AAEC-ES/DM-6

UNCLASSIFIED

Rig No.: - X193
Reactor: - HIFAR
Facility:- 6HGR8

ES/DM/6

ES/DM/6

ENGINEERING SERVICES DEPARTMENT

DESIGN MANUAL

for

URANIUM ANALYSIS RIG X193

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Sponsor: - Physics Division

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1. INTRODUCTION

1.1 Foreword

The necessity of duplicating a rig for the analysis of uranium ore was established during the latter half of 1975 and it was proposed that the 6HGR8 facility on HIFAR be used. The new rig (designated X193) was proposed to be basically similar to the uranium ore assay rig previously installed in MOATA(1) but to incorporate any features found desirable as a result of past operational experience, or necessary as a requirement for operation in HIFAR.

1.2 Principle of Operation

The analysis of a uranium ore sample, by the delayed neutron technique, involves the fission of the naturally occurring nuclide U^{235} with thermal neutrons. In the HIFAR Reactor, the horizontal facilities are a source of thermal neutrons suitable for the irradiation of uranium ore samples.

Saturation of the uranium ore samples, with respect to delayed neutron production, takes place in ~ 4 minutes, however, practical experience has determined that an irradiation period of ~ 1 minute is satisfactory. Because of the relatively short half lives of some of the delayed neutron producing nuclides, it is essential to count the delayed neutrons being emitted from the irradiated ore sample as quickly as possible. A time limitation of 3 s was placed on the transport of an ore sample from the irradiation facility to a counting chamber, the transport being accomplished by means of pneumatic conveying.

1.3 Operational Features

As a result of variation of the percentage of uranium occurring in ore samples sent for analysis, it is desirable to be able to vary the thermal neutron radiation dose received by the samples. With the MOATA Reactor, this is readily achieved by changing the operating power of the reactor. This, however, cannot be done with HIFAR so a method of varying the thermal neutron flux whilst the reactor is at (constant) power, had to be devised.

This is accomplished by providing means for adjusting the location of the sample in a variable thermal neutron flux field. The amount of movement necessary to fulfill the range of thermal neutron flux as required for irradiation of the ore samples, was established during a series of thermal neutron flux measurements made along the beam hole of the collimator X164/1 which was located in the facility 6HGR8 prior to May 1976. The results of the measurements made, are shown in figure 1.

A cause for attention, in the operation of HIFAR, is the increasing level of Argon 41 gas which is released, via the Active Exhaust System, to atmosphere.

Because a major contribution to the production of Ar^{41} comes from experimental rigs using compressed air, considerable thought in the design of the X193 rig has been given to minimising the use of air for conveying purposes.

2. DESCRIPTION

The rig comprises five major items together with interconnecting pipework, electrical and pneumatic connections, as shown in figure 2. The major items will now be described and the operation of the rig will be explained in the following text.

2.1 Equipment

2.1.1 In-Pile Rig (Drg No. AOE47536)

This item (refer to figure 3) consists of a shield plug, externally identical to the collimator X164/1, with a tube located on its central axis. Inside this tube is contained an Adjustment Tube which positions the location of the polythene can for its irradiation. The Adjustment Tube is moved by means of a threaded section, externally driven by means of a double reduction gearmotor and a spur gear set which turns a threaded nut. The Adjustment Tube is prevented from rotating by means of a key; the motion is thus translated to an axial movement. The length of movement has been determined by the range of thermal flux required for typical ore specimen irradiations.

The Adjustment Tube is supported externally, by a ball bearing mounted in a housing attached to the rig head. Internal support is obtained by means of an'O'ring sealed plunger section of the Adjustment Tube. The range of adjustment is controlled by the positioning of two micro-switches at the limits of movement of the Adjustment Tube.

As a means of providing remote control of the Adjustment tube, the reversing gearmotor directly drives a rotary potentiometer. The potentiometer provides an output voltage to a digital read-out volt meter which is located in the counter control console No. 41, in the HIFAR basement. By means of suitable calibration, the exact position of the polythene can is established.

Two helium gas purge tubes are spirally would through the shielded section of the rig to the inner end; when required helium gas flushes the void at the inner end. A series of neoprene 'O' ring seals, prevent the escape of contaminated gas into the Reactor Sealed Building.

Five chromel/alumel thermocouples are provided to monitor the rig temperature at five predetermined positions. Three are attached to the wall of the inner end (TC3, TC4, & TC5), and the remaining two (TC1 & TC2) are attached to the centre (fixed) tube. A photo diode device is positioned at the inlet flange so that an indication that the polythene can has entered the rig, can initiate the relevant control functions (described in section 2.2).

A conveying air tube allows movement of air to the inner end of the fixed tube, whilst a further tube is provided for flux measurement along the length of the collimator.

All service tubes through the shield portion of the rig are spiralled.

Shielding of the "in-pile" rig is obtained by a steel shot concrete fill of all voids. The head section of the rig, consists of a 130 mm thick lead filled shield. During the commissioning period, with the exception of the centre "core" of the rig which is externally shielded, the shielding of X164 collimator (which this rig replaces) is temporarily used after being modified to suit. Although radiation levels are acceptable to health physics standards, borated paraffin wax blocks, lead bricks, and steel plates were incorporporated to satisfy radiation background requirements (especially neutrons) by adjacent experiments. A proper shielding (Drg No. AOE50206) is being manufactured based on the optimised temporary shielding configuration, with emphasis on ease of handling, assembly and reach for maintenance.

2.1.2 Breech Loading Mechanism (Drg No. BE39953)

The breech loading mechanism which is supported off the counting chamber shield assembly, consists of a cylindrical aluminium housing in which rotates a rotor. The rotor is actuated by means of an air cylinder and crank arm which causes it to rotate between a "LOAD" position and an "EJECT/STORE" position. Passageways in the rotor enable the polythene cans to be pneumatically conveyed to the "in-pile" rig or to a counting chamber.

Two micro switches are mounted off the housing at positions which correspond to the limit of travel of the crank and two mechanical stops are also provided to limit the amount of "over-travel". A handle, at the air cylinder connection to the crank, enables the system to be manually operated if air systems should fail.

2.1.3 Counting Chamber (Drg No. AOE 5273)

The purpose of the counting chamber is to measure the delayed neutrons emanating from the uranium ore samples contained in the polythene cans. Its construction is essentially an aluminium housing through which passes the pneumatic conveyor tube. The housing is filled with non borated paraffin wax in which are embedded the counting devices viz boron tri-fluoride counters (20th Century Electronics type 31 EB40).

The polythene cans are stopped during their passage through the counting chamber by a polythene stop. This stop is actuated by a two way air operated cylinder. Immediately after the can's arrest in the counting chamber, a captivity stop is actuated by a spring loaded plunger of an air operated cylinder.

The two stops position the sample for counting in the centre of the chamber to ensure constant geometry for all samples whilst they are being measured.

At the inlet and outlet of the counting chamber pneumatic conveying lines, are located photo diodes. The purpose of these devices is explained in section 2.2)

2.1.4 Shield Assembly (Drg No. AOE47377)

The counting chamber is surrounded by massive neutron shielding in the form of steel encased borated paraffin wax[2]. The shielding is designed to eliminate stray neutrons from entering the counting chamber and influencing the number of delayed neutrons counted from the uranium ore sample being measured.

The shielding has ready access to the counting chamber through a front opening door. The counters themselves are easily removed from the counting chamber. The top of the shielding is utilised to locate the counter controls and teletype unit which are associated with the counting chamber. Shielding calculations are summarized in Appendix A.

2.1.5 Spent Capsule Container (Coffin) (Drg No. AOE47632)

When the ore sample in the polythene can has been measured in the counting chamber, it is ejected and pneumatically conveyed to a storage area. Cans are collected in a tube which has a "quick" connection at one end, and a lever operated connection at the other end. When a tube is filled, and is safe to handle, it is disconnected from the pneumatic system and allowed to roll within the container.

Because the cans will contain ore samples with varying degrees of activity, which will depend upon the decay time of each sample, shielding is required. The shielding is provided by a 50 mm lead brick wall along the front face of the container, and by means of a 10 mm steel plate (lid) and distance at the top of the container.

Pneumatic lines and associated connections are made between the end of the receiving tube and the air valve which controls the air movement, to the HIFAR Active Exhaust System.

2.1.6 Can Assembly (Drg No. A4E47673)

The uranium ore samples are received by the A.A.E.C., from various exploratory sources, in ∅ 22 mm x 33 mm long polythene containers. These containers are heat sealed and located into "extra high density" polythene cans which are the vehicles used for pneumatic conveying. The suitability of the "extra high density" polythene for irradiation purposes has been demonstrated by the Experimental Reactor Physics Section in the MOATA Reactor. Each can will be employed only once for pneumatic conveying of ore samples

All cans are to be checked by means of a can test gauge (Drg No. PE39991) before use in the pneumatic conveyor.

2.1.7. Load/Unload Tube Assembly (Drg No. A2E47654)

When the cans are loaded with an ore sample they are assembled into load/unload tubes. These tubes are made from a polycarbonate material which is a clear plastic material not susceptible to cracking and discoloration as is perspex. On one end of each tube is fitted an adaptor, which locates in the breech loading mechanism (for the load tubes) or in the spent capsule container (for the unload tubes). At the other end of the tube, are two caps used for the loading process; the outer cap is removed when the tube is used for unloading.

2.1.8 Piping detail-rig flange to reactor floor (Drg No. A0E47639)

This drawing details the pneumatic conveying pipework from the rig flange to the floor of the reactor.

2.1.9 Piping - reactor floor to basement

The pneumatic conveying pipework between the reactor floor and the equipment located in the basement (i.e. breech loading mechanism, counting chamber and spent capsule container) is routed as shown on Drg. AOE47688. The pipework which is of stainless steel, 31.75 mm O.D. x 29.3 mm I.D., is protected by a wire mesh guard from accidental damage. All pipework is required to be tested by the passage of a special test can (Drg No. PE39990) which is slightly larger than the normal can, to ensure that there is no restriction. From the rig head to the reactor floor, the pneumatic conveyor is 34.9 mm O.D. x 31.75 mm I.D. (see Commissioning Report).

2.1.10 Pneumatic circuit (Drg No. A2E47858)

Operation of the pneumatic conveyor is by means of a system of solenoid valves and air valves as diagrammatically shown in figure 4. The pneumatic system uses "control air" at a pressure of 700 kPa and "conveying air" at a pressure of 200 kPa. The method of operation is explained in section 2.2.

2.1.11 Control circuit (Drg No. A1E47890)

Controls to permit the system to function in its proper mode will be supplied by the Instrumentation and Control Division, with the electronic and print-out apparatus for the counting chamber being supplied by the Physics Division. The I. & C. Division controls will be in the form of a control console (No. 40) and the pneumatic valves are fixed to a panel at the back of the console cabinet.

The counting chamber control console (No. 41) and a teletype machine will be mounted on top of the counting chamber shielding.

2.2 Operation of the Rig

2.2.1 Preparation of the samples

The uranium ore samples are received by the AAEC Physics Division prepacked in polythene containers. These sample containers, after checking of the heat sealing, are placed inside numbered cans. (Each can is selected on the basis that its two parts match with a tight fit) The hole in each can will then be heat sealed by an electric soldering iron. Up to 40 cans are loaded into a load/unload tube; of these 40 cans, there would be a number of cans which would contain a "standard ore" or a "standard metal" sample, and possibly two blank (empty) cans.

The ends of each tube are capped and then despatched to the HIFAR Operations Section for irradiation, accompanied by the appropriate documentation (refer Appendix B).

Upon arrival at HIFAR the tubes are placed in the racks provided for their storage. When the rig is available for analysing samples, a tube is taken from the storage rack, one of the end caps is removed and an adaptor screwed on in its place, and the tube is then inserted into the breech loading mechanism.

As the irradiation dose received by the samples and the resultant count of the delayed neutrons is dependent upon the amount of uranium in the ore, a knowledge of the range of uranium content of the samples received, is advisable. This can be gained by experience i.e. a knowledge of the range of uranium content, usually given by the client. If this information is unknown for a new batch of ore samples, it will be necessary first to irradiate an ore sample in a position in the in-pile section of the rig, at a low thermal flux value. An adjustment to the irradiation position can then be made based on the count result.

Having selected the irradiation position in the in-pile section of the rig, which is accomplished by driving the gearmotor on the rig head to a specified position (indicated by a digital readout meter), and having placed an unload tube in the spent capsule container, the load tube can then be attached to the breech loading mechanism. The system is then ready to be operated.

2.2.2 Pneumatic Conveying System

The pneumatic conveying system operates as follows:

(a) Shut off the system depressurising valve.

(b) Turn on the main compressed air line valve to the control console.

(The above two valves are located on the reactor wall behind the breech)

(c) Set the air pressure regulator reading at the back of the control console No. 40 at 30 psig.

(d) Switch on the electrical supply to consoles No. 40 & 41 and the latter associated modules.

Startup

i) Manual operation:

The manual condition should only be used when the prior status at the rig is known. It can be used for a "one-off" job, or in order to pass a test can through the rig. If during manual operation a can fails to arrive at its next destination within a predetermined time, an alarm will be initiated.

ii) Clear operation:

The clear mode is specifically designed for "cold" start up or when the prior status of the rig is unknown. When the main CMC is switched to clear, the rig will progress through one complete sequence from eject to store. If no alarm occurs, the rig will be ready to commence automatic operation. If a can has been left in the core and an attempt is made to eject it during the clear sequence, then this presumed "hot" can will be held in the counting chamber.

If during the clear mode a "stray" can is detected, the system will indicate the position of the can and will give an audible alarm.

iii) Automatic Operation:

In the automatic mode, the rig will carry out overlapping sequences until the supply of cans is exhausted, at which stage a low level audible alarm will automatically sound.

As the "last can" alarm is initiated, the knob of the CMC must be pressed in order to return the system to the auto mode. This must be done after replenishing the supply of cans.

The pneumatic conveying system functions as follows:

I. Load:

(1) As the LOAD sequence is actuated, SV2 is energised, and the air cylinder AC1 on the breech loading mechanism, receiving air via PV2 rotates the breech rotor from the EJECT/LOAD position to SEND position (Figure 5).

(2) As microswitch MS1 is contacted, SV3 is energised and PV3 admits air to the conveying line, moving the can from the breech loading mechanism to the rig head. Air is exhausted via BV1. After a short period (nominal 8s) SV3 is de-energised and the conveying air is cut off.

(3) As the can enters the rig head, it "breaks" the light beam to photo diode PD1, thus starting an irradiation timer. The can is held in position at the inner end of the irradiation tube by the vacuum effect of the Active Exhaust System which is connected to the pneumatic conveyer via BV1.

(4) Nominal irradiation time of 60 s passes before the breech loading mechanism is returned (on a signal from the timer) to the EJECT/LOAD position.

II. Eject:

(1) When the EJECT/LOAD microswitch MS2 confirms that the breech loading mechanism is in position, SV1 and SV5 are energised, thus operating valves PV1, PV4, BV1 and PV6. In this state, air is admitted to the inner end of the rig and the can is transported to the counting chamber.

(2) As the can enters the counting chamber, it passes photo diode PD2 which actuates a counting scaler. It also de-energises SV6, thus operating AC3 plunger to the in position. The can is then captivated in the counting chamber.

In the meantime, the breech loading mechanism is returned to the SEND position via energising SV2. At this stage, the second can is ready for its cycle in the process as in (I) & (II) above.

III. Store:

(1) The can already in the counting chamber remains for a nominal 50 s for counting. At the end of this time, the timer actuates SV4, SV3, SV5 and SV6. The air cylinder AC2 retracts the front stop allowing the can free passage to the storage container (coffin). As SV3 is energised, air is admitted via PV3 transporting the can from the counting chamber to the coffin. AC3 rear stop will move to the out position. Air is exhausted via PV6 to the Active Ventilation System.

(2) The can passes photo diode PD3 at the entrance to the coffin. The breaking of the light beam to the photo diode provides an "enable" signal which if not observed, will stop the automatic operation and

activate an audible alarm.

(3) The system will shut down automatically when the last can reaches the storage container (coffin), due to PD1 not recording the passage of a can into the rig.

Auto Mode Safety Trips

- Fail to load; If a "send to core" sequence is initiated and the can does not pass PD1 then LOAD button will the illuminated red.
- Fail to eject; If a "send to castle" sequence is initiated and the can does not pass PD2 then the EJECT button will be illuminated red.
- Fail to store; If a "send to store" sequence is initiated and the can does not pass PD3 then the store button will be illuminated red.
- Excess count time; If the count time exceeds the irradiation time, then the count button will be illuminated red.

In all cases above, an audible alarm accompanies the red light.

The operation of the breech loading device as described above, is illustrated in figures 5 and 6.

2.2.3 Disposal of the samples

When the samples in a load tube have passed through the irradiation process and have arrived at the unload tube in the coffin, before further samples can be loaded, the irradiation samples have to make way for an empty unload tube. This is done by an operator who must first ascertain that radiation levels, at the end of the unload tube where handling will take place, are safe; viz. the preset audio/visual alarms of the radiation detector are off.

If these alarms are off, i.e., the monitored reading of $\beta + \gamma$ radiation level is less than 1.4 μGys^{-1} (500 mR/hour), then the tube may be quickly disconnected and allowed to roll into the storage area inside the coffin. An empty tube can then be quickly inserted for receipt of the next batch of samples.

After all samples have been processed, or the storage area is full (it will hold six tubes including the tube which is still connected to the system for receipt of samples), the storage area is surveyed for radiation. If contact radiation levels are less than 140 $nGys^{-1}$ (50 mR/hour), the tube(s) can then be removed and stacked in the shielded storage rack. The adaptors are unscrewed from the tube ends and are replaced by a screwed cap. The tubes are then placed in polythene bags and sealed, ready for despatch to Physics Division.

Upon arrival at the Physics Division building, the loaded tubes are unloaded and the cans are stored. The tubes are cleaned ready for loading the next consignment of samples

3. INSPECTION, ASSEMBLY AND TESTING PROCEDURES

3.1 Inspection

The current control, planning and manufacturing procedures in use by the manufacturing section, require that all jobs are allotted to specific categories(3). Each category ensures that certain standards of quality control are enforced, and thus the degree of inspection on each job is established.

The category of each major item issued for manufacture is listed below:

	Category:
In-pile rig	B
Breech loading mechanism	C*
Counting chamber	C*
Shield Assembly	C
Spent Capsule Container	C
Can Assembly	B
Load/Unload Tube Assembly	C
Piping detail - rig flange to reactor floor	C
Supplementary Shielding	C
Storage Rack	C*
Piping - reactor floor to basement	C

Certain critical items of those jobs noted category B and C* are subjected to 100 percent inspection, thus ensuring the quality of the finished item.

3.2 Assembly

Prior to the out-of-pile testing of the complete rig, which will be undertaken by the Irradiation Rigs Sub Section, it will be necessary to assemble certain components and check their critical (assembled) dimensions. The assembly and checking of these components is described in a separate document "Tests and Checks Schedule".

3.3 Testing

Before installation into HIFAR, the major components of the rig will require testing as a system, by the Irradiation Rigs Sub Section. The objective of the tests will be to ensure the correct mechanical, pneumatic, electtrical and electronic operation of all items. Static components such as supplementary shielding will not be involved. The drive motor for the in-pile rig will require calibration with a digital read-out meter, so that remote indication of the position of the irradiation can is obtained. The digital read-out meter, and any associated electrics, is to be then located in console No. 41. The mechanical operation of the drive motor and the adjustment tube should be verified as being satisfactory. Also, the support of the flange insert should be checked to determine its adequacy.

The pneumatic connection of all components and their correct operation in conjunction with the control console, is then tested. The test can is fired through the system after the pneumatic conveying pipework has been assembled. Upon the successful conveying of the test can, a series of tests is carried out, conveying some sample cans. Results of the tests will be recorded in a separate document.

4. INSTALLATION

4.1 Preliminary Work

After the tests, as outlined in section 3.3, have been completed, the items of equipment are disconnected from the pneumatic systems and then cleaned as required. All major components are identified with drawing number tags and the in-pile rig is marked with a vertical centre line to assist in its orientation during assembly. The adjustment tube on the in-pile rig is driven to the full "in" position before electrically disconnecting the gear-motor.

The installation of the in-pile rig cannot be accomplished with the rig fully assembled. In particular, the following components have to be removed:-

gearmotor and support bracket,

flange insert and support brackets,

swagelok union elbows, and

rig head connection bracket (A2E47566).

The Cannon plug which terminates the thermocouples does not require disconnection from the thermocouple leads but the other plugs will be removed with the rig head connection bracket. (Refer to Drg No. A2E47854 for details of equipment removal.)

4.2 Removal of Collimator X164

The X193 in-pile rig is to be installed into facility 6HGR8 which, at present, houses the neutron collimator X164. Hence it will be necessary to remove this collimator. Health Physics personnel will be in attendance during all stages of the in-pile rig installation.

As all of the out-of-pile equipment for X164 has previously been removed, and all external connections have been diconnected, the removal of the collimator can take place during a major shut-down (i.e. where portion of the core has been unloaded) of HIFAR. It has been ascertained that it was possible to move the collimator in its facility hence there should be few problems in the removal of the collimator.

The rotating plug of the collimator is unloaded before attaching the counterweight bar to the outer face of the fixed plug. The appropriate counterweights are attached and the collimator is withdrawn using the established procedures for this work.

4.3 Installation of In-Pile Rig

The following description of the installation is not necessarily intended to indicate the order in which items of equipment are to be installed; the order of installation will depend upon workshop's work loading and availability of equipment.

In order to load the in-pile section of the X193 rig, using the standard counterweight bar, it will be necessary to attach the adaptor (Drg No. A2E47840) to the rig head (refer Drg No. A2E47854). Note that only specified bolt holes are used to secure the adaptor to the rig head - refer figure 7. The counterweight bar is secured to the adaptor and the rig is then loaded into the 6HGR8 facility using established procedures. Constant surveillance by Health Physics personnel will be required during the installation of the in-pile rig.

After securing the rig into its facility, the components which were previously removed are assembled as follows:

The gearmotor and support bracket are carefully lined up with the driven spur gear to give the correct centre distance, i.e. backlash checked to be adequate, and they are then dowelled in position. A temporary electrical connection is made to the gearmotor and the adjustment tube is driven to the mid position.

The flange insert and support brackets are then assembled, "lined-up" and then secured. The temporary plug (Drg No. A3E47841) is then placed in the flange insert whilst further assembly work at the rig head proceeds. When the components previously removed (refer 4.1) have been assembled, the temporary plug is withdrawn.

All electrical connections are checked for continuity and the mechanical operation of the adjustment tube is verified. Only after satisfactory mechanical operation of the adjustment mechanism is obtained, should the pneumatic conveying pipework be attached to the rig.

4.4 Installation of Basement located Equipment

The shielding around the counting chamber is the first item which is to be located in the HIFAR basement area. The assembly of the counting chamber should also proceed at the same time as the assembly of the shielding, as pneumatic pipework, which is connected to the counting chamber, is incorporated in the shielding. The photo diode device, located at the inlet of the counting chamber, will require installation at the same time as the counting chamber.

The breech loading mechanism, which is supported on a bracket located off the counting chamber shield, can now be installed. The spent capsule container was connected to the pneumatic conveying tube emerging from the counting chamber shield, together with PD3 also can be installed. A 50 mm thick lead brick wall will be required to be erected along the face of the spent capsule container (coffin).

4.5 Installation of Pneumatic Conveying Pipework

The original stainless steel tubing allocated for the pneumatic conveyor was 34.9 mm O.D. x 31.75 mm I.D. However, due to aerodynamic considerations during commissioning in HIFAR, it was decided to replace the Conveyor Tube section from the 15' floor level to the breech loading mechanism by a 31.75 mm O.D. x 29.3 mm I.D. Stainless Steel tube. The tubing is to be run from the breech loading mechanism to the rig head, as shown on Drg A0E47639 and A0E47688.

Particular attention should be given to the bending and handling of the conveyor tubing. The minimum centre line bend radius is 330 mm and all tubing must be free of dents and wrinkles.

From the reactor floor level down to the basement, the tubing passes through the floor space, over the floor support structure before emerging over the edge of the D_2O plant room concrete shield into the basement. All sections of the pneumatic conveyor tubing must freely pass the test can (Drg No. PE39990).

The conveyor tubing between the rig head and the reactor floor level, must not impose any loading upon the rig flange. To achieve a connection with the rig flange without misalignment, an additional bracket will be installed to support the rig flange.

In order to protect the pneumatic conveyor tubing in the basement from accidental damage, a guard made from heavy wire mesh is to be installed.

4.6 Installation of Supplementary Shielding

As soon as the conveyor tubing installation has been completed, some supplementary shielding can be positioned as required. This arrangement is temporary and will be replaced by permanent shielding which is being manufactured.

4.7 Installation of Pneumatic Circuit

HIFAR supply of dry, oil free air, at a pressure of 700 kPa is suitable for the pneumatics. The pneumatic circuit is to be connected in accordance with the details as shown on the appropriate drawings (Drg No. A2E47858 and A1E47833). In general, all fixed lines are to be of copper, with flexible connections of high pressure nylon or equivalent material. Saddles are to be located so as to give adequate support to the lines.

To complete the pneumatic circuit, it is necessary to break into the Active Ventilation (extract) System for the pneumatic conveyor exhaust. Three air filters are to be installed in the pneumatic circuit to ensure particle free air. Details of this work are also shown on Drg No. A0E47688.

4.8 Electrical Installation

To complete the operation of the rig, it is necessary to provide electrical power at the required location, and to connect various items of equipment. Details of the connections to be made and the routing of cables are described in the installation schedule issued by the I & C Division.

The electronic connection between the BF_3 counters in the counting chamber, and the counting console, are to be made by Physics Division personnel. They will also arrange for the connection of the teletype machine to the counting console.

5. COMMISSIONING

Before commencing commissioning, it will be necessary to recheck the operation of the separate components both mechanically and electrically. Having determined that the various items are functioning properly, the commissioning of the rig will then be undertaken.

As the most important single item in the operation of the rig is the control console, most of the commissioning activities will revolve around the proper operation of this device. A separate manual, describing the mode of operation of the control console, "trouble shooting" and complete with all necessary wiring diagrams, prepared by the I & C Division, is to be used. For the purposes of checking out the operation of the equipment, cans with polythene billets to simulate the anticipated target weight were used.

6. HAZARDS ANALYSIS

During the design, many hazards have been considered so that the rig, when operational, may incorporate as many features as are needed for its safe operation. The major hazard involved in the operation of the rig is that of radiation. Calculations determining the amount of shielding are given in Appendix A and calculation showing the quantity of Argon 41 gas generated are given in Appendix C.

The hazards which have been considered, and the safeguards which have been applied, are tabulated in Appendix D.

7. REFERENCES

(1) Brown, G.K. and Rose, A. "Apparatus for the Analysis of Uranium in Ores by Delayed Neutron Detection" AAEC Internal Report RP/TN157.

(2) Cato, D.H. "The Mixing of Borated Paraffin for High Efficiency Neutron Shielding" AAEC Internal Report MP/TN17.

(3) Engineering Services Department - Instruction 75/7 "The Current Control, Planning and Manufacturing Procedure in the Manufacturing Section".

(4) Glasstone S., "Principles of Nuclear Reactor Engineering, 1960".

(5) Rockwell, T., "Reactor Shielding Design Manual, 1958".

8. ACKNOWLEDGEMENTS

The Project Engineer wishes to thank Building 42 Technicians and Drawing Office Team for the devoted efforts during the design, manufacturing and commissioning of this rig. The valuable contributions from Mr. A. Barker, Mr. L. King and I & C Division's Mr. P. Weir, during the Commissioning of this project are specially acknowledged.

Mr. T. Wall's cooperation, representing the Sponsor, is highly regarded.

HIFAR X193 URANIUM ANALYSIS RIG

MAIN ITEMS DRAWING LIST

A0E47991	Pneumatic piping route layout
A0E47688	X193 General Assembly
A2E47854	X193 Lifting Assembly
A1E47833	Pneumatic Valve arrangement
A0E50713	Counting Chamber Assembly
BE41910	Breech Mechanism Assembly
A0E47632	Spent Capsule Container Sub-Assembly
A0E47639	Piping detail from rig flange to reactor floor
A0E47536	In-pile Rig General Assembly
A2E47858	X193 Pneumatic Schematic Diagram
A0E50206	X193 Rig Head Shield Sub Assembly
A3E49600	X193 C40 Console Terminal Strip Connections
A3E49601	X193 Plant Interconnection Cabling

APPENDIX A

SHIELDING CALCULATIONS

Ref. (4), (5).

Basis for Calculations

Maximum mass of target	:	10 g
Measured γ dose rate on normal ore sample leaving reactor MOATA	:*	6 R/hour
Number of specimens irradiated per week	:	1000
Measured maximum γ dose rate on "rich" ore sample leaving MOATA	:*	60 R/hour
Average number of rich ore samples anticipated, per week	:	2
Maximum transit time between rig and counting chamber	:	3 s

* These are measured dose rates close to can surface, immediately after irradiation.

Shielding calculations have been made to determine the shielding required for the beam stop, and to determine personnel shielding required along the flight path of the irradiated cans, and at the spent capsule container.

1. BEAM STOP

From the Health Physics Survey Report on the beam strength emanating from the X164 collimator, the following information was derived.

Beam size at end of X164 collimator	:	ϕ 10mm
Length of flight tube	:	2016mm
Beam size at inner end of flight tube	:	ϕ 10mm
Neutron dose rate measured 1m from the reactor face	:	1,25 R/hour
Gamma dose rate measured 1m from the reactor face	:	55 R/hour
Beam size emanating from X193 rig	:	ϕ 86mm
Length of flight tube	:	2045mm
Beam size at inner end of flight tube	:	ϕ 33mm

The beam intensity expected with the X193 rig can be approximated using the measured values for the X164 rig (reference H.P. survey report 15/H/76/10) and applying factors due to the geometry difference. From the information obtained it can be shown that the beam intensity 1m from the reactor face for the X193 rig will be $(\frac{33}{10})^2$ times the measured values for the X164 rig, i.e., about 11 times.

Neutron Shielding

Incident neutron dose rate : 13,75 R/hour

Attenuation through 625mm of borated paraffin wax and 250mm of lead, is given by -

$$D = D_o e^{\frac{-Z}{\lambda}} \quad \text{where}$$

D = dose rate .... R/hour

Z = shield thickness.... m

λ = relaxation length ...m

λ (borated paraffin wax) = $9,2 \times 10^{-2}$m

λ (lead) = 9×10^{-2}m

$$D_1 = 13,75\ e^{\frac{62,5}{-9,2}} = 15,4 \text{ mR/hour}$$

$$D_2 = 15,4 \times 10^{-3}\ e^{\frac{25,0}{-9,0}} = 0,96 \text{ mR/hour}$$

Gamma Shielding

Incident gamma dose rate : 605 R/hour

Attenuation through 625mm of borated paraffin wax and 200mm of lead is given by

$$D = D_o e^{\frac{-Z}{\lambda}}$$

λ (borated paraffin) = 25×10^{-2}m

λ (lead) = $2,5 \times 10^{-2}$m

$$D_1 = 605\ e^{\frac{62,5}{-25,0}}$$

$$= 49,6 \text{ R/hour}$$

$$D_2 = 49,6\ e^{\frac{25,0}{-2,5}}$$

$$= \sim 2,2 \text{ mR/hour}$$

2. FLIGHT TUBE

2.1 Experimental Equipment Operator at "15 ft" Floor Level

2.1.1 Normal sample - no shielding

It will be assumed as a worst case that an operator can stand continuously adjacent to the flight tube. The distance from the flight tube to the operator being : 10^{-1} m (to feet), 1,0m (to gonads). The radius of the sample container is $1,5 \times 10^{-2}$m.

Measured dose rate on normal sample as it leaves reactor is 6 R/hour

Dose time is 1000 samples/week x 3(s) = 3×10^3 s

$$\text{Absorbed dose (feet) per week} = \frac{6}{3600} \times \left(\frac{1,5 \times 10^{-2}}{10^{-1}}\right)^2 \times 3 \times 10^3$$

$$= 112 \text{ mR}$$

$$\text{Absorbed dose (gonads) per week} = \frac{6}{3600} \times \left(\frac{1,5 \times 10^{-2}}{1}\right)^2 \times 3 \times 10^3$$

$$= 1,1 \text{ mR}$$

2.1.2 "Hot" Sample - No Shielding

Dose time in 2 samples/week x 3s = 6s

Measured dose on 5% U ore as it leaves the reactor ~ 60 R/hour

$$\text{Absorbed dose (feet) per week} = \frac{60}{3600} \times \left(\frac{1,5 \times 10^{-2}}{10^{-1}}\right)^2 \times 6$$

$$= 2,2 \text{ mR}$$

Absorbed dose (gonads) per week is << 1mR

With these calculations, it is shown that it would be possible to tolerate in excess of the two "hot" samples per week.

2.2 X193 Rig Operator at Console in HIFAR Basement

2.2.1 Normal sample - no shielding

The operator will be exposed to radiation due to the passage of the can whilst in flight and also during its 40s residence time in the counting chamber. It will be assumed that the operator stands 2m from the resident sample.

Dose time is 1000 samples/week x 40s = 4×10^4s

$$\text{Absorbed dose (gonads) per week} = \frac{6}{3600} \times \left(\frac{1,5 \times 10^{-2}}{2}\right)^2 \times 4 \times 10^4$$

$$= 3.7 \text{ mR}$$

Absorbed dose (gonads) due to flight of can is as previously calculated, hence total absorbed dose (gonads) is ~ 5 mR per week.

2.2.2 "Hot" sample - no shielding

On the basis of two "hot" cans per week, the total absorbed dose would be

$$\frac{60}{3600} \times \frac{(1,5 \times 10^{-2})}{2} \times 80 = << 1 \text{ mR}$$

Since dose time = 2 samples/week x 40s = 80 .

3. "STUCK" CAN

It will be assumed that a can would be stuck in the flight tube adjacent to an operator and that such a happening could occur once per week. From the decay characteristics of the ore sample (refer figure A1), it will be assumed that the contact dose rate is significant over a 15 minute period.

3.1 Experimental equipment operator at "15 ft" floor level

3.1.1 Normal sample - no shielding

Dose time is 15 minutes = 900s

$$\text{Absorbed dose (feet) per week} = \frac{6}{3600} \times \left(\frac{1,5\text{x}10^{-2}}{10^{-1}}\right)^2 \times 900$$

$$= 33.7 \text{ mR}$$

$$\text{Absorbed dose (gonads) per week} = \frac{6}{3600} \left(\frac{1,5\text{x}10^{-2}}{1}\right)^2 \times 900$$

$$= < 1 \text{ mR}$$

3.1.2 "Hot" sample - no shielding

Absorbed dose (feet) per week = 340 mR

Absorbed dose (gonads) per week = 3 mR

The absorbed dose for the rig operator in the HIFAR basement, would be less than these values.

4. STORAGE OF IRRADIATED SAMPLES

After the cans are processed, they are then stored in the spent capsule container, or the storage rack. The storage rack is used for low activity samples only.

4.1 Spent Capsule Container "Coffin"

Measured contact γ dose rate on a normal ore sample leaving the counting chamber : 4R/hour.

If the air space around the sample tubes is 10 cm then the dose rate at the inner surface of the shielded container is reduced (distance) by a factor of $\left(\frac{1.5}{10}\right)^2$

Samples are ejected into the spent capsule container once every minute, hence the total dose rate due to the load tubes being filled, is determined as follows:

Residence time (minutes) in shielded container	Dose rate at shield inner surface
0	89 mR/hour
1	66
2	36
3	28
4	23
5	16
6	11
7	8
8	6
9	5
10	4
11 to 40	1
TOTAL	292 mR/hour

It will be assumed that the effect of the other cans in tubes previously unloaded (a total of 5 unload tubes holding 200 cans) will raise the total dose rate inside the shield to 350 mR/hour.

The shielding of the Spent Capsule Container consists of a 50 mm lead brick wall at the front face, and a 10 mm thick steel cover. Assuming that an operator can stand continuously (the container would only be full for 4 hours) alongside the Spent Capsule Container, i.e. feet adjacent to the lead brick wall, then

Absorbed dose (feet) per week =

$$\frac{1000 \text{ samples}}{240 \text{ samples in container}} \times 4 \times 60 \times 60 \times \frac{0,350}{3600} \times e^{\frac{-5\times10^{-2}}{2,5\times10^{-2}}}$$

$$= 790 \text{ mR}$$

For an operator standing alongside the shielded container,

Absorbed dose (gonads) per week

=

$$\frac{1000}{240} \times 4 \times 60 \times 60 \times \frac{0{,}350}{3600} \times e^{\frac{-5 \times 10^{-2}}{3{,}7 \times 10^{-2}}} \times \left(\frac{10^{-1}}{1}\right)^2$$

$$= \sim 8 \text{ mR}$$

4.2 Storage Rack

As the Spent Capsule Container will hold six load tubes, three full load tubes (i.e. 120 cans) will be required to be held in the storage rack. Assume that the dose rate from the 120 cans is equal to 120 mR/hour. For the physical layout of the storage rack i.e. distance from load tube centre to shield material of 9 cm and thickness of steel plate 6 mm, the absorbed dose received by an operator located adjacent to the shield (the storage rack would only be required for 3 hours) would be

$$\frac{0.120}{3600} \times \left(\frac{1{,}5\times10^{-2}}{9\times10^{-2}}\right)^2 \times e^{-\frac{6\times10^{-3}}{3{,}7\times10^{-2}}} \times \frac{1000}{(120 + 240)} \times 3 \times 60 \times 60$$

$$= 24 \text{ mR.}$$

5. EXPECTED RADIATION LEVELS FROM STUCK CAN IN THE IN-PILE RIG

Main elements in an irradiated ore sample contributing to radiation are Al^{28} and Mn^{56}.

Estimated percentage weight of each element in an ore sample = 0.2%

For 10 gm sample, mass of Al^{28} = mass of Mn^{56} = 0.02 gm.

For Al^{28}: $T_{½}$ = 2.24 min, σ = 0.23B, A = 27 gm/mole

For Mn^{56}: $T_{½}$ = 2.582 hr, σ = 13B, A = 55 gm/mole

Assume sample is subject to flux $\leq 10^9$ n Cm^{-2} Sec^{-1} (outer end of the adjustment tube) for 10 minutes.

(i) In the case of Al^{28} when decay during irradiation cannot be neglected.

$$\therefore \frac{\lambda N}{3.7 \times 10^{10}} = C_i = 0.6 \frac{G}{A} \sigma \phi \ (1 - e^{-\lambda t})$$

$$\lambda = \frac{0.693}{2.24 \times 60} = 0.00516 \ Sec^{-1}$$

$$\therefore \frac{\lambda N}{3.7 \times 10^{10}} = \frac{0.6 \times 0.02 \times 0.23 \times 10^9}{27 \times 3.7 \times 10^{10}} \ (1 - e^{-0.00516 \times 10 \times 60})$$

$$= 2.64 \times 10^{-6} \ C_i$$

R/hr at 10 cm = 6 C_i x E   E in MeV

$= 6 \times 2.64 \times 10^{-6} \times 1.78$

$= 2.82 \times 10^{-5}$

(ii) For Mn^{56} where $T_{½}$ > the irradiation time,

$$\frac{\lambda N}{3.7 \times 10^{10}} = C_i = 0.6 \frac{G\sigma \ \phi \ t\lambda}{A \times 3.7 \times 10^{10}}$$

$$\lambda = \frac{0.693}{2.582 \times 3600} = 7.455 \times 10^{-5} \ Sec^{-1}$$

$$\frac{\lambda N}{3.7 \times 10^{10}} = \frac{0.6 \times 0.02 \times 13 \times 10^9 \times 10 \times 60 \times 7.455 \times 10^{-5}}{55 \times 3.7 \times 10^{10}}$$

$$= 3.43 \times 10^{-6} \ C_i$$

R/hr at 10 cm = 6 C_i x E

$= 6 \times 3.43 \times 10^{-6} \times 0.84$

$= 17.28 \times 10^{-6}$

Total R/hr at 10 cm from Al^{28} and Mn^{56} = 4.55×10^{-5} C_i/hr

(iii) Radiation from U present in Ore

a) Consider a sample of 1%U in Ore

$\therefore$ For 10 gm ore sample, weight of U = 0.1 gm

* But for pure uranium metal, 2 mg of natural U produces 250 mR/hr at contact of outer capsule container after one minute irradiation in flux of 1.2×10^{12} n cm^{-2} Sec^{-1} and a decay of one minute.

$\therefore$ Dose from U alone in a sample $= 10 \times \frac{1}{100} \times \frac{1}{2 \times 10^{-3}} \times 250$

$= 12.5$ R/hr

In the case of a sample which is subjected to flux $<10^9$ n Cm^{-2} Sec^{-1} (at outer end of the adjustment tube) for 10 minutes, it will be assumed that U activation is linear with flux and non lined with time. For the latter relationship, the activity produced after ten minutes will be assumed to be five times the value produced after one minute.

$\therefore$ Dose from U alone in a sample irradiated for ten minutes in $\phi \leq 10^9$ n Cm^{-2} Sec^{-1}

$$= 12.5 \times \frac{10^9}{10^{12}} \times 5 = 62.5 \text{ mR/hr.}$$

b) Consider a sample of 5%U in Ore

$\therefore$ For 10 gm ore sample, weight of U = 0.05 gm

Following the above procedure we get -

Dose from U alone in a sample = 312.5 mR/hr.

Hence total radiation expected from 10 gm ore sample with 0.2% $A\ell^{28}$, 0.2% Mn^{56} and 1%U when subjected to $\phi 10^9$ n Cm^{-2} Sec^{-1} for ten minutes is 62.5 mR/hr. If U percentage in the ore is 5% with the same conditions, total radiation expected is 312.5 mR/hr.

* (Ref: Private communications with T. Wall)

APPENDIX B

REQUEST FOR MINOR IRRADIATION

X193 URANIUM ANALYSIS RIG

Number of load tubes accompanying this request _____

Maximum anticipated uranium content of ore samples ___%

LOAD TUBE REFERENCE	A	B	C	D	E	F
Quantity of cans in load tube						
Identification numbers of cans in load tube						
Quantity of test cans in load tube						
Identification numbers of test cans in load tube						
Quantity of blank cans in load tube						
Identification numbers of blank cans in load tube						

Date: ________________ Packed by: ____________________

Date desptached: ____________________ E.R.P.S.

For H.O.S. Use Only

Date of Irradiation: ______________________

Operator: ___________________________________

Rig adjustment tube setting: ______________

Date returned to Experimental Reactor Physics Section: _________________

H.O.S. Form

APPENDIX C

Argon 41 Gas Release

Argon 41 gas is generated by the neutron activation of Argon 40 gas contained in the conveying air inside the rig. The conveying air is introduced to the rig at the rate of $7 \times 10^{-3}\ m^3\ s^{-1}$ for one second, the air space in the rig remains static for 60 s then the conveying air is re-introduced at the rate of $7 \times 10^{-3}\ m^3\ s^{-1}$ for one second to discharge the can.

Assuming the irradiation of 1000 samples per week i.e. 200 per day, the irradiation of air in the rig is as follows:-

$2(7 \times 10^{-3}\ m^3)$ irradiated for 1 s, 200 times/day.
Volume of rig irradiated for 60s. 200 times/day.
Volume of rig irradiated for 24 x 60 x 60 - 200(61)s

$$= 7{,}4 \times 10^4\ s$$

<u>Data:</u>

Volume of argon gas in air	: 0,94%
Density of argon gas ($20^\circ C$)	: 1,66 kg m^{-3}
Thermal Activation Cross section of argon gas (σ)	: $0.53 \times 10^{-28}\ m^2$
Half life of Argon 41 ($T_{1/2}$)	: $6{,}54 \times 10^3$ s
Avogadro's number N	: 6.02×10^{23} atoms/mole
Atomic mass number of Argon 41 (M)	: 41 g/mole
Temperature of air being irradiated	: 313K ($40^\circ C$)
λ = decay constant of Argon 41	

$$= \frac{0.693}{T_{1/2}}$$

$$= \frac{0.693}{6.54 \times 10^3} = 1.06 \times 10^{-4}\ s^{-1}$$

(a) Consider the irradiation of the volume of air in the rig for the period 7.4×10^4 s; as this period $> 10\ T_{1/2}$ then the activation of the argon gas is given by

$$A_s = \frac{6{,}02 \times 10^{23}}{M \times 10^{-3}}\ G\ \phi\ \sigma$$

G = mass of Argon 40 gas irradiated

$$= \frac{0{,}94}{100} \times 1{,}66 \times \frac{293}{313} \times \text{volume of rig } (m^3)$$

As the thermal flux varies along the length of the air passages, known increment of volume will be considered and the appropriate flux used to determine the Activity from

$$A = \frac{6{,}02 \times 10^{23}}{41 \times 10^{-3}} \times 0{,}94 \times 10^{-2} \times 1{,}66 \times \frac{293}{313} \times 0{,}53 \times 10^{-28} \int \phi' \, d\,V$$

$$= 1{,}14 \times 10^{-5} \int \phi \, d\,V$$

From the graph (figure 1) and the physical dimension of the rig, the following table is derived.

INCREMENTAL DISTANCE FROM RIG END (m)	INCREMENTAL VOLUME (dV) (m^3)	AVERAGE FLUX (ϕ) (NEUTRONS/m^2/s)	ϕ d V
$2,2x10^{-2}$	$2,2x10^{-5}$	$3,0x10^{16}$	$6,6x10^{11}$
$5,0x10^{-2}$	$6,3x10^{-6}$	$1,0x10^{16}$	$6,3x10^{10}$
$1,0x10^{-2}$	$9,2x10^{-6}$	$4,1x10^{15}$	$3,8x10^{10}$
$1,0x10^{-2}$	$9,2x10^{-6}$	$3,1x10^{15}$	$2,8x10^{10}$
		$2,2x10^{15}$	$2,0x10^{10}$
Constant	Constant	$1,5x10^{15}$	$1,4x10^{10}$
		$1,0x10^{15}$	$9,2x10^{9}$
at	at	$7,6x10^{14}$	$7.0x10^{9}$
		$5,5x10^{14}$	$6,0x10^{9}$
$1,0x10^{-2}$	$9,2x10^{-6}$	$4,2x10^{14}$	$3,9x10^{9}$
		$3,2x10^{14}$	$3,0x10^{9}$
		$2,5x10^{14}$	$2,3x10^{9}$
		$1,9x10^{14}$	$1,8x10^{9}$
		$1,4x10^{14}$	$1,3x10^{9}$
		$1,2x10^{14}$	$1,1x10^{9}$
		$9,5x10^{13}$	-
		$7,5x10^{13}$	-
		$6,0x10^{13}$	-
		$4,8x10^{13}$	-
		$3,9x10^{13}$	-
		$3,1x10^{13}$	-
TOTAL DISTANCE $26,2x10^{-2}$ m	TOTAL VOLUME OF RIG $20,3x10^{-5}$ m^3		$\sum 8,6x10^{11}$

Total saturation activity $A_s = 9,8 \times 10^6$ Bq

(b) Consider the irradiation of volumes of air, for short periods of time; the activation of the argon gas is given by

$$A = \frac{6,02 \times 10^{23}}{M \times 10^{-3}} G \phi \sigma (1 - e^{-\lambda t})$$

where t = irradiation time (s).

Hence for a known residence time in the rig, the activation of the rig air volume can be calculated as a proportion of the saturation activity (A_s).

(i) Consider 200 samples per day being irradiated

Rig volume = $2,03 \times 10^{-4}$ m^3

Air flow = 7×10^{-3} m^3 s^{-1}

Residence time (t) = 0,03 s

The percentage saturation is $\ll$ 1%, and although occurring 200 times per day, the activity is still $<$ 1% A_s.

(ii) Consider the rig volume which is irradiated for 60 s, 200 times per day

$$(1 - e^{-\lambda t}) = 0,00634$$

$A = 200 (0,00634) A_s$

$= 12,4$ MBq

(iii) Consider the rig with the air volume changing continuously, from an assumed residence time, the activity can be calculated, and the number of volume changes determined. This information can be shown graphically (refer figure C1). From the graph, within realistic times for a volume change, it can be seen that a maximum value of activity of $\sim$90 MBq per day, is reached.

Hence the total maximum activity of Argon 41 gas which could be produced with this rig, is 102 MBq ($2,76 \times 10^{-3}$ Ci) every day.

APPENDIX D

Hazard Analysis

The hazards considered during the design of this rig, fall into two categories viz radiation, and others. Radiation is by far the greatest hazard as, unlike a conventional horizontal facility collimator, the beam which is used for the irradiation process cannot be sealed within the confines of the reactor by means of a shield plug. In addition, there are problems associated with the pneumatic conveying of active samples which have required attention.

The following is a summary of hazards which have been examined, and the safeguards which are to be applied for both the installation and operation of the rig X193.

A. INSTALLATION

HAZARD	SAFE GUARD
(1) Unloading of the existing collimator in 6HGR8	(a) It has been demonstrated previously that the collimator X164/1 can be moved. (b) The unloading will be undertaken during a shut-down of HIFAR when a partial core unload will assist to reduce radiation levels. (c) The actual removal of the collimator will be undertaken, after normal working hours, by the HIFAR Active Handling Section. (d) Personnel involved have had previous experience in this work and Health Physics Surveyors will be available at all stages of the removal. (e) Equipment to carry out the unloading is available.
(2) Loading rig X193	(a) Existing equipment (counterweight bar) with an adaptor plate is to be used. (b) A temporary plug (Drg No. A3E47841) is used to reduce radiation levels during handling of the rig. (c) The loading of the rig into the facility is undertaken by the HIFAR Active Handling Section, outside of normal working hours. (d) Health Physics Surveyors will be present during the installation work. (e) Temporary lead block shielding will be used until the final shield has been placed into position.

(3) Installation of shielding at rig	(a) Until the pneumatic conveying pipework has been run and fitted into position, it is not possible to install the permanent shielding at the rig. Workshops personnel assembling the pipework will need to limit the time that their hands remain in the γ beam, in accordance with the instructions issued by the Health Physics Surveyor.

B. <u>OPERATION</u> (Note: Absorbed dose and absorbed dose rates are given in S.I. units with the value of dose equivalent shown in brackets immediately following the S.I. units.

HAZARD	SAFE GUARD
(1) Radiation at "in-pile" rig head	(a) The shielding as designed will give adequate personnel protection from all forms of radiation. (b) It is possible that some small leak paths may occur allowing neutrons to affect sensitive equipment located nearby. Blocks of neutron absorbing material (borated paraffin wax) encased in aluminium sheeting are provided to eliminate this problem during commissioning of the rig.
(2) Transient radiation	(a) The effect of "stray" neutrons during the transfer of an irradiated sample along the pneumatic conveyor tube, is minimised by:- (i) choice of the route of the conveyor tubing by taking advantage of existing shielding, and taking the shortest path to the shielded counting and storage areas, and (ii) provision of adequate shielding along the conveyor at the experimental equipment level. (b) Gamma radiation effects on personnel are reduced by means of shielding (distance or remote location of the conveyor tube from personnel) and limitation of the total time of exposure. The maximum absorbed dose calculated for personnel permanently located adjacent to the conveyor tube is within acceptable limits (refer Appendix A)
(3) Radiation at operator's position in basement	(a) Neutron shielding is adequate

	(b) Gamma radiation shielding is achieved by distance effect (mainly) with some slight effect due to shield material. The maximum γ radiation dose calculated for an operator permanently located at the control console is: 50 µGy (5 millirem) per week (refer Appendix A)
(4) Radiation at the shielded storage container	(a) Neutron effects are negligable due to the delay period of the irradiated sample in the counting chamber. (b) Gamma shielding is provided by shield material (lead bricks and steel plate). The maximum calculated radiation dose received by a person permanently located adjacent to the shielded container is within acceptable limits (refer Appendix A). (c) During unloading of the specimen tubes an operator will be exposed to radiatiation. The effect is minimised by: (i) Installed detector will monitor radiation level before operator handles unload tube. No handling will take place unless preset audio visual alarms of the detector are off. (ii) Providing a quick release mechanism for holding the load/unload tubes so that contact time is kept to a minimum.
(5) Radiation at the storage rack	Radiation levels are low and shielding is provided by means of a sliding shield panel. A person permanently located adjacent to the storage rack would receive and absorbed dose of 236 µGy (24 millirem) in one week (whole body dose).
(6) Radiation due to a "stuck" can	(a) On the basis that the "stuck" can is one whose uranium content of the ore sample is high, the absorbed dose received by an operator who was unaware that this situation had occurred, would be 3,4 m Gy (340 millirem) to the feet and 34 µGy (3 millirems) to the gonads (refer Appendix A). (b) With the radiation values occurring for such a "stuck" can, the HIFAR gamma monitors would detect this additional radiation and set off alarms if the "stuck" can was in an un-shielded location. (c) The event of a "stuck" can in the conveying system, however, may be considered highly unlikely since the testing and commissioning of this rig will ensure a free and easy passage of can through such system. In the meantime, the procedure outlined in item (9) below deals with possible cause of this problem.

(7) Incorrect selection of irradiation position, giving rise to high radiation level on sample	This hazard can occur with ore samples from a new area thus nullifying the experience which an operator would have in determining the irradiation position. A high radiation level would be obvious when the teleprinter records the delayed neutron counter. Possibly two samples would be "hot" before corrective action would take place. The corrective action would be to stop the process and re-set the adjustment tube, allowing the "hot" samples to decay in the spent capsule container. The "hot" samples would be re-irradiated after a suitable time interval.
(8) Contamination arising from the disintegration of a can and inner container	The outer can has been designed with tight tolerances as each can will be irradiated once only. Due to the tight tolerances it is highly unlikely that the outer can two halves could come aprart allowing the exposure of the inner heat sealed container holding the ore sample and causing possible spillage. However, the following precautionary measures are considered to prevent the spread of any possible contamination. (i) lining the spent capsule container with white plastic sheeting, (ii) checking load/unload tubes for contamination before removal from the spent capsule container, (iii) "bagging" the load/unload tubes before despatch, and (iv) protective clothing if needed will be recommended by Safety Section. (v) Providing shielded air line filter between the spent capsule container and the active extract svstem.

(9) "Stuck" Capsule

(a) During assembly of all components, an oversize capsule will be used to check that there is no possible area for a can to stick in either the conveying line or items of equipment,

(b) during testing and commissioning, the same oversize capsule will be used to ensure a free passage in all parts of the conveying system,

(c) all capsules used will be required to pass a standard can test gauge before their acceptance in the rig,

(d) all capsules will be inspected prior to packing to ensure that damaged capsules, or ill fitted capsule halves will not be used.

(e) a gamma monitor will be located so that warning of a 'stuck' can in the conveying tube will be given.

(f) If the above procedure is followed, it is highly unlikely for a capsule to stick in the adjustment tube of the in-pile rig. However, in such an event, the following actions are to be followed -

(1) If a capsule is not ejected after the nominated irradiation time of one minute, observe the time T (say 10.35.am.).

(2) Immediately switch on power to the Adjustment Tube Motor Control Unit (Switch is located on the left hand side of this unit which is located at Console 41). Press the button "Drive OUT" on this unit until the adjustment tube which contains the stuck can is driven to its maximum outer position. This ensures that the capsule will be subjected to minimum flux level ($\leq 10^9$ n cm^{-2} Sec^{-1}).

(3) Increase the air pressure via the pressure regulator located at the back of Console 40, in steps of 5 psi.

(4) Press button EJECT on Console 40.

(5) Repeat steps (2) and (3) above until the capsule is ejected from the in-pile rig to the counting chamber.

(6) If the capsule is not ejected after applying a MAXIMUM of 50 psi and within 10 MINUTES from the observed time T (i.e., at 10.45.am. in this example) shut down the rig with the adjustment tube still at its maximum outer position.

(7) Following (5) above, if the capsule is ejected it will be sent to the counting chamber. Shut down the rig for a minimum of twelve hours to allow the capsule activity to decay in the highly shielded counting chamber.

D4 (Continued)

(8) Following (6) above, during the following HIFAR shutdown period, dismantle the shield of the rig face, gear motor, pneumatic tube, etc., to remove the adjustment tube. Place the flange insert in position to reduce radiation hazards. Health Physics should monitor radiation levels at the rig face at all stages to make sure that these levels are acceptable. The Active Handling Group may then transfer the adjustment tube to the hot cells for stuck capsule removal.

(10) Leakage of reactor graphite blanket gas (helium)	(a) series of "O" rings and a gasket, are placed between the plug, head and reactor face to eliminate leakage of the reactor graphite blanket gas, (b) the seal welds on the plug are pressure tested with helium gas during assembly
(11) High temperature of the aluminium thimble	Three thermocouples are located on the inner wall of the sheath to record temperatures which may be monitored and recorded by DAS
(12) High temperature of the cans being irradiated	(a) The temperature at the inner end of the adjustment tube is monitored by two thermocouples, (b) helium purge gas, supplied to the sheath end of the plug, could be used for cooling if necessary, (c) calculated temperature rise of the ore sample is only ~$9^{o}C$ (refer Appendix H).
(13) Electrical malfunction or loss of electrical power during the irradiation of a sample	(a) The electrical supply to the control console is taken from the rig supply source, (b) the solenoid valves used to perform the pneumatic system operations, are provided with manual over-ride push buttons, thus enabling the pneumatic circuit to be operated manually, on loss of power.
(14) Loss of compressed air	The compressed air used, is from a HIFAR source. Emergency air bottle will be available to supply enough compressed air to clear the last capsule from the in-pile rig.
(15) Failure of an air valve in the pneumatic circuit	(a) The air valves use a dry, oil free air, (b) the valves are inter-changeable, (c) a spare valve is included in the "spare parts" supply with the rig.

APPENDIX E

NUCLEAR HEATING

(a) Data

Mass of ore samples (m)	: 10^{-2} kg
Maximum uranium content of ore	: 5%
Irradiation time (t)	: 60 s
Gamma dose rate (D)	: $3{,}3 \times 10^{-1}$ Gy s^{-1}
Thermal neutron flux (max) (Φ)	: 2×10^{16} neutron $m^{-2}s^{-1}$
Gamma heating factor (averaged for elements in ore sample) (f)	: 0,86

(b) Gamma heat rate

$$Q = mDf$$

$$= 10^{-2} \times 3{,}3 \times 10^{-1} \times 0{,}86 = 2{,}88 \times 10^{-3} \text{ W}$$

(c) Fission heat rate

Mass of fission material (U^{235}) in ore sample (m_f) is

$$m_f = \frac{5}{100} \times \frac{0{,}72}{100} \text{ (m)}$$

$$= 3{,}6 \times 10^{-6} \text{ kg}$$

Fission rate is given by

$$r = \sigma \frac{N}{M} \Phi m_f \quad \text{fission/second}$$

where σ = fission cross section

$$= 5{,}75 \times 10^{-26} \text{ m}^2$$

N = Avogadro's number

$$= 6{,}03 \times 10^{23} \text{ atoms/mole}$$

M = Atomic mass number

$$= 235 \text{ g/mole}$$

$$\therefore r = 5{,}75 \times 10^{-26} \times \frac{6{,}03 \times 10^{23}}{235 \times 10^{-3} \text{ (kg)}} \times 2 \times 10^{16} \times 3{,}6 \times 10^{-6}$$

$$= 1{,}06 \times 10^{10} \text{ s}^{-1}$$

Total energy release per fission of U^{235} is 199 MeV

Hence Fission heat rate $= 1,06 \times 10^{10} \times (199 \times 10^{6}) \times 1,602 \times 10^{-19}\ J\ s^{-1}$

$= 3,39 \times 10^{-1}\ W$

(d) Total heat rate $= 2,88 \times 10^{-3} + 3,39 \times 10^{-1}\ W$

$= 3,42 \times 10^{-1}\ W$

(e) Total heat generated during irradiation period (60 s)

$$Q = 3,42 \times 10^{-1} \times 60$$

$$= 20,5\ J$$

(f) Temperature rise of sample (Δt)

$$\Delta t = \frac{Q}{m\ C_p}$$

Where C_p = specified heat of ore sample

Assume that the value of C_p for UO_2 will apply in this case, i.e.

$$C_p = 0,24\,kJ\ kg^{-1}\ k^{-1}$$

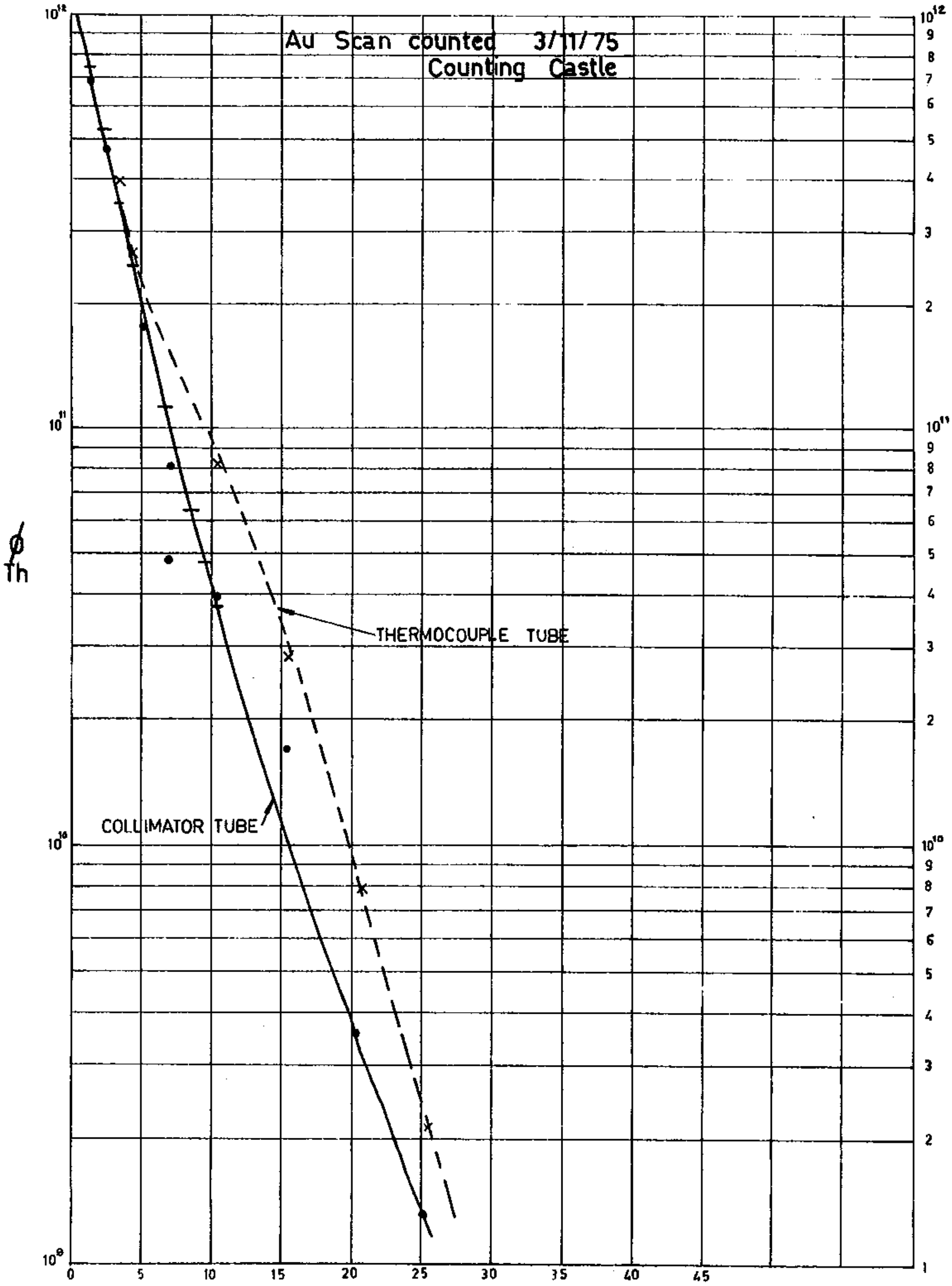
$$\text{Hence } \Delta t = \frac{20,5 \times 10^{-3}}{10 \times 10^{-3} \times 0,24}$$

$$= 9k = 9^{o}C$$

URANIUM ANALYSIS RIG X193

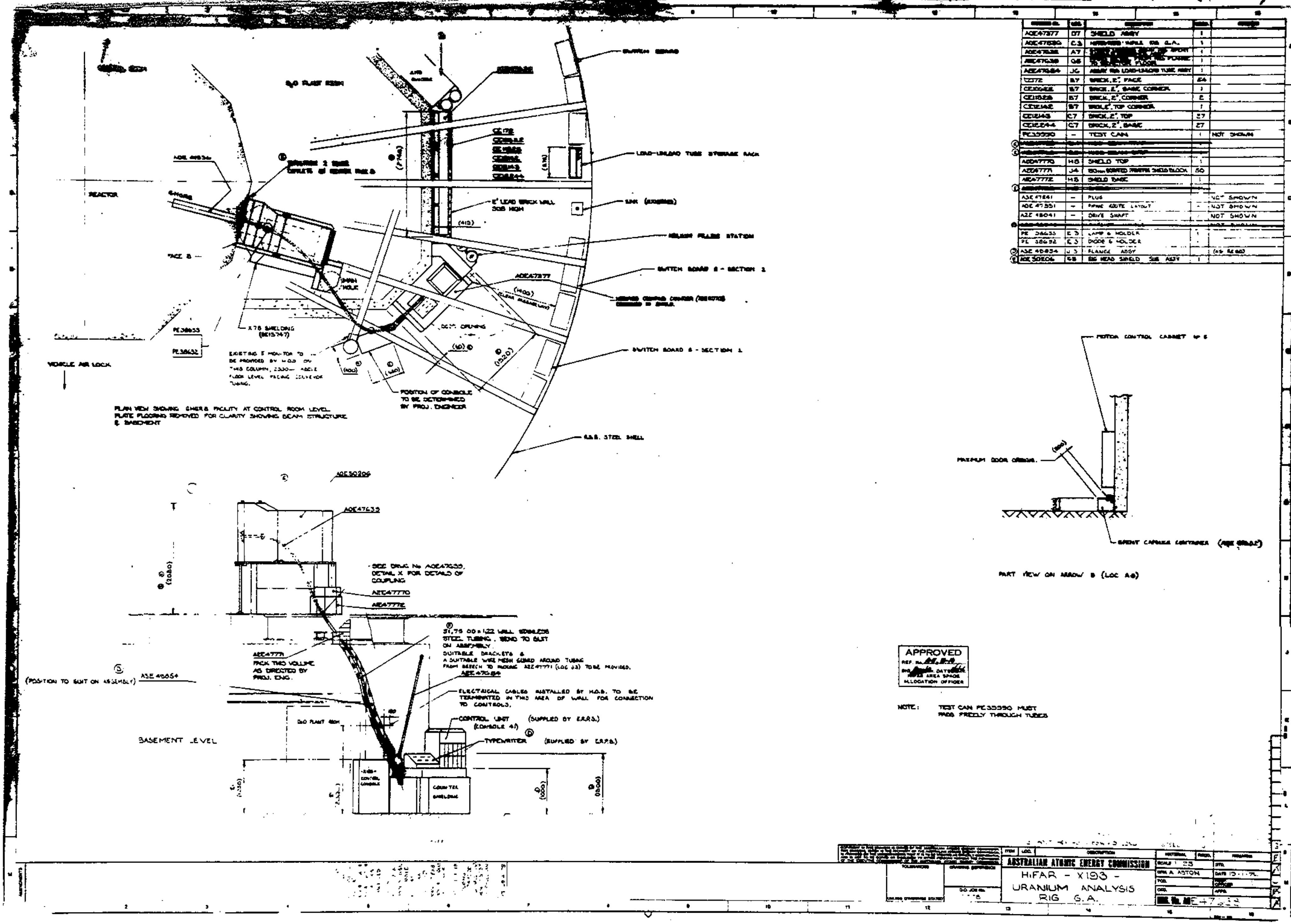
DESIGN MANUAL

Figures List



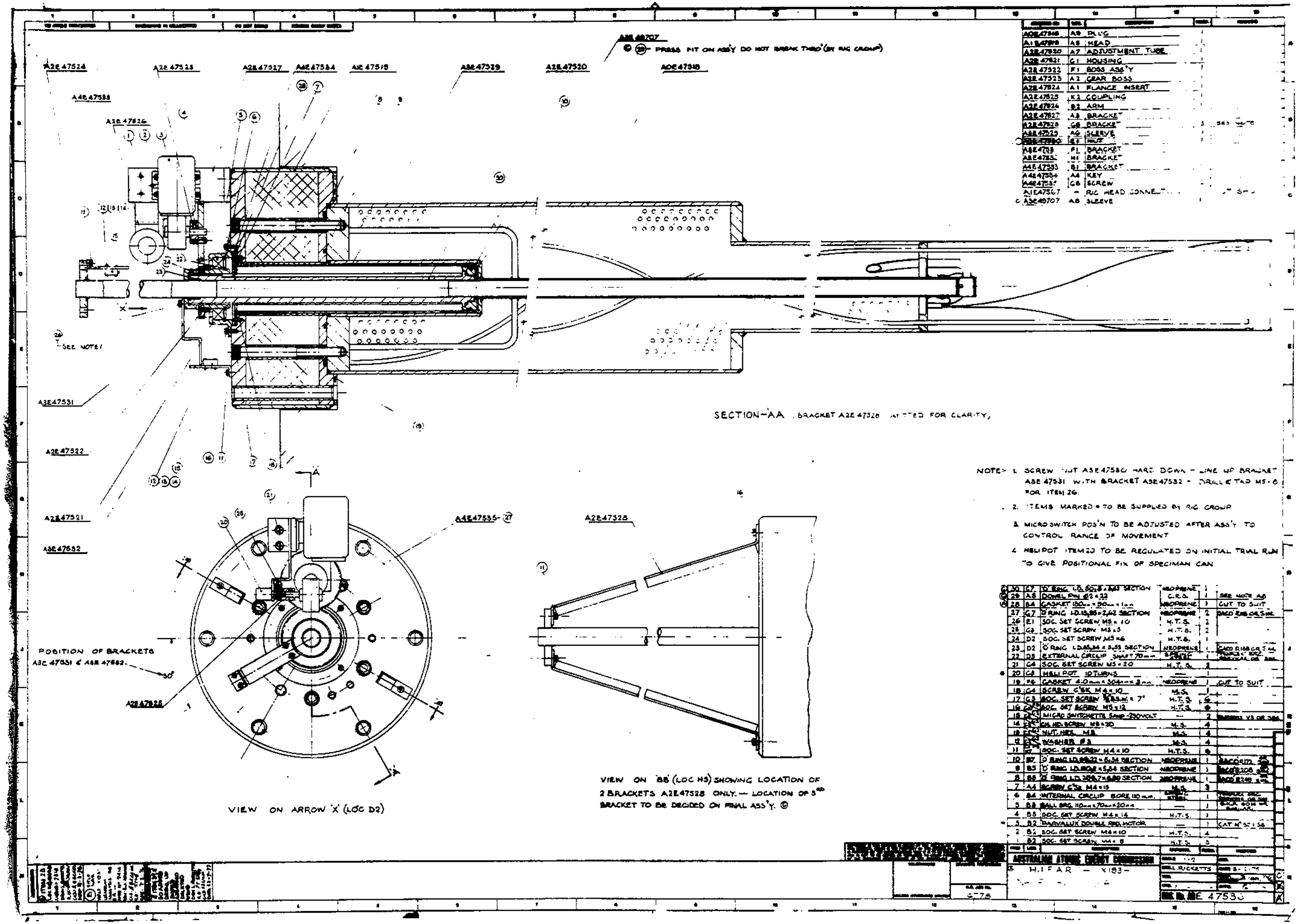
Au Scan counted 3/11/75
Counting Castle
THERMOCOUPLE TUBE
COLLIMATOR TUBE
ϕ_{Th}
CENTIMETRE

FIG. 1.



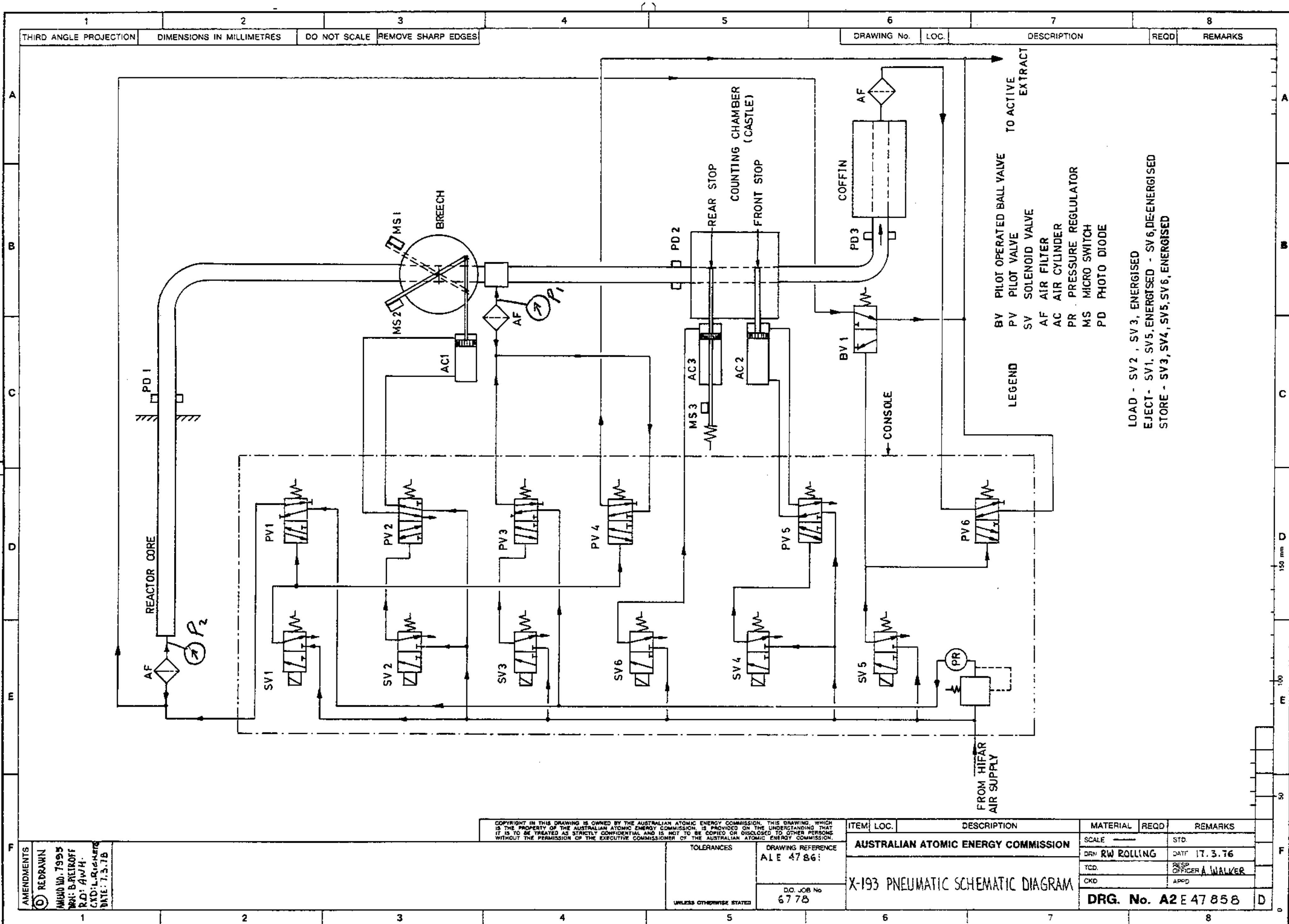
AUSTRALIAN ATOMIC ENERGY COMMISSION
HIFAR - X193 -
URANIUM ANALYSIS
RIG G.A.
SCALE 1:25
DRN. A. ASTON
APPROVED
NOTE: TEST CAN PE35590 MUST PASS FREELY THROUGH TUBES
PART VIEW ON ARROW B (LOC A6)
MAXIMUM DOOR OPENING
SPENT CAPSULE CONTAINER
MOTOR CONTROL CABINET
PLAN VIEW SHOWING SHIELD FACILITY AT CONTROL ROOM LEVEL.
PLATE FLOORING REMOVED FOR CLARITY SHOWING BEAM STRUCTURE & BASEMENT
REACTOR
VEHICLE AIR LOCK
LOAD-UNLOAD TUBE STORAGE RACK
SINK
HELIUM FILLING STATION
SWITCH BOARD 5 - SECTION 1
SWITCH BOARD 5 - SECTION 2
S.S.S. STEEL SHELL
X78 SHIELDING
POSITION OF CONSOLE TO BE DETERMINED BY PROJ. ENGINEER
2" LEAD BRICK WALL 508 HIGH
BASEMENT LEVEL
CONTROL UNIT (CONSOLE 4) (SUPPLIED BY E.A.R.S.)
TYPEWRITER (SUPPLIED BY E.A.R.S.)
ELECTRICAL CABLES INSTALLED BY H.O.S. TO BE TERMINATED IN THIS AREA OF WALL FOR CONNECTION TO CONTROLS.
31.75 OD x 1.22 WALL SEAMLESS STEEL TUBING, BEND TO SUIT ON ASSEMBLY.
SUITABLE BRACKETS & A SUITABLE WIRE MESH GUARD AROUND TUBING
SEE DRG. No ADE47633, DETAIL X FOR DETAILS OF COUPLING
PACK TWO VOLUME AS DIRECTED BY PROJ. ENG.
(POSITION TO SUIT ON ASSEMBLY) ASE 45854
ADE47377 D7 SHIELD ASSY 1
CE772 B7 BRICK, 2" FACE 54
PE35590 TEST CAN 1 NOT SHOWN
ADE47770 H6 SHIELD TOP 1
ADE47772 H5 SHIELD BASE 1
ASE 47841 PLUG NOT SHOWN
ASE 47551 PIPING ROUTE LAYOUT NOT SHOWN
ASE 48041 DRIVE SHAFT NOT SHOWN
PE 38633 E3 LAMP & HOLDER
PE 38632 E3 DIODE & HOLDER
ASE 45854 J3 FLANGE ASSY
ADE 50206 G8 BIG HEAD SHIELD SUB ASSY 1

Fig 2



PRESS FIT ON ASS'Y DO NOT BREAK THRO' (BY RIG GROUP)
A2E 47524
A2E 47523
A2E 47527
A4E 47534
A3E 47519
A3E 47529
A2E 47520
A0E 47518
A4E 47533
A2E 47526
SEE NOTE 1
A3E 47531
A2E 47522
A2E 47521
A3E 47532
SECTION-AA. BRACKET A2E 47528 OMITTED FOR CLARITY.
NOTE:- 1. SCREW NUT A3E 47530 HARD DOWN - LINE UP BRACKET A3E 47531 WITH BRACKET A3E 47532 - DRILL & TAP M5x6 FOR ITEM 26.
2. ITEMS MARKED * TO BE SUPPLIED BY RIG GROUP
3. MICROSWITCH POS'N TO BE ADJUSTED AFTER ASS'Y TO CONTROL RANGE OF MOVEMENT
4. HELIPOT ITEM 20 TO BE REGULATED ON INITIAL TRIAL RUN TO GIVE POSITIONAL FIX OF SPECIMAN CAN
A4E 47535
A2E 47528
POSITION OF BRACKETS A3E 47531 & A3E 47532
30°
A2E 47525
VIEW ON ARROW 'X' (LOC D2)
VIEW ON 'BB' (LOC H5) SHOWING LOCATION OF 2 BRACKETS A2E 47528 ONLY. — LOCATION OF 3RD BRACKET TO BE DECIDED ON FINAL ASS'Y.
A9 PLUG
A5 HEAD
A7 ADJUSTMENT TUBE
G1 HOUSING
F1 BOSS ASS'Y
A2 GEAR BOSS
A1 FLANGE INSERT
K2 COUPLING
B2 ARM
A3 BRACKET
G8 BRACKET
A6 SLEEVE
F1 BRACKET
H1 BRACKET
B1 BRACKET
A4 KEY
G6 SCREW
RIG HEAD CONNECT...
A8 SLEEVE
30 C7 'O' RING I.D. 50.8 x 3.53 SECTION NEOPRENE 1 SEE NOTE A8
29 A8 DOWEL PIN Ø3 x 22 C.R.S. 1
28 B4 GASKET 130mm x 50mm x 1mm NEOPRENE 1 CUT TO SUIT
27 G7 'O' RING I.D. 15.85 x 2.62 SECTION NEOPRENE 2
26 E1 SOC. SET SCREW M5 x 10 H.T.S. 2
25 G2 SOC. SET SCREW M3 x 5 H.T.S. 2
24 D2 SOC. SET SCREW M3 x 6 H.T.S.
23 D2 'O' RING I.D. 85.34 x 3.53 SECTION NEOPRENE
22 D3 EXTERNAL CIRCLIP SHAFT 70mm
21 C4 SOC. SET SCREW M5 x 20 H.T.S. 2
20 C8 HELIPOT 10 TURNS
19 F6 GASKET 4.0mm x 304mm x 3mm NEOPRENE 1 CUT TO SUIT
18 C4 SCREW C'SK M4 x 10 M.S.
17 G3 SOC. SET SCREW H.T.S. 6
16 SOC. SET SCREW M5 x 12 H.T.S. 6
15 MICRO SWITCHETTE 5amp 250VOLT 2
14 CH. HD. SCREW M3 x 20 M.S. 4
13 NUT, HEX. M3 M.S. 4
12 WASHER Ø3 M.S. 4
11 SOC. SET SCREW M4 x 10 H.T.S. 6
10 B7 'O' RING SECTION NEOPRENE 1
9 B5 'O' RING SECTION NEOPRENE 1
8 B8 'O' RING SECTION NEOPRENE 1
7 A4 SCREW C'SK M4 x 15 M.S. 3
6 B4 INTERNAL CIRCLIP BORE 110mm
5 B3 BALL BRG. 110mm x 70mm x 20mm 1
4 B3 SOC. SET SCREW M4 x 14 H.T.S. 1
3 B2 PARVALUX DOUBLE RED. MOTOR 1 CAT Nº
2 B1 SOC. SET SCREW M4 x 10 H.T.S. 4
1 B2 SOC. SET SCREW M4 x 8 H.T.S. 3
AUSTRALIAN ATOMIC ENERGY COMMISSION
HIFAR - X193 -
RICKETTS
E 47530

Fig 3


THIRD ANGLE PROJECTION
DIMENSIONS IN MILLIMETRES
DO NOT SCALE
REMOVE SHARP EDGES
DRAWING No.
LOC.
DESCRIPTION
REQD
REMARKS
TO ACTIVE EXTRACT
AF
COFFIN
PD 3
COUNTING CHAMBER (CASTLE)
REAR STOP
FRONT STOP
PD 2
BREECH
MS 1
MS 2
AC 1
AC 2
AC 3
MS 3
BV 1
CONSOLE
PD 1
REACTOR CORE
P_1
P_2
PV 1
PV 2
PV 3
PV 4
PV 5
PV 6
SV 1
SV 2
SV 3
SV 6
SV 4
SV 5
PR
FROM HIFAR AIR SUPPLY
LEGEND
BV PILOT OPERATED BALL VALVE
PV PILOT VALVE
SV SOLENOID VALVE
AF AIR FILTER
AC AIR CYLINDER
PR PRESSURE REGULATOR
MS MICRO SWITCH
PD PHOTO DIODE
LOAD - SV 2 , SV 3, ENERGISED
EJECT - SV 1, SV 5, ENERGISED - SV 6, DE-ENERGISED
STORE - SV 3, SV 4, SV 5, SV 6, ENERGISED
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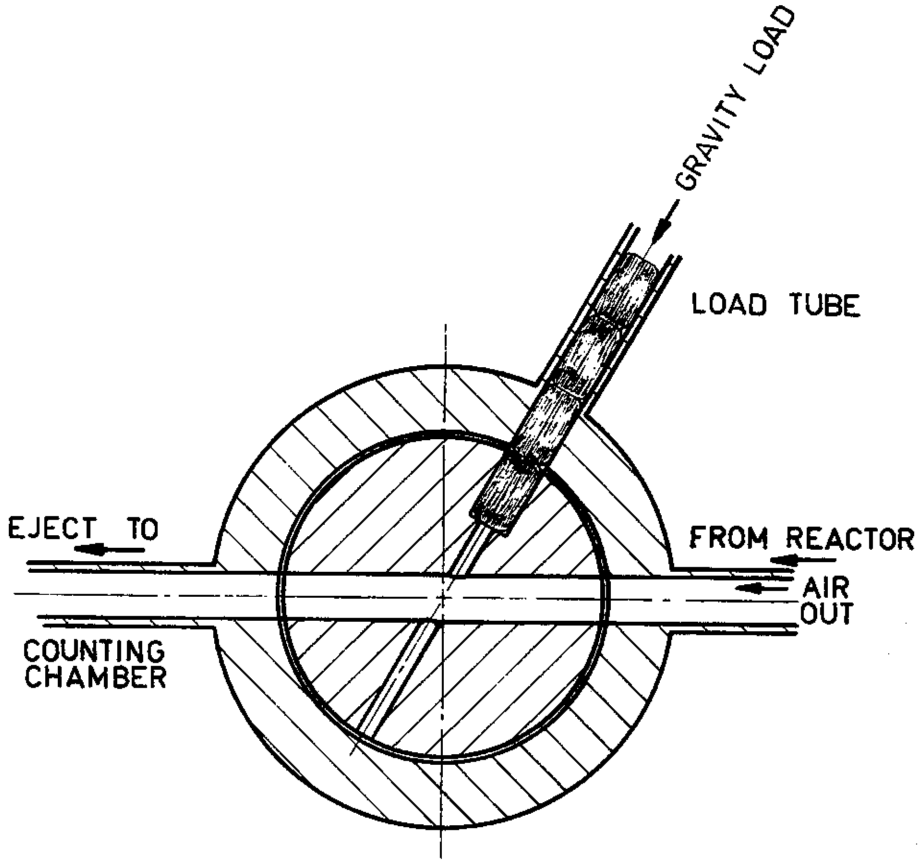
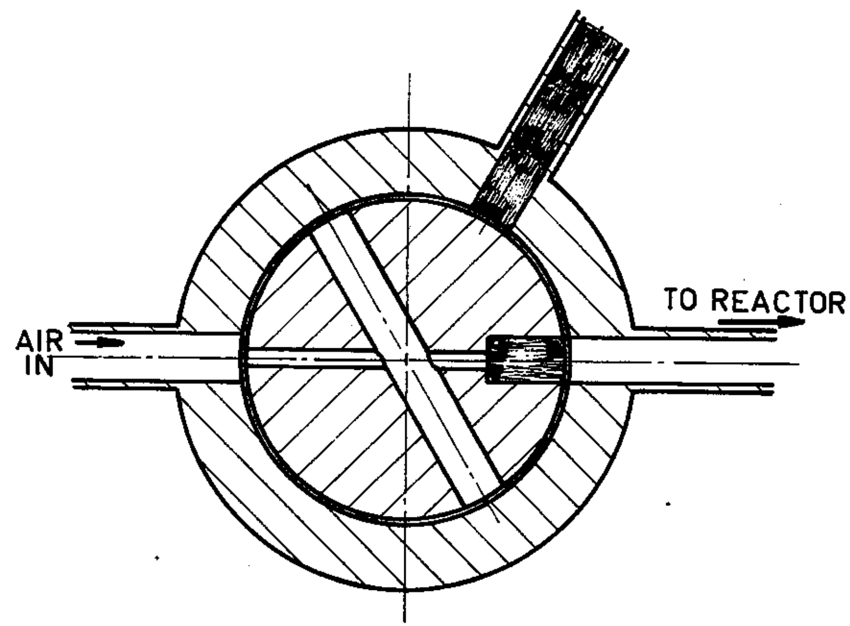
TOLERANCES
UNLESS OTHERWISE STATED
DRAWING REFERENCE AIE 47861
D.O. JOB No 6778
ITEM LOC. DESCRIPTION
AUSTRALIAN ATOMIC ENERGY COMMISSION
X-193 PNEUMATIC SCHEMATIC DIAGRAM
MATERIAL REQD REMARKS
SCALE —
STD.
DRN RW ROLLING
DATE 17.3.76
TCD.
RESP OFFICER A WALKER
CKD
APPD
DRG. No. A2 E 47858 D
AMENDMENTS
0 REDRAWN
AMEND NO. 7993
DRN: B.PIETROFF
R.D: AWH.
CKD: L.Richens
DATE: 7.3.78

Fig 4



LOAD EJECT

FIG. 5.



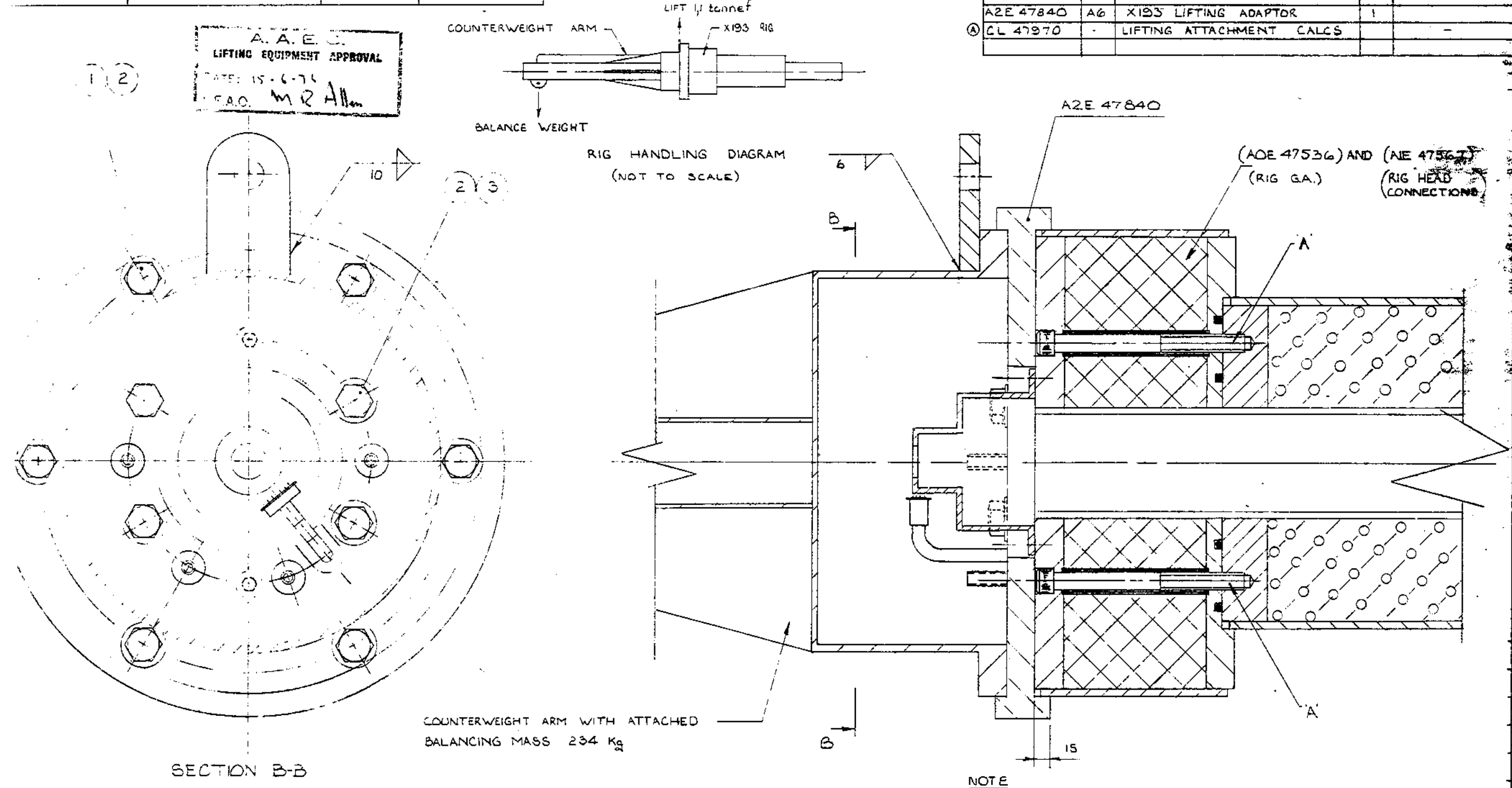
SEND

FIG. 6.

ANGLE PROJECTION	DIMENSIONS IN MILLIMETRES	DO NOT SCALE	REMOVE SHARP EDGES

	DRAWING No.	LOC.	DESCRIPTION	REQD	REMARKS
	A2E 47840	A6	X193 LIFTING ADAPTOR	1	
Ⓐ	CL 47970	-	LIFTING ATTACHMENT CALCS		-

A. A. E. C.
LIFTING EQUIPMENT APPROVAL
DATE: 15-6-76
E.A.O. M R Allen



ASSEMBLY INSTRUCTIONS FOR LIFTING.

1 REFERENCE DRAWINGS REQUIRED, RIG ASSY AOE 47536, RIG HEAD CONNECTIONS AIE 47567.
2 REFER DRW AOE 47536 — TO CLEAR LIFTING ADAPTOR (A2E 47840), REMOVE MOTOR BRACKET MOTOR & GEARS ETC (C2) & FLANGE INSERT & BRACKET (D1), & BRACKETS (F1) (H1). REMOVE 4 SCREWS ITEM 17 (G3) LEAVING 2 SCREWS IN PLACE AS SHOWN ONE AT TOP & ONE AT BOTTOM. (SEE NOTE E6)
3 REFER DRW AIE 47567 REMOVE & ITEMS 2 & 3, & CAREFULLY REMOVE THERMOCOUPLE SOCKET FROM BRACKET ITEMS 6 TO 10 THENCE REMOVE BRACKET.
4 BOLT X193 LIFTING ADAPTOR IN PLACE. WITH ITEM 2 & 3
5 BOLT COUNTERWEIGHT ARM TO ADAPTOR. WITH ITEM 1 & 3

NOTE

BEFORE LIFTING CHECK SCREWS MARKED 'A' (2 OFF) LOC. B7-E7, ARE IN PLACE AND PROPERLY TIGHTENED.

FOR TESTING USE:

RIG MASS 767 kg + 76 = 843 kg AND
COUNTERWEIGHT OF 234 kg + 23 = 257 kg

ITEM	LOC.	DESCRIPTION	MATERIAL	REQD	REMARKS
3	B3	BOLT HEX HD 5/8 SSW x 8 3/8" LG.	STEEL	4	AS. N° B.100
2	A1/B3	WASHER FLAT Φ 16	STEEL	10	
1	A1	BOLT HEX HD M16 x 40 LG	STEEL	6	TENSILE STRENGTH 400 MPa.

Ⓐ ADDED CL 47970 (A6) AHNS N° 7420 DRN R.J.Rollings CKD A.Aylesbury R.O. [illegible] DATE 12-5-76

Ⓑ WELD'S ADDED (B3) (B5) AHNS N° 7456 DRN R.J.Rollings CKD [illegible] R.O. [illegible] DATE 18-6-76

TOLERANCES: UNLESS OTHERWISE STATED

DRAWING REFERENCE

D.O. JOB No. 6778

AUSTRALIAN ATOMIC ENERGY COMMISSION

HIFAR - X193 - RIG
LIFTING ASSY

SCALE 1:2,5 | DRN. R.J. Rollings | TCD | CKD. [illegible] 20/5/76 | STD. | DATE 17-3-76 | RESP. OFFICER [illegible] | APPD.

DRG. No. A2E 47854 B

Fg 7

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