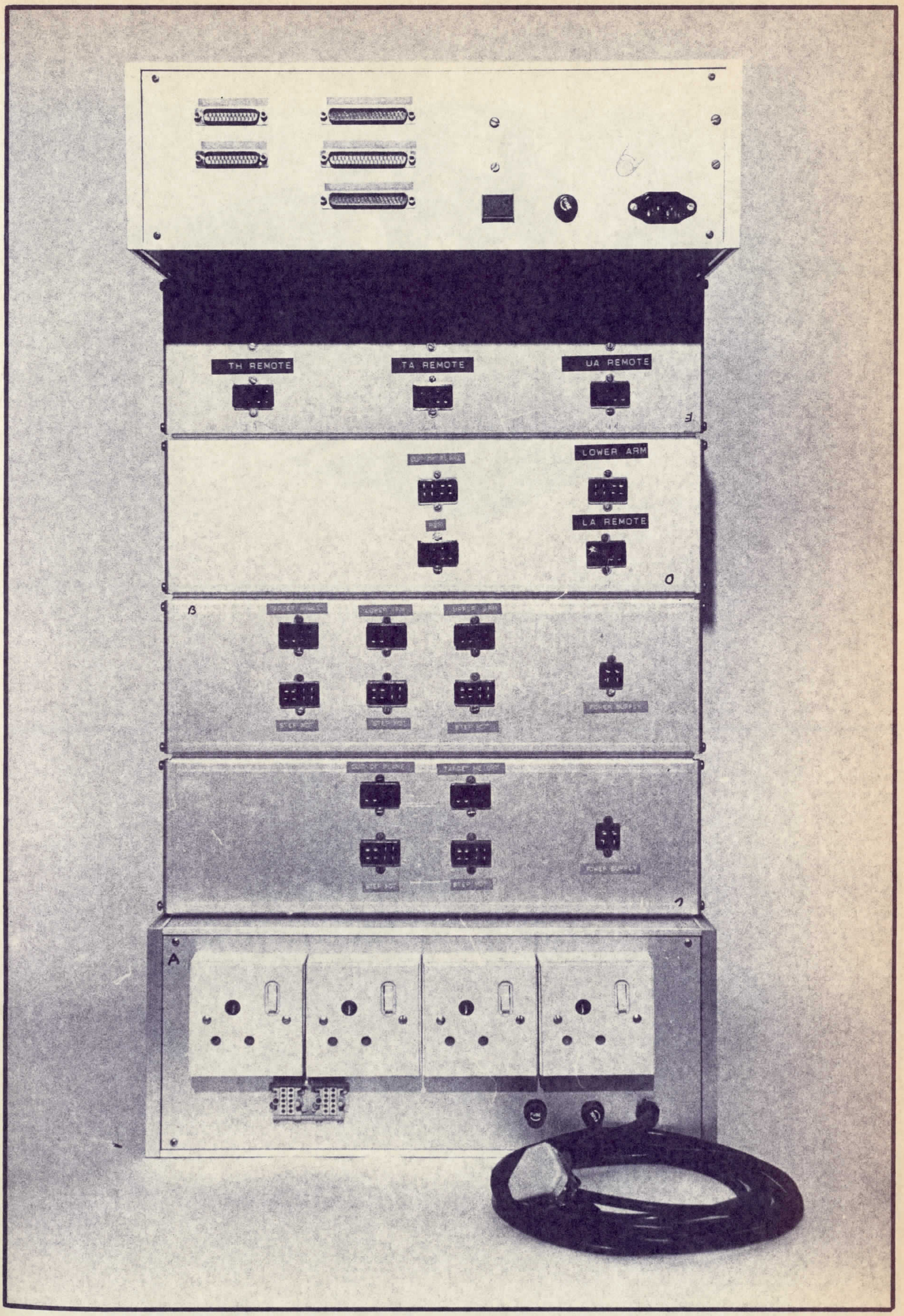


Fig 3.3 Back view of the Scattering Chamber control system

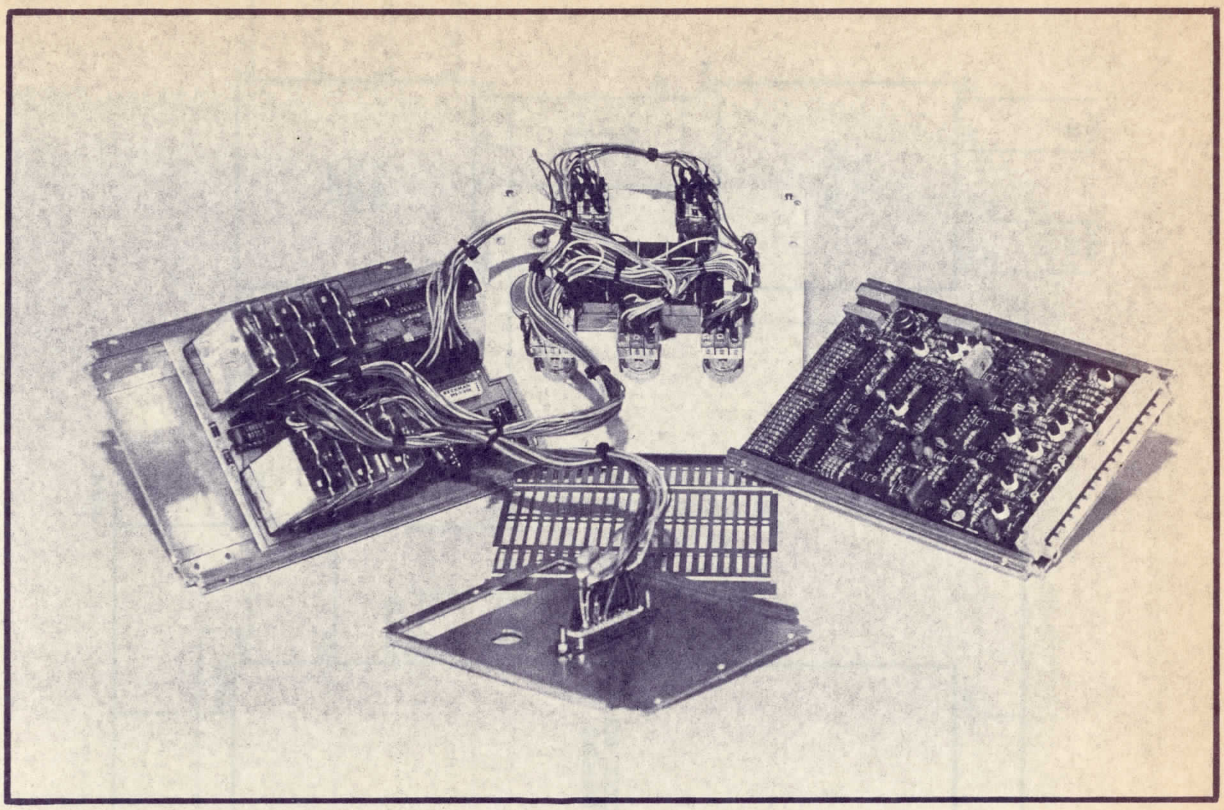


Fig 3.4 Disassembled control module

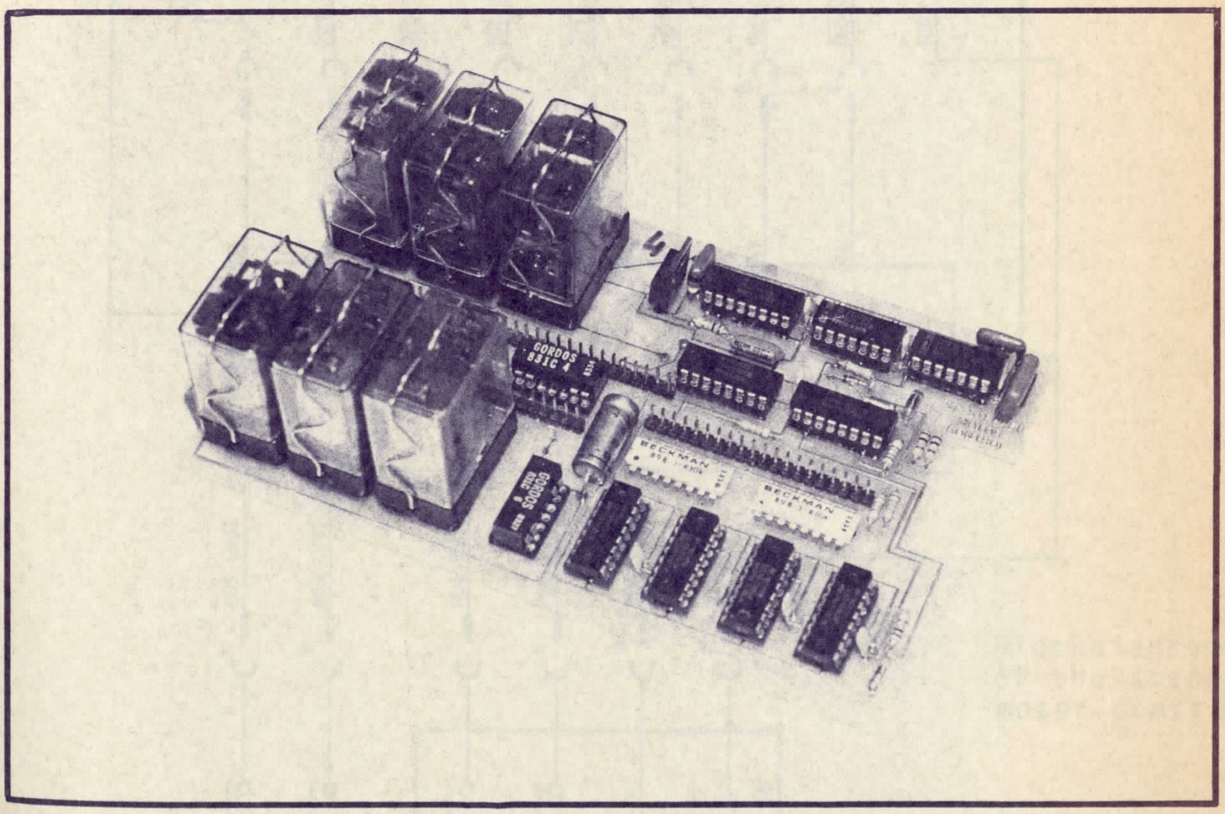


Fig 3.5 NAV D2 control card

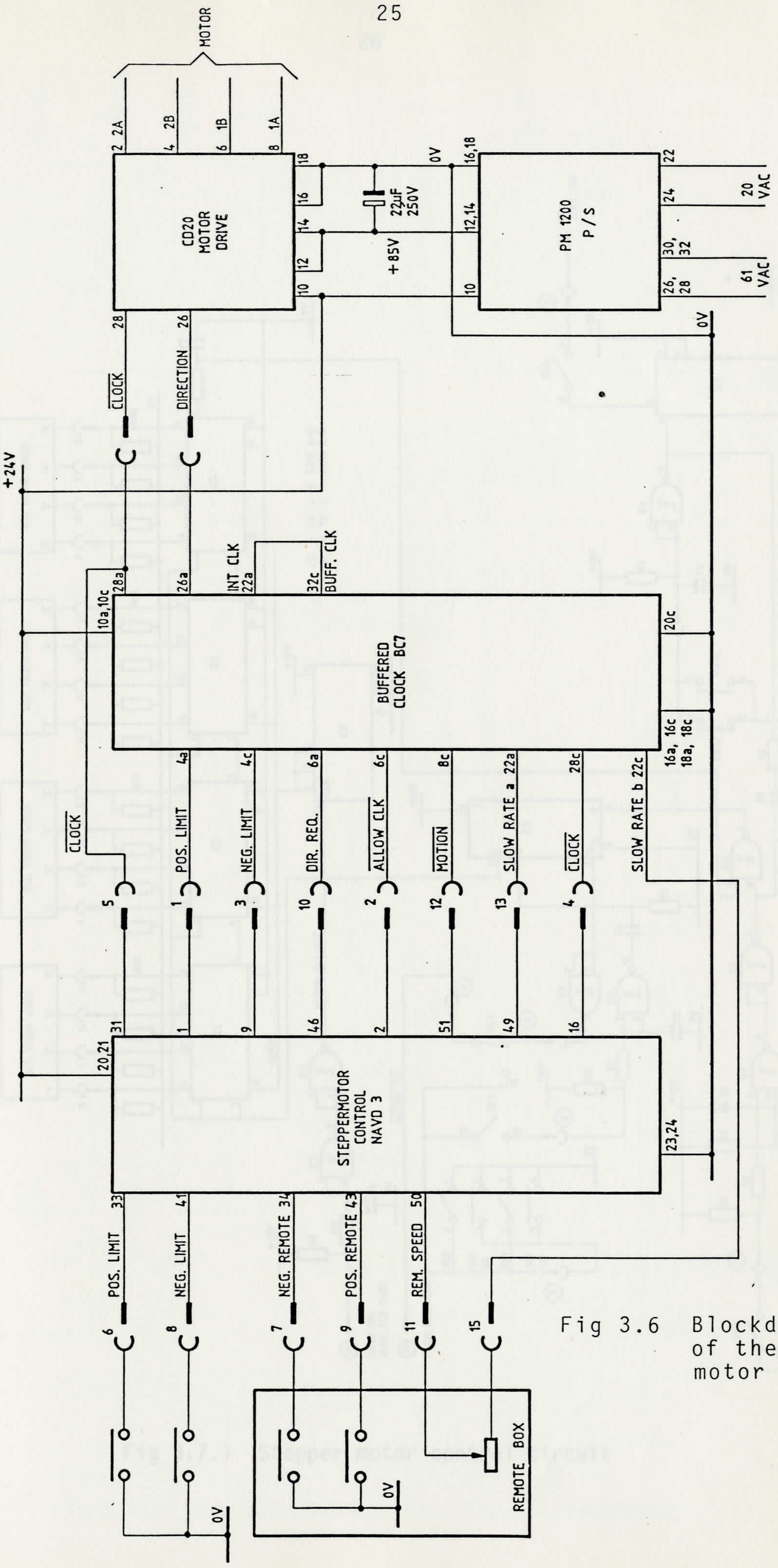


Fig 3.6 Blockdiagram of the stepper motor control

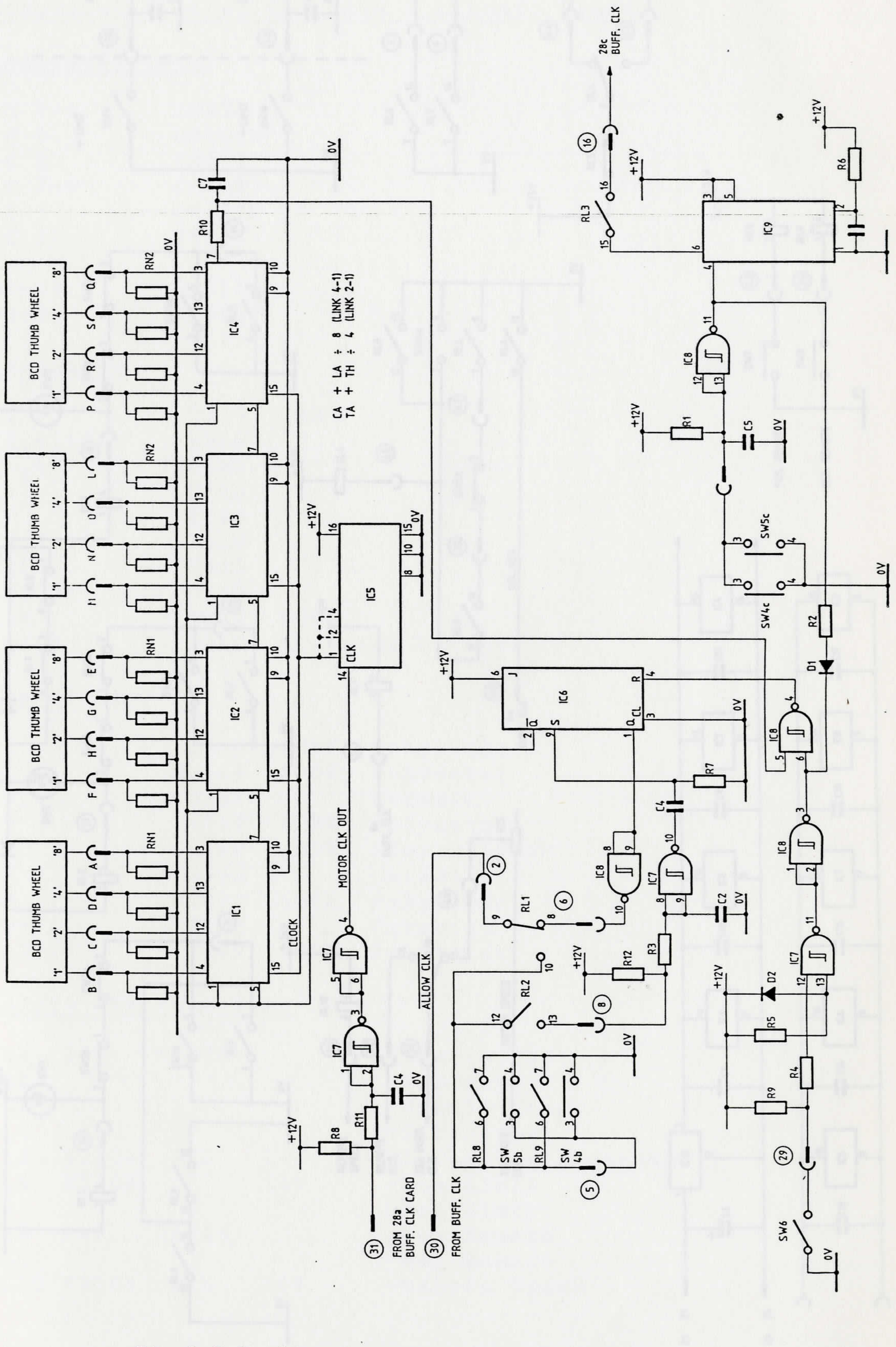


Fig 3.7.1 Stepper motor control circuit

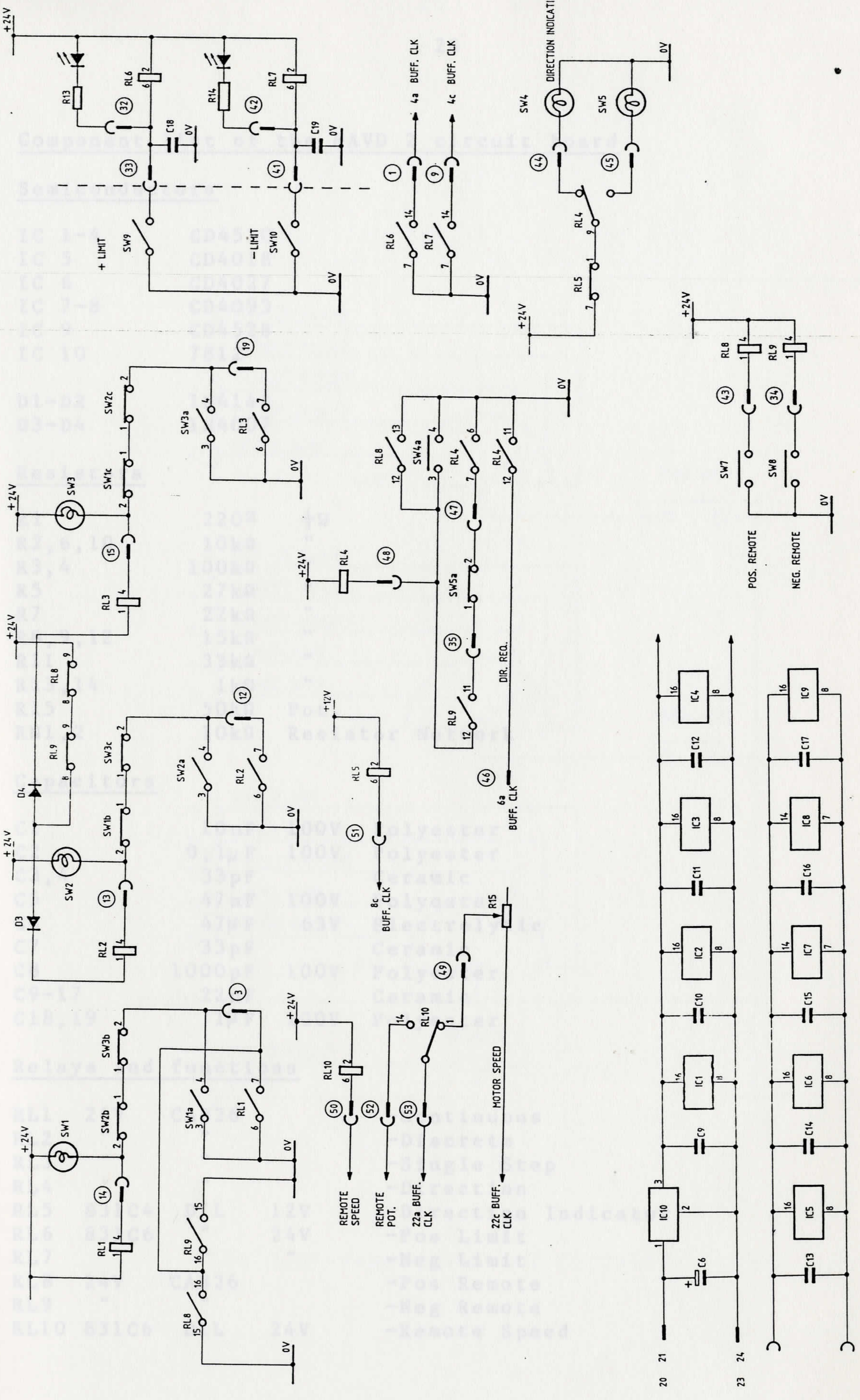


Fig 3.7.2 Stepper motor control circuit (continued)

Component list of the NAVD 2 circuit board

Semiconductors

IC 1-4	CD4510
IC 5	CD4018
IC 6	CD4027
IC 7-8	CD4093
IC 9	CD4528
IC 10	7812
D1-D2	1N4148
D3-D4	1N4007

Resistors

R1	220Ω	$\frac{1}{3}$W
R2,6,10	10kΩ	"
R3,4	100kΩ	"
R5	27kΩ	"
R7	22kΩ	"
R8,9,12	15kΩ	"
R11	33kΩ	"
R13,14	1kΩ	"
R15	50kΩ	Pot.
RN1,2	10kΩ	Resistor Network

Capacitors

C1	10nF	100V	Polyester
C2	0,1μF	100V	Polyester
C3,4	33pF		Ceramic
C5	47nF	100V	Polyester
C6	47μF	63V	Electrolytic
C7	33pF		Ceramic
C8	1000pF	100V	Polyester
C9-17	22nF		Ceramic
C18,19	1μF	100V	Polyester

Relays and functions

RL1	24V	CAB26		-Continuous
RL2	"	"		-Discrete
RL3	"	"		-Single Step
RL4	"	"		-Direction
RL5	831C4	DIL	12V	-Direction Indicator
RL6	831C6	"	24V	-Pos Limit
RL7	"	"		-Neg Limit
RL8	24V	CAB26		-Pos Remote
RL9	"	"		-Neg Remote
RL10	831C6	DIL	24V	-Remote Speed

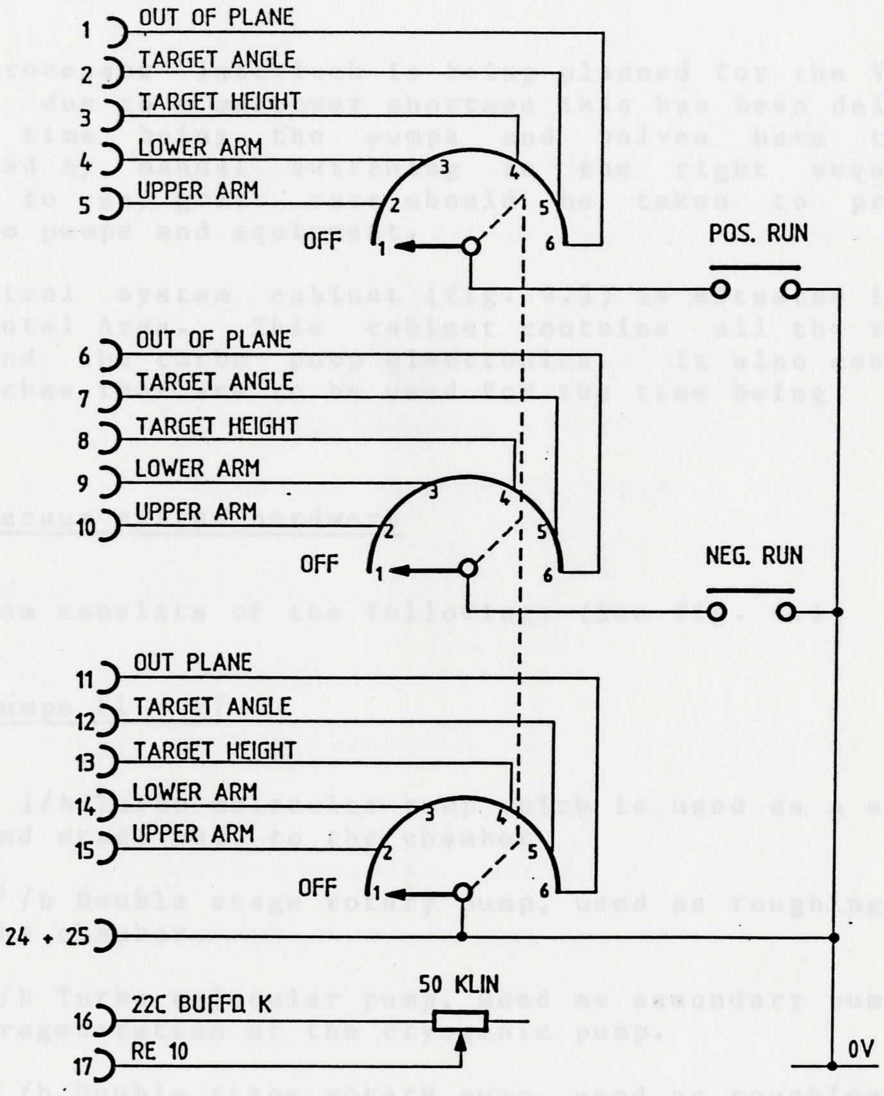


Fig 3.8 Remote control circuit

4. THE SCATTERING CHAMBER VACUUM SYSTEM

In order to prevent unwanted nuclear reactions with gas molecules and to minimize losses after reactions on the targets have occurred, experiments must be done in a high vacuum.

A microprocessor interlock is being planned for the Vacuum system; due to a manpower shortage this has been delayed. For the time being the pumps and valves have to be controlled by manual switching in the right sequence. Needless to say great care should be taken to prevent damage to pumps and equipment.

The control system cabinet (fig. 4.2) is situated in the Experimental Area. This cabinet contains all the vacuum meters and the turbo pump electronics. It also contains the switches that are to be used for the time being. [5]

4.1 Vacuum system hardware

The system consists of the following: (See fig. 4.1)

4.1.1 Pumps P1 - P7

P1 1000 l/h Turbo molecular pump which is used as a second second stage pump to the chamber.

P2 60 m³/h Double stage rotary pump, used as roughing pump to the chamber.

P3 50 l/h Turbo molecular pump, used as secondary pump for the regeneration of the cryogenic pump.

P4 16 m³/h Double stage rotary pump, used as roughing pump for the regeneration of the Cryo pump.

P5 Cryogenic pump, which is the final stage pump on the chamber. It is a very effective pump for water vapour.

P6 170 l/h Turbo molecular pump, used as second stage pump on the beam-stop line.

P7 16 m³/h Double stage rotary pump, used as roughing pump for the beamstop-line.

4.1.2 Electropneumatic valves V1 - V10

V1	150 mm	Between beam-line and S.C.
V2	150 mm	Between S.C. and beamstop.
V3	140 mm (5½")	Between S.C. and P1, P2.
V4	150 mm	Between S.C. and P5.
V5	40 mm	Between P5 and P3, P4.
V6	25 mm	Between P3, P4 and parking chamber.
V7	15 mm	With 1mm venturi for venting P1.
V8	15 mm	With 1mm venturi for venting P3.
V9	100 mm	Between beamstop and P6, P7.
V10	25 mm	With 1mm venturi for venting P6.

4.1.3 Manual valves VM1 - VM5

VM1	25 mm	For venting S.C.
VM2	15 mm	For venting beamstop
VM3	100 mm	On parking chamber, not in use yet.
VM4	-	On parking chamber, not in use yet.
VM5	-	On parking chamber, not in use yet.

4.1.4 Vacuum gauges G1 - G12

Six Alcatel CFA 222 display units are used each with a Pirani (10^3 - 10^{-2} mbar) and a Penning (<10^{-2} mbar) gauge. Note that there is a top and a bottom scale on the analog meter. Two LED's underneath indicate which scale is being displayed.
[6]

G1, G2	Vacuum on S.C.
G3, G4	Vacuum on P1, P2.
G5, G6	Vacuum on P3, P4.
G7, G8	Vacuum on P5.

G10, G11 Vacuum on P6, P7.

G11, G12 Vacuum on beamstop.

4.2 Pumping down the S.C.

If the lid or beam-line connections have been removed clean the o-ring and grooves, and make certain that the o-rings seat properly. A small amount of vacuum grease may be used.

Close the hand vent VM1.

Check V1 is closed (normally it should be in the closed position, if the chamber is not in use). For safety reasons V1 is not operated from the control rack, and must be opened by hand. This is done by turning the screw next to the solenoid 180°. There is an indication of this position on the valve.

Close V2 and V4 (they are normally already closed).

If the Cryo pump is not on at this stage, now is a good time to start it for it takes 1½ hours to cool down. See section (4.3) : Starting the cryogenic pump.

If G3, G4 show 10^3 mbar open V3. If not check that P1, P2 are off and vent line by opening V7. Close V7. If line is at atmosphere, open V3.

Switch on P2. If G1, G2 are not below 1 mbar in 30 minutes, the chamber leaks.

If G1, G2 are at or below 1 mbar, switch on P1. After a few minutes check if the Turbo is at full speed (LED on P1 control).

If G1, G2 are at 10^{-3} mbar and the cryo pump is < 24K, V4 may be opened.

V2 may be opened if G1, G2 and G11, G12 are within a decade of each other. This applies only if the vacuum on both sides is $< 1 \times 10^{-3}$ mbar.

V1 may be opened if G1, G2 and the A-line vacuum are within 1 decade of each other and both sides are $< 1 \times 10^{-4}$ mbar. There is a temporary vacuum gauge next to the quadrupole magnet. The operator must otherwise be consulted. Typically this valve must not be opened if the vacuum on G1, G2 is $> 1 \times 10^{-4}$ mbar.

V1 and V2 MUST be opened before the beam is requested or damage to the valves may occur.

4.3 Starting the Cryogenic pump

P5 will usually be kept under vacuum.

V4, V6 and V8 must be closed and P3, P4 and P5 must be off.

V5 may be opened if the pressure on the valve is between the following limits: Within a decade (lower than 1 mbar) or not more than a $\frac{1}{4}$ decade (above 1 mbar).

The pressure can be equalized by either venting V8 or pumping down P4. As the volume of the line is small this must be done only momentarily.

Switch on P4.

When G7, G8 are at 1 mbar switch on P3, After a few minutes check that the normal LED, situated on the turbo control P3, is on.

When G7, G8 show 1 x 10^{-3} mbar, the Cryo pump may be started. It takes 1½ hours for the Cryo pump to reach the 12 - 24K range. The temperature may be read from the digital display. If this temperature has been reached, V4 may be opened.

4.4 Pumping down the beamstop

The beam-stop is usually kept under vacuum.

V2 and V10 should be closed and P6 and P7 should be off.

VM2 should be closed manually.

If V9 is closed it may only be opened if the pressure over the valve is nearly equal or within the following limits: Below 1 mbar: within a decade and above 1 mbar: not more than a $\frac{1}{4}$ decade.

If not within this range P7 should be switched on or V10 should be opened to equalize the pressure. As the volume of the line is small this must be done only momentarily.

Switch on P7.

If G11, G12 are at 1 mbar, switch on P6. After a few minutes check that the turbo is at full speed. There is an analogue frequency meter on the pump control, where this can be determined.

4.5 Venting the S.C.

Close V1, V2 and V4 (remember V1 must be closed manually).

Switch off P1 and P2.

Crack VM1 slowly for the first few seconds to avoid a shock wave and to allow the turbo to run down. After this VM1 may be opened a few turns.

4.6 Venting the beamstop

Close V2 and V9.

Open V10.

Open VM2 manually.

4.7 Regenerating the Cryogenic pump

The Cryo pump must be regenerated occasionally. If the temperature goes higher than 24 Kelvin, it indicates that the cryogenic head of the pump is dirty.

Close V4, and P5 must be off.

Open V5 if the pressure on the valve is between the following limits: Within a decade (lower than 1 mbar) or not more than a $\frac{1}{4}$ decade (above 1 mbar).

Start P4.

If G7, G8 are at 1 mbar, start P3 and check that the "normal" LED turns on after a while.

If G7, G8 $<1 \times 10^{-3}$ the pump has been regenerated. This can take up to 12 hours depending on the condition of the pump.

4.8 Shutting down

If the S.C. is not going to be used for a long period, it should preferably be kept under vacuum.

Close V1, V2, V4, V5 and V9.

Shut of P1 - P7.

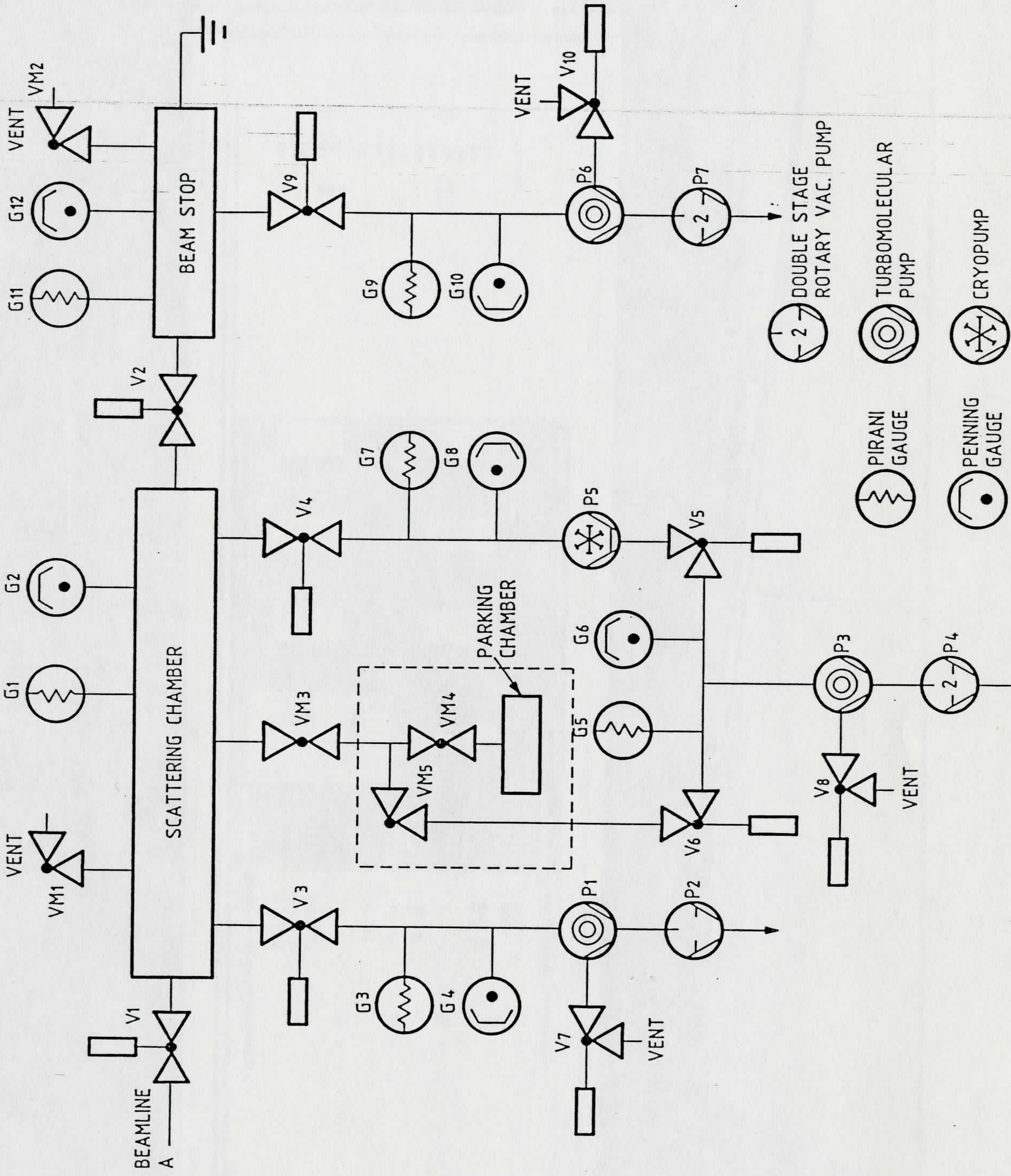


Fig 4.1 Scattering Chamber vacuum system

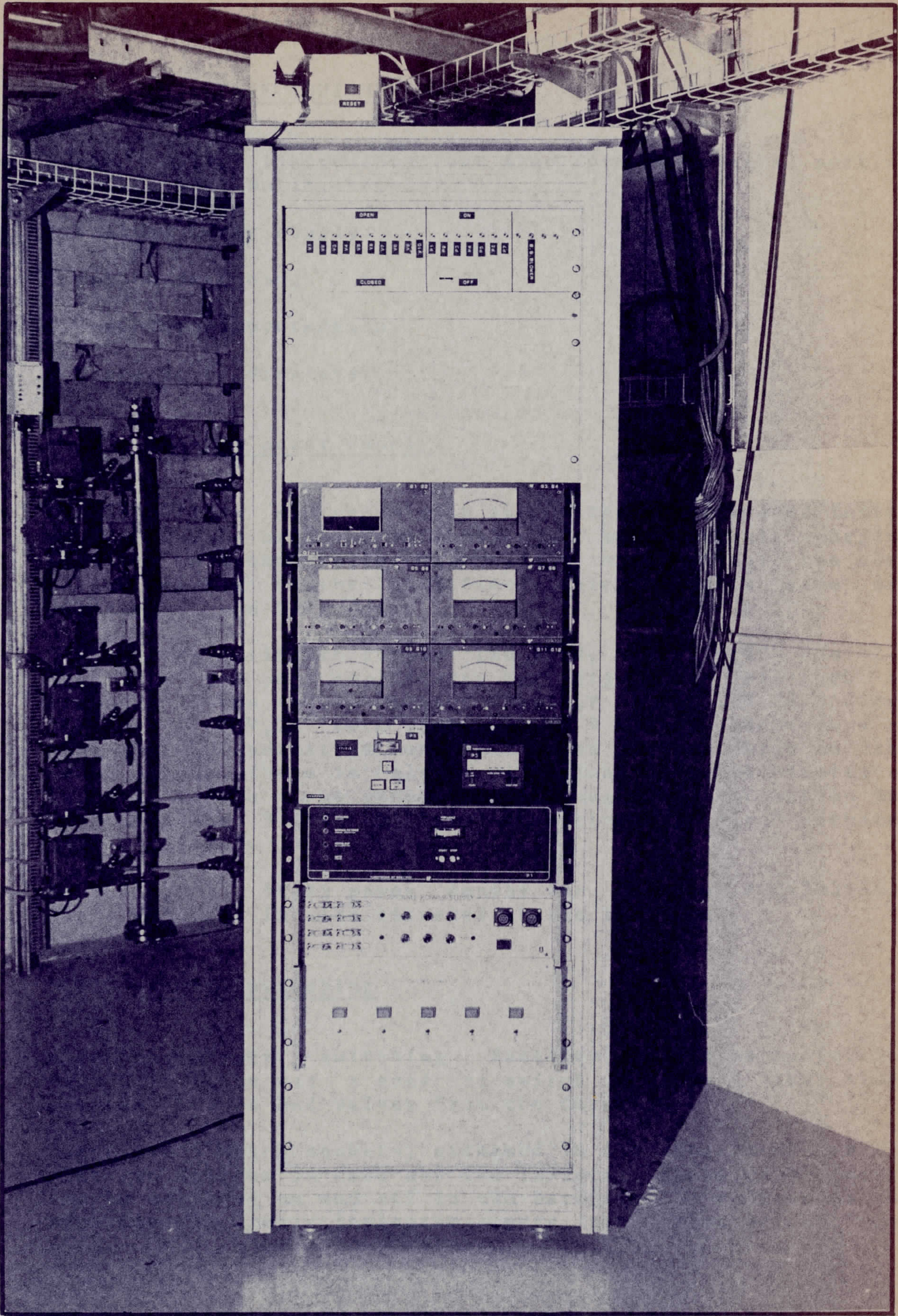


Fig 4.2 Vacuum control cabinet

5. AUXILIARY EQUIPMENT

A few smaller instruments that also form an integral part of the S.C. were built, namely:

* Pre-amp power supply.

* Remote switching.

* H.T. Vacuum protection.

* Temperature displays.

5.1 Pre-amp power supply

Pre amplifiers are used with the detectors situated inside the S.C. They are used to amplify the small signals emerging from the photomultiplier tubes and to match them to the coax cables leading to the amplifiers, which in this case are situated in the Data Area.

A rack was built to supply the +12V, -12V, +24V and -24V needed by the pre amplifiers. See fig. 5.1. This rack is situated in the vacuum cabinet. Two OLV 30-12 12V,4A and two OLV 30-24 24V,2A were used. Eight 9 pin "D" connectors as well as LED indicators and test pins are situated on the front panel. There is also a cable leading to the inside of the S.C. via a Lemo vacuum feedthrough. A distribution box with eighteen 9 pin "D" type connectors is also situated inside the S.C.

An OLV 30-5 5V,2A power supply for the two SBD43-363H31 shaft encoders is also situated inside this rack.

5.2 Remote switching

A remote on-off switching facility was also built. See fig. 5.2 There was a need to switch equipment like video cameras, lights and valves from the Data Area.

There are 5 Mains sockets, situated in the Experimental Area, that can deliver 5A each and 15A in total. These power points can be switched on and off in the Data Area as well as in the Experimental Area. Indicator lights are situated at both ends.

5.3 H.T. vacuum protection

The detectors need up to 3kV H.T. for their photomultiplier tubes. Under certain vacuum conditions the air molecules in the S.C. can start ionizing, shorting the H.T. supplies and damage can occur to the detectors. The H.T. must thus be switched off between 100 mbar and 1 x 10^{-3} mbar for proper protection of the equipment.

A rack with 12 mains sockets situated in the Data Area has been built. All the H.T. supplies used for S.C. experiments are plugged into these sockets. See fig 5.3.

The Alcatel CFA222 vacuum gauges in the Experimental Area have 2 setpoints that were utilized. When the pressure is >100 mbar or $< 1 \times 10^{-3}$ mbar the HT POWER ON switch (SW2) can be pushed latching RL1 and RL2. RL2 in turn puts 220V on the 25A contactor (RL3) making power available to the the H.T. power supplies.
[6]

If the vacuum for some reason moves into the unsafe region RL1 and Rl2 lose power and the power to the HT supplies is cut off. Even if the vacuum moves to the safe region the power stays off. This is done to prevent damage to certain types of detectors where the H.T. voltage is slowly turned up by hand. If desired, the protection can be overridden by lifting the protective cover on the PROTECTION OVERRIDE switch (SW3) and pushing it. A red warning light indicates if this function is selected.

5.4 Temperature displays

In some experiments temperatures of the detectors have to be measured. A circuit originally developed for a hand held LCD temperature meter was used here. There are three of these displays in one rack in the Data Area.

The temperature transducer used is the AD590 which produces an output current proportional to absolute temperature. It acts as a constant current generator passing 1μ A/°K. The AD590 is useful in remote sensing applications and is insensitive to voltage drops over long lines due to its high impedance current output.
[7]

Fig 5.4 shows the EGE 28 Temperature Sensor board. IC1 is a stable 5V reference source which produces an offset through resistors R1, R2 and R3 of 273μA changing K to °C. The offset can be slightly changed by turning potentiometer R3. The slope is determined by the value of R4, R5 and the potentiometer R6. IC3 supplies the negative voltage required for the operational amplifier (IC2). The output of this circuit board is 1mV/°C.

The best way to calibrate this circuit is first to hold the AD590 in steam, when R6 must be turned for a 100mV output. The transducer must then be put into melting ice water: turn R3 until the reading is zero. This must be repeated a few times because the potentiometers influence each other slightly.

IC1 in fig 5.5 is an ICL 7136 3½ digit A/D converter which can interface with a liquid crystal display. It includes seven segment decoders, display drivers, a reference and a clock. IC2 supplies a negative voltage. For calibration purposes potentiometer R2 can be turned. Accuracies of 0,5°C were obtained. The temperature range of the AD590 is between -55° and 150°C.
[8]

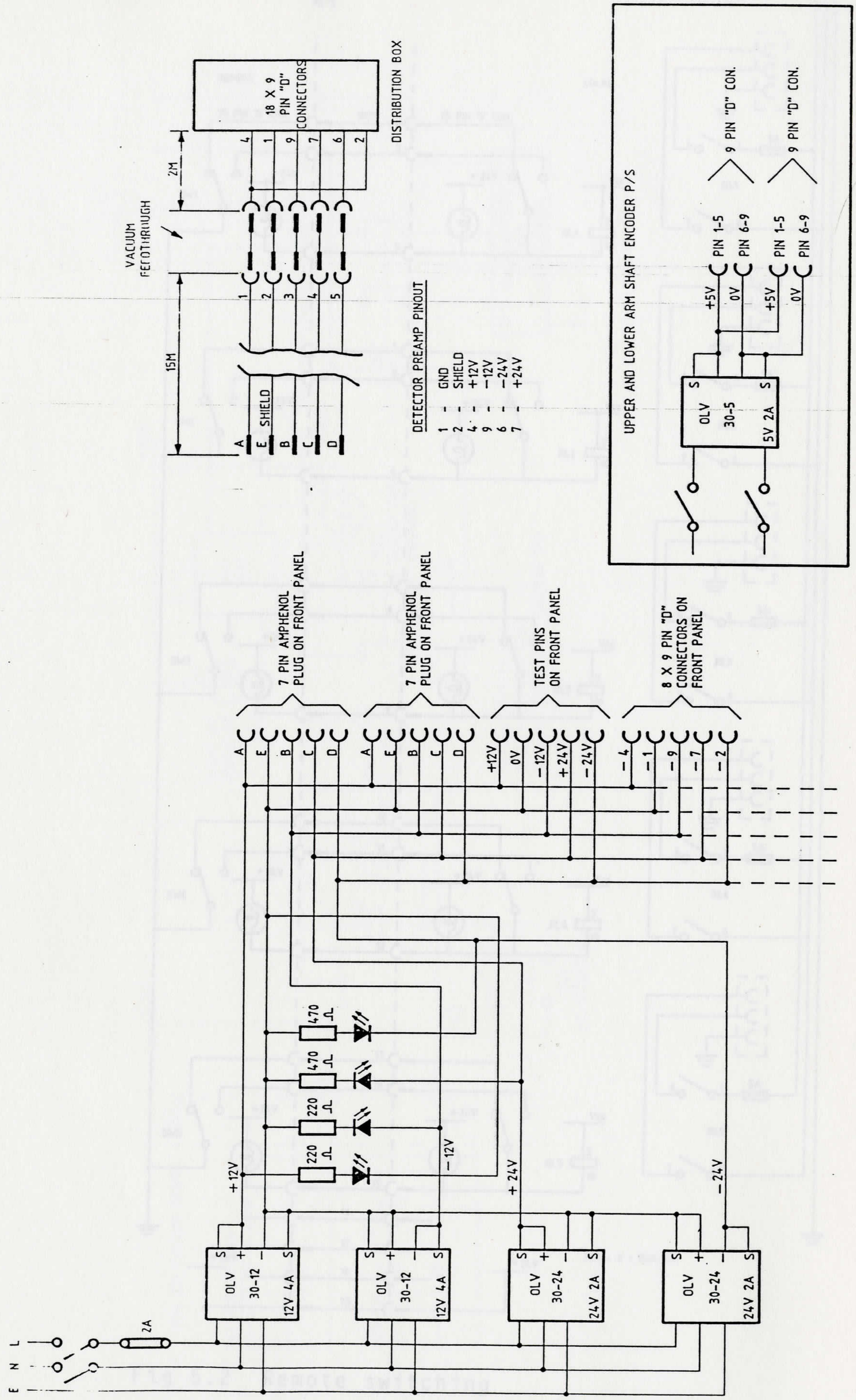


Fig 5.1 Pre-amp power supply

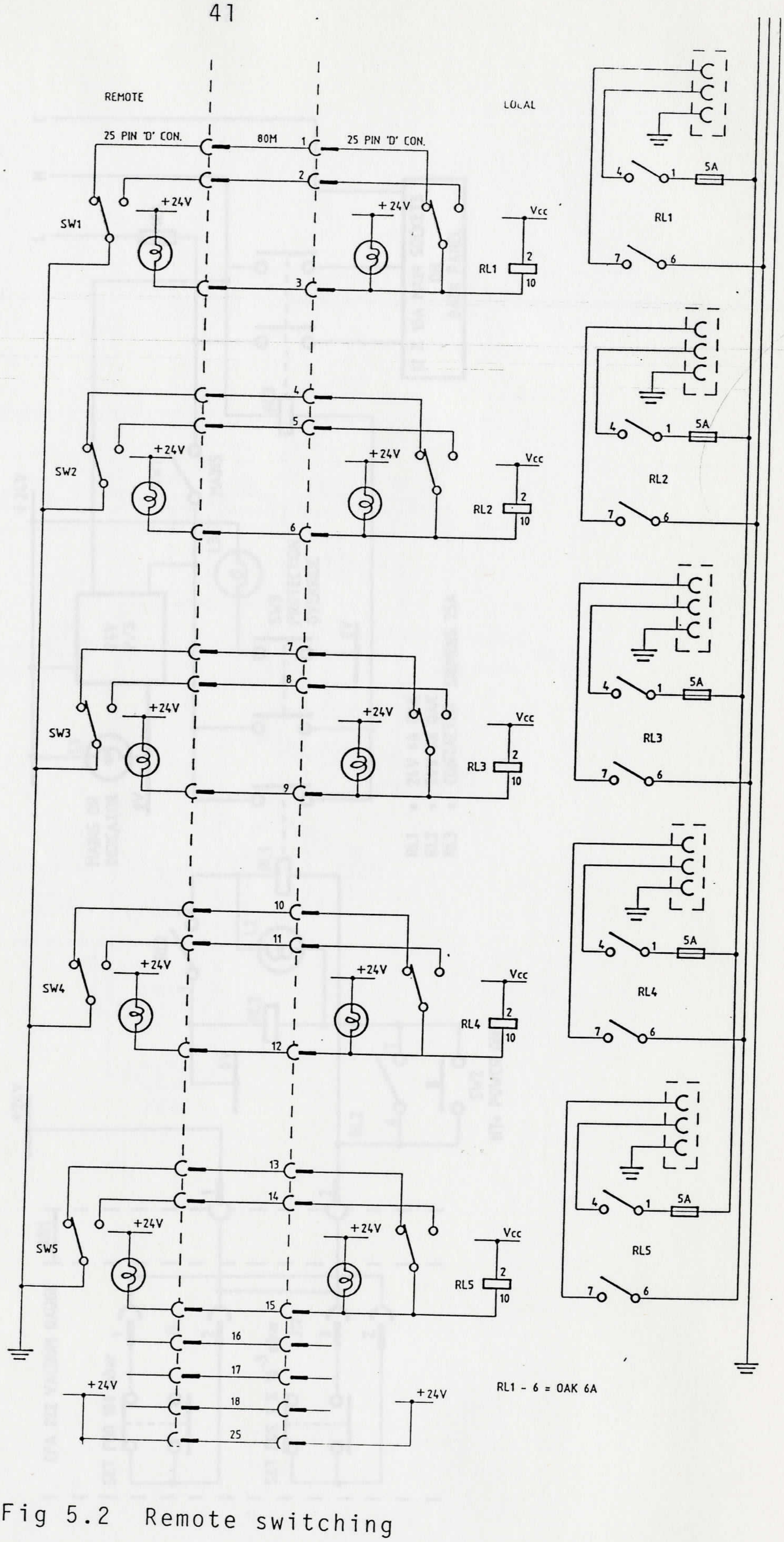


Fig 5.2 Remote switching

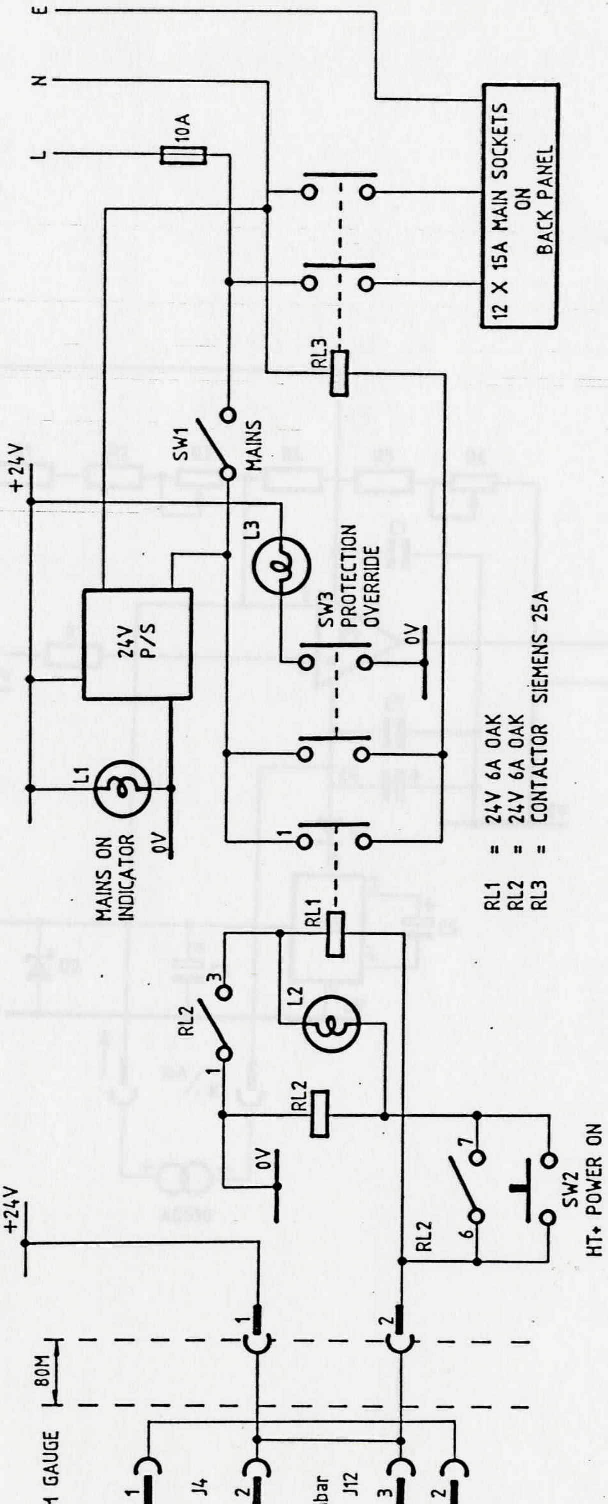


Fig 5.3 H.T. vacuum protection

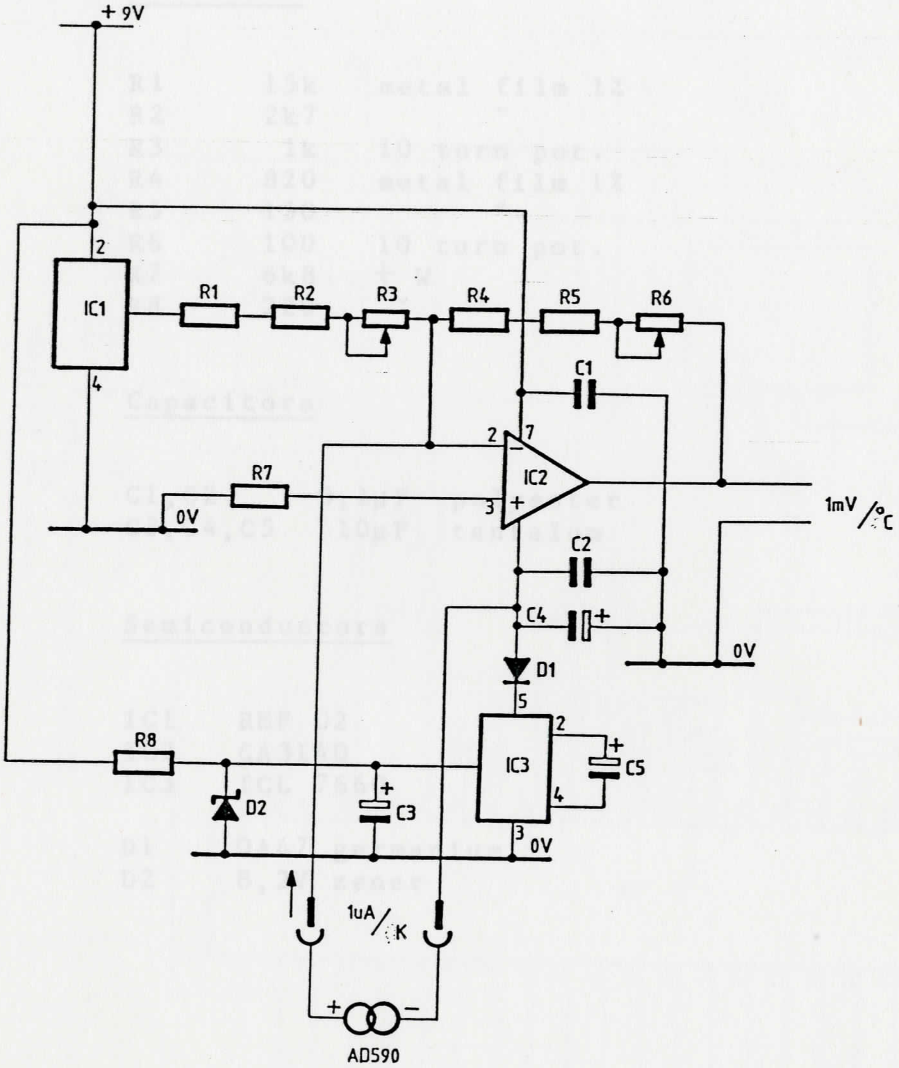


Fig 5.4 Temperature sensor

Component list of the Temperature sensor EGE 28

Resistors

R1	15k	metal film 1%
R2	2k7	"
R3	1k	10 turn pot.
R4	820	metal film 1%
R5	150	"
R6	100	10 turn pot.
R7	6k8	$\frac{1}{3}$ W
R8	220	"

Capacitors

C1,C2	0,1µF	polyester
C3,C4,C5	10µF	tantalum

Semiconductors

IC1	REF 02
IC2	CA3140
IC3	ICL 7660
D1	0A47 germanium
D2	8,2V zener

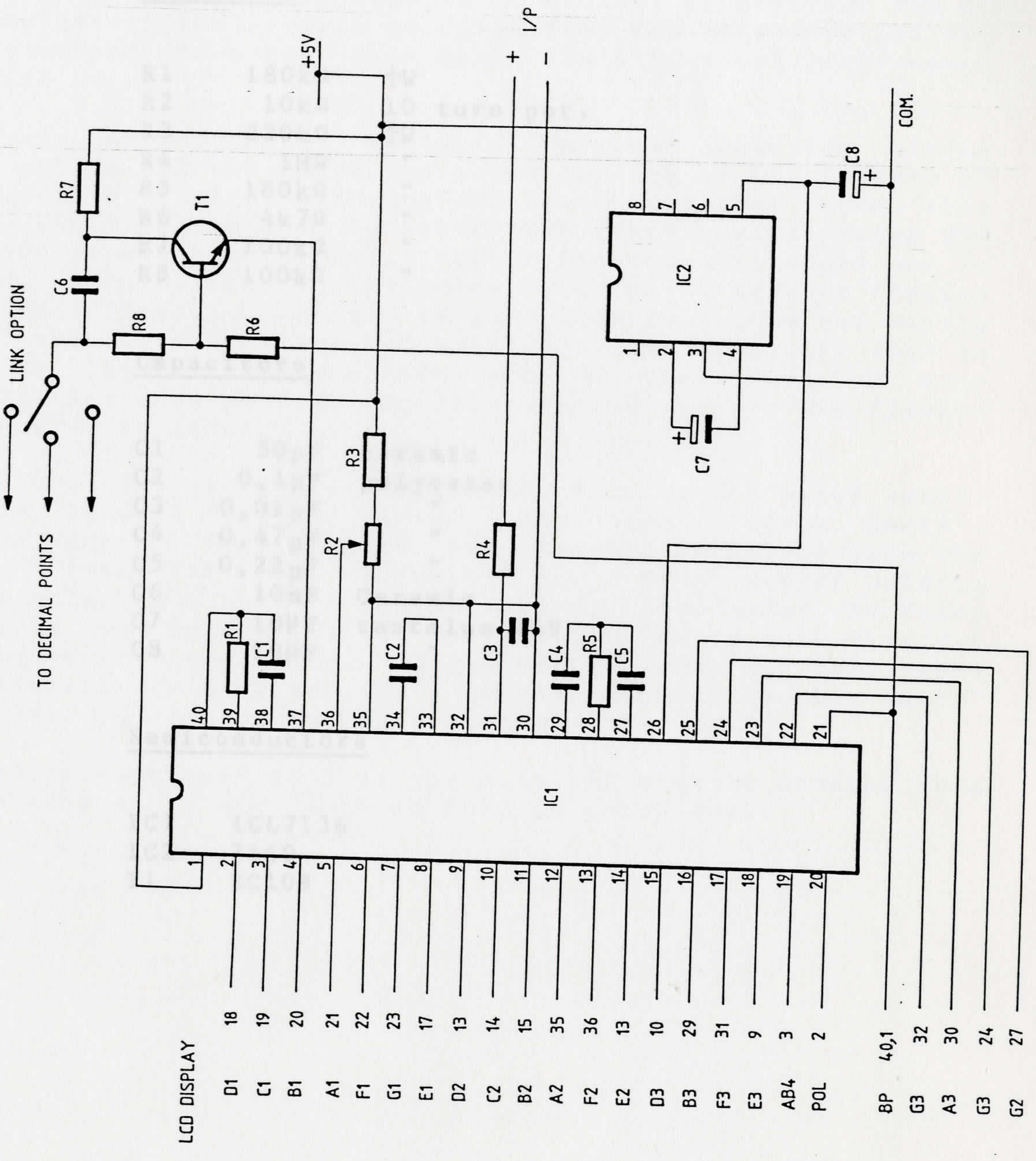


Fig 5.5 3½ Digit LCD display

Component list LCD display board EGE 11

Resistors

R1	180kΩ	⅓W
R2	10kΩ	10 turn pot.
R3	220kΩ	⅓W
R4	1MΩ	"
R5	180kΩ	"
R6	4k7Ω	"
R7	100kΩ	"
R8	100kΩ	"

Capacitors

C1	50pF	ceramic
C2	0,1μF	polyester
C3	0,01μF	"
C4	0,47μF	"
C5	0,22μF	"
C6	10nF	Ceramic
C7	10μF	tantalum 16V
C8	10μF	"

Semiconductors

IC1	ICL7136
IC2	7660
T1	BC109

6. EARTHING OF THE S.C.

Earth loops on the S.C.had to be avoided at all cost due to the nature of the signals emerging from the detectors and the 80m distance from the Data Area. The electrical environment is also noisy.

The S.C. is completely isolated. Perspex isolation pieces were put in all the lines and pipes leading to it. Collars to isolate the bolts clamping the parts together were also made. The S.C. was also isolated from the floor. Isolated BNC and SHV (used for the H.T.) vacuum feedthroughs could not be found, so unisolated feedthroughs, mounted on perspex flanges were used instead. Perspex is excellent in vacuum and easily machinable. Some types of scintillating detectors need to work in light free conditions and as there was no non-translucent 20mm perspex available in the country the flanges all had to be painted.

There are two sockets to earth the S.C. on the patch panel. One is labeled "Mother Earth", the other "Clean Earth". "Mother Earth" is connected to a copper rod driven into the soil, "Clean Earth" is connected to a 25mm^2 copper welding cable going to a grid of copper bars situated under the false floor in the Data Area. All the electronics in this area are connected to these bars. "Clean Earth" must be used when experiments are done and (as a safety feature) "Mother Earth" when the S.C. is not in use or being worked on.

The crane hook used to lift the S.C. lid must be removed from the chains as it was found to form an earth loop.

7. CONCLUSION

A few successful experiments have already been done on the Scattering Chamber. Some of these experiments were done by researchers from external organizations. The system was found to be easy to operate, even by people using it for the first time. An international article has also been published on an experiment done with the help of the Scattering Chamber.

The accuracies of the movements were within specifications as measured by a surveyor: within 0,01° for the Upper and Lower arms, within 0,1° for the Target angle, and within 0,01 of an inch for the target height. The Scattering Chamber itself was positioned within 0,1mm with respect to the beam. These measurements were verified by an experiment specially done to check these accuracies.

The only modifications that proved necessary involved the definition of POS RUN and NEG RUN. It was originally intended that pos run would mean that the arms would move in a clockwise direction increasing the angle. Due to the fact that the shaft encoders on the arms had to be inverted, this was not so. For consistency, therefore, the POS RUN and NEG RUN labels on the control modules were interchanged such that pos run now always means an increase of the reading on the display even if the arms move ccw.

The vacuum section also works satisfactorily. A few leaks were encountered and repaired. The pump-down time depends on the amount of "dirty" equipment inside the chamber. The first pump-down takes about 1½ hours to reach the low 10^{-6} mbar region. If quick changes have to be made inside the chamber, clean dry nitrogen can be vented up to 10 mbar. A subsequent pump down then takes only 20 minutes. A computer controlled interlock system for the vacuum control is in the process of being constructed.

Care should also be taken with earth loops on the Scattering Chamber while experiments are being done. These loops are not always obvious and can sometimes be formed by equipment like video cameras and oscilloscopes.

8. REFERENCES

1. For more information on the National Accelerator Centre the following annual reports are available from:-

   The Librarian
   NAC
   P.O. Box 72
   FAURE
   7131

   National Accelerator Centre Annual Reports
   NAC/AR/79-01 (CSIR 1979), NAC/AR/80-01 (CSIR 1980),
   NAC/AR/81-01 (CSIR 1981), NAC/AR/82-01 (CSIR 1982),
   NAC/AR/83-01 (CSIR 1983), NAC/AR/84-01 (CSIR 1984),
   NAC/AR/85-01 (CSIR 1985), NAC/AR/86-01 (CSIR 1986),
   NAC/AR/86-01 (CSIR 1986), NAC/AR/87-01 (CSIR 1987).

2. JBA England, Techniques in Nuclear Structure Physics (Macmillan 1974). Chapter 2.2 Scattering Chambers.

3. CD20, CD30, CD40 Stepper motor drives (Digiplan).

4. Clock card instruction manual (Digiplan).

5. D. Raavé, Operating manual for the Scattering Chamber vacuum control. National Accelerator Centre internal report (NAC/VA/87-07). (CSIR 1987) Page 1 - 6.

6. CFA221 and CFA222 vacuum gauges (CIT Alkatel).

7. Data acquisition components and subsystems (Analog Devices 1980).

8. Intersil application note A023. Low cost digital panel meter design.

9. APPENDIX

9.1 SBD43 - 363H31 and BVD11 - 102P3 shaft encoder cable connections

Function	37 Pin "D" connector	LEMO Feed-through inside	LEMO Feed-through outside	25 Pin On display Box	80 meter Cable to S.C. Colour
BCD '1'	1	1	22	1	Brown
BCD '2'	2	2	23	2	Red
BCD '4'	3	3	24	3	Orange
BCD '8'	4	4	18	4	Yellow
BCD '10'	5	5	19	5	Green
BCD '20'	6	6	20	6	Blue
BCD '40'	7	7	21	7	Violet
BCD '80'	8	8	13	8	Grey
BCD '100'	9	9	14	9	White
BCD '200'	10	10	15	10	Black
BCD '400'	11	11	16	11	Pink
BCD '800'	12	12	17	12	Red/Black
BCD '1000'	13	13	8	13	Orange/Blue
BCD '2000'	14	14	9	14	Yellow /Red
BCD '4000'	15	15	10	15	Green/Red
BCD '8000'	16	16	11	16	Blue/Black
BCD '10,000'	17	17	12	17	Light green
BCD '20,000'	18	18	4	18	Grey/Blue
OV	35	22	7	See note	Yellow/Blue Green/Blue
5 VDC	36	24	3	See note	Red/Brown White/Blue

+5V goes to pins 1 to 5 of the 9 pin "D" connector behind the Pre-amp power supply, and OV goes to pins 6 to 9.

The BCD '10,000' and '20,000' bits are not used for the BVD 11 - 102P3 shaft encoder.

9.2 BVD11 - 362P6 and BVD11 - 102P3 cable connections

Function	Decoder O/P lead	37 Pin "D" Connector at S.C.	80 m Cable to S.C.	37 Pin "D" connector on Display Box
+12V	Black	1	Blue	1
1	White-Brown	2	White	2
'2'	Red	3	Orange	3
'2'	White-Red	4	White	4
'4'	Orange	5	Green	5
'4'	White-Orange	6	White	6
'8'	Yellow	7	Brown	7
'8'	White-Yellow	8	White	8
'10'	Green	9	Grey	9
'10'	White-Green	10	White	10
'20'	Blue	11	Blue	11
'20'	White-Blue	12	Red	12
'40'	Violet	13	Orange	13
'40'	White-Violet	14	Red	14
'80'	Grey	15	Green	15
'80'	White-Grey	16	Red	16
'Cont'	Brown	17	Brown	17
'Cont'	Red-Violet	18	Red	18
'100'	White	19	Grey	19
'100'	White-Black	20	Red	20
'200'	Orange-Black	21	Blue	21
'200'	White-Orange-Black	22	Black	22
'400'	Yellow-Brown	23	Orange	23
'400'	White-Yellow-Brown	24	Black	24
'800'	Brown-Red	25	Green	25
'800'	White-Brown-Red	26	Black	26
'1000'	Red-Yellow	27	Brown	27
'1000'	White-Red-Yellow	28	Black	28
'2000'	Red-Green	29	Grey	29
'2000'	White-Red-Green	30	Black	30

9.3 VK0046b LED numeric display module connections

Used as position displays for the shaft encoders.

Pin No.	Function	Pin No.	Function
1	BCD '1'	6	BCD '4'
2	BCD '8'	7	BCD '2'
3	Gnd.	8	Gnd
4	Vcc.	9	Vcc.
5	Vcc.	10	Decimal point

9.4 Outputs of the block V-screen BCD to BCD decoder circuit board NAV D3

Function	DIL plug no.
BCD '1'	16
BCD '2'	15
BCD '4'	14
BCD '8'	13
BCD '10'	12
BCD '20'	11
BCD '40'	10
BCD '80'	9

Function	DIL plug no.
BCD '100'	3
BCD '200'	4
BCD '400'	5
BCD '800'	6
BCD '1000'	7
BCD '2000'	8
+ 5V	2
Gnd	1

9.5 Inputs of the Block V-scan BCD to BCD decoder circuit board NAV D3

Function edge	64 pin edge connector	37 pin "D" connector on back panel
'1'	1b	2
'2'	2b	3
'2'	3b	4
'4'	4b	5
'4'	5b	6
'8'	6b	7
'8'	7b	8
'10'	8b	9
'10'	9b	10
'20'	0b	11
'20'	11b	12
'40'	12b	13
'40'	13b	14
'80'	14b	15
'80'	15b	16
'Cont'	16b	17
'Cont'	17b	18
'100'	18b	19
'100'	19b	20
'200'	20b	21
'200'	21b	22
'400'	22b	23
'400'	23b	24
'800'	24b	25
'800'	25b	26
'1000'	26b	27
'1000'	27b	28
'2000'	28b	29
'2000'	29b	30
+ 5V	1a	1
Gnd	32a	-

The bits "read" between transitions are printed in bold.

9.6 Stepper motor control card to control module connections

Pin No.	Connections	25 Pin "D" connector on backplate
1	4a Buff. clk.	
2	6c Buff. clk.	2
3	SW 1a-4, SW 3b-2	
4	NC	
5	SW 5b-3, SW 4b-3	
6	NC	
7	NC	
8	NC	
9	4c Buff. clk.	3
10	NC	
11	NC	
12	SW 2a-4, SW 3c-2	
13	SW 1b-2, SW 2 lamp	
14	SW 2b-2, SW 1 lamp	
15	SW 1c-2, SW 3 lamp	
16	28c Buff. clk.	4
17	NC	
18	NC	
19	SW 3a-4, SW 2c-2	
20	+ 24 In	18
21	+ 24 In	19
22	NC	
23	GND.	24
24	GND.	25
25	GND.	
26	SW 4c-3, SW 5c-3	
27	NC	
28	NC	
29	Reset switch	
30	NC	
31	28a Buff. clk.	5
32	LED anode Pos. Limit	
33	Pos. Limit switch	6
34	Neg. Remote	7
35	SW 5a-1	
36	NC	
37	NC	
38	NC	
39	NC	
40	NC	
41	Neg. Limit switch	8
42	LED anode Neg. Limit	
43	Pos. Remote	9
44	SW 5 lamp	
45	SW 4 lamp	

Pin No.	Connections	25 Pin "D" connector on backplate
46	6a Buff. clk.	10
47	SW 5a-2	
48	SW 4a-3	
49	22a Buff. clk.	13
50	Remote speed	11
51	8c Buff. clk.	12
52	Slow rate	15
53	50k pot. wiper	
-	Pot. - Buff.clk. 22c	14
-	Motor direc. - Buff. clk. 26c	

Gnd. is also connected to SW 1a-3, SW 2a-3, SW31-3, SW 4a-4, SW 4c-4, SW 4b-4, SW 4 light, SW 5b-4, SW 5c-4, SW5 light and reset.

+ 24 V is also connected to SW1-SW3 lights, SW2b-1, SW 3b-1, SW 1b-1, SW 3c-1, SW 1c-13 and SW 2c-1.

9.7 Control module connections

25 Pin "D" connector	32 Pin edge connector	8 Pin Painton Connector to S.C.	8 Pin Painton to Remote box	Function
1	4a			Pos Limit
2	6c			Allow clock
3	4c			Neg. lim
4	28c			Motor clk.out
5	28a	3		Motor clk.out
6	NC	5		Pos. Limit switch
7	NC		3	Neg. Remote
8	NC	6		Neg. Limit Switch
9	NC		4	Pos. Remote
10	6a			Dir. Req.
11	NC		5	Rem.speed
12	8c			Motion
13	22a		6	Slow rate
14	22c			Slow rate
15	NC		7	Slow rate rem
16	NC			
17	NC			
18	10a, c	1		+ 24 V
19	10a, c			+ 24 V
20	10a, c			+ 24 V
21	NC			
22	NC			
23	16a, c	7		Gnd
24	16a, c			Gnd
25	16a, c			Gnd
-	26a, c	2		Motor direction
-	20c			Gnd

32a and 32b are linked.

9.8 Motor drive box to Motor control box connections

Function	8 Pin Painton connector	32 Pin connector Buff. clk.	32 Pin connector ct to CD20
+ 24 V	1	10a, c	10
Motor Direction	2	26a, c	26
Motor clk.	3	28a, c	28
NC	4	-	-
Pos. Limit	5	4a	-
Neg. Limit	6	4c	-
Earth	7	61a, c	16, 18
NC	8	-	-

9.9 Motor drive rack to S.C. connections

Function	8 Pin Painton connector	Vacuum Feedthrough	32 Pin connector from CD20
2A Stepper motor	1	1	2
2B Stepper motor	2	2	4
1B Stepper motor	3	3	6
1A Stepper motor	4	4	8
Pos. Limit	5	5	-
Neg. Limit	6	6	-
Gnd	7	7	16, 18
NC	8	8	-

9.10 Transformer rack to Motor drive rack connections

Function	Souriau connector	4 pin Painton connector	32 Pin connector on PM1200
60 VAC	a1, a2	1	30, 32
60 VAC	a4, a5	2	26, 28
20 VAC	b1, b2	3	24
20 VAC	b4, b5	4	22