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SYMPOSIUM ON HIFAR-
CONSTRUCTION AND INITIAL OPERATION

HELD AT
LUCAS HEIGHTS RESEARCH LABORATORIES

11 MARCH 1988

(IN OBSERVANCE OF THE 30TH YEAR OF HIFAR OPERATION)

SPONSORED BY THE

AUSTRALIAN NUCLEAR ASSOCIATION

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CO-SPONSORS: THE AUSTRALIAN INSTITUTE OF NUCLEAR
SCIENCE AND ENGINEERING

THE LUCAS HEIGHTS SCIENTIFIC SOCIETY

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SCIENCE AND TECHNOLOGY ORGANISATION

ISBN 0 949188 03 4

- AGENDA -

- Chairman of First Session E.A. Palmer -

9.15 am Opening Remarks, D.G. Walker, C.N. Watson-Munro

9.30 Project Organisation Design and Procurement, F.H. Carr

Aspects of Construction, UK and Lucas Heights, K.J. Cooke

Some Aspects of HIFAR Design, R.W.S. Carlson and D.R. Ebeling

11.00 Coffee Break (courtesy of LHSS)

- Chairman of Second Session A.C. Wood -

11.30 Instrumentation and Control Aspects of HIFAR, J.K. Parry

HIFAR Commissioning and Operation, G.A. Tingate

Current Operations and Refurbishing, N.A. Parsons and M.R. Allen

1.00 pm Closing

1.15 Lunch - available for purchase in canteen

2.15 HIFAR visit (optional)

HIFAR - PROJECT ORGANIZATION
DESIGN AND PROCUREMENT

F.H.CARR

1.0 INTRODUCTION

Several earlier reports have been written on the subject of the HIFAR reactor (1,2,3), and others covering the period of the formation of the Australian Atomic Energy Commission (AAEC) and the early construction work at the Research Establishment at Lucas Heights (4,5). However, these publications do not report in detail on the construction of the HIFAR reactor and its early operational history, and it is considered that both of these areas are worthy of further comment. Firstly, the HIFAR reactor and its associated buildings were constructed in a period of two years and seven months. That is, from the date of placing the order in the United Kingdom on the 27 June 1955, to when the reactor was made critical on 26 January 1958. Few would argue that this achievement could not be repeated in Australia today. Secondly, this reactor has operated very satisfactorily in the subsequent thirty year period with its major components intact, and no doubt will continue its safe operation for a number of years to come.

The construction of HIFAR was an engineering project undertaken by staff of the AAEC in co-operation with the United Kingdom Atomic Energy Authority (UKAEA). This paper describes the contractual procedures adopted for the supply of the reactor and its assembly; and the involvement of the UKAEA, the main contractor Head Wrightson Processes Ltd., and the staff of the AAEC in the design and procurement of the components for the reactor in the UK.

A further paper describes the construction of the reactor on the site at Lucas Heights.

2.0 CHRONOLOGICAL ORDER OF EVENTS.

A chronological order of events of interest is shown in Table 1. This list is not meant to cover all events over the period 1949 -1958, but is shown in order to demonstrate that much was achieved in a relatively short period of time. From the formation of the Industrial Atomic Energy Policy Committee in 1949 to the setting up of the AAEC Office at Coogee, Sydney, in 1953 took some four years, and by the end of 1955 a greater part of the research staff had been recruited and were in place at Harwell, UK. The task of recruiting these engineers and scientists, and implementing the program of work to be undertaken by the AAEC staff at Harwell was conducted by the Chief Scientist, Mr C.N. Watson - Munro and the Chief Engineer, the late Dr G.C.J.Dalton.

By mid 1956 some staff engaged on the construction of the reactor had moved back to Lucas Heights, and by the end of 1957 the majority had followed. On the 26 January 1958 the AE443 (renamed HIFAR) reactor was made critical, and commenced routine full power operation in January 1960.

3.0 AE443 (HIFAR) CONTRACT.

On the 27 June 1955 the order was formally placed with London firm of Head Wrightson Processes Ltd.- "to design, to supply, to test, to supervise the assembly and erection on site at Menai, NSW of a Heavy Water Reactor (the commissioning of the Reactor when charged is not included). The Reactor is to be to the same design as Reactor E443 erected by you for the United Kingdom Atomic Energy Authority, but including such modifications and improvements as were effected during the construction of that Reactor and any

special modifications (if any) as may be detailed and agreed later." The reactor E443 was the initial designation of the reactor DIDO. Similarly, the initial designation of HIFAR was AE443.
It was agreed that the cost was - "not exceeding Seven hundred and fifty thousand pounds sterling. Actual price to be determined under contract conditions."
The extent of supply for the HWP contract was as follows:

(i) Supply all reactor equipment and materials and deliver F.O.B. UK or European Port. Goods of Australian origin delivered to site.

(ii) Erection of the reactor plant at site, including HWP supervision, but excluding civil works.

The extent of supply for the AAEC:

(i) Shipment of reactor components from the UK and W.Germany.
(ii) Civil design and construction.
(iii) Customers costs.

With regard to the completion date, the contractor was requested to use his utmost endeavours to complete the work by the 30 June, 1957. This was two years from the date of placing the order. This was indeed a target date and some overrun was expected, and did to the extent of seven months, but nevertheless at the time it was not considered unreal. One is tempted to reflect on current local conditions and estimate the construction time and cost for a similar project today.
A copy of the Contract Schedule is held by the AAEC. This Schedule contains the usual categories in a document of this type, and some comment relating to several of these categories is in order.
Reference is made in the schedule to specifications, documents, information, etc.. The UKAEA (Harwell) were the design authority for the E443, and design specifications prepared and issued by them to the Contractor (HWP) for E443 were also used by the AAEC for the AE443.
In this contract all components supplied by sub-contractors to the main contractor (HWP) for the reactor had to go to tender, and the supplier recommended by HWP had to be acceptable to the engineering staff of the AAEC. Likewise, the payments to the sub-contractors for equipment were authorised jointly by the AAEC; the late W.H.(Bill) Roberts initially and myself when the former returned to Lucas Heights; and the Chief Procurement Officer (....Goad) at Australia House, London. Such conditions in the contract proved to be worthwhile on a number of occasions. As discussed later in the paper, the AAEC had assistance from the UKAEA (Risley), and in particular assistance from their Inspectorate Department. The majority of sub-contractors selected by HWP were those who had previously supplied the same components for the E443 reactor and were acceptable on the grounds of quality, cost, and delivery. In a number of cases, due to high workshop loading, some sub-contractors did not tender and new suppliers had to be found. In these circumstances the sub-contractors recommended by HWP did not always meet the standards set by the UKAEA, and as a result the AAEC were able to be selective under the terms of the contract. There is little doubt that such procedure avoided costly delays to the project.

4.0 UKAEA (E443) ORGANIZATION.

Prior to discussing the AAEC organization in the UK, it is necessary to examine the UKAEA organization which was set up for the E443 project. This is shown in Figure 1.

On a contractual basis the UKAEA (Harwell) were the customer and the reactor design authority. As the design authority they were responsible for issuing the specifications for all reactor plant and equipment, and it should be appreciated that these were early days in the areas of nuclear plant design and manufacture. Before being employed on a full time basis on the AE443 project, I was attached to the E443 design team. Here the approach to the design of components in the nuclear field had much in common with that in the aeronautical field in which I had recently been employed in the UK and Australia, in that research and development played an important role in the design of components. This work was carried out at Harwell and Risley, and extended into industry to the manufacturers of reactor components. Development contracts were placed with selected suppliers to develop their components to meet new requirements, or to develop manufacturing methods for other components. The development contracts were additional to the procurement contracts.

One example was the reactor aluminium tank. These tanks for both E443 and AE443 were manufactured by the A.P.V. Co.Ltd., who was also awarded a development contract. This tank is of 99.8% pure aluminium and has a number of nozzles for coolant inlets and outlets, as well as thimbles for experimental holes and the "false-bottom" plenum chamber, and represented a complicated piece of welding to unusually exacting standards, one of which was the necessity of identical analysis of weld metal and parent metal. This and other development contracts incurred an additional expense from which the AAEC was spared.

HWP Ltd served as a link in the transition from design to manufacture. This Firm had no previous experience in the nuclear field, but at that time few, if any, did. Their main claim to experience was in the design of oil refineries and similar plant. They were contracted to do the detailed design of the reactor components, preparation of working drawings, procurement and inspection, and the erection of the reactor on site. The UKAEA (Risley) also participated in this area in what appeared to be an advisory role. No doubt their experience and expertise in the nuclear plant construction field stood them in good stead. This applied particularly to the manufacture and fabrication of stainless steel components. Their welding school was probably the first of its kind in Europe.

Finally,the civil and construction work for the design and erection of the reactor buildings was undertaken by the Ministry of Works.

The AAEC was indebted to the UKAEA and the UK Ministry of Works for all drawings and specifications of the E443 (DIDO) reactor on which the AE443 (HIFAR) designs were based.

5.0 AAEC (AE443) ORGANIZATION UK.

The AAEC organization in the UK is shown in Figure 2. This shows the AAEC as the customer with HWP Ltd as the main contractor. Essentially HWP's role was similar to that carried out for the UKAEA. There were no contractual ties with the UKAEA (Harwell), but co-operation at a working level was always there if needed. A good relationship was maintained over the life of project between the E443 Project Leader Mr W.Woods and his deputy Mr C.Blumfield, and the AAEC engineers.

As discussed previously in Section 3.0, the participation of the UKAEA (Risley) on inspection visits to the sub-contractors' works was of great assistance to us. They were also able to assist on the supply of stainless steel on a number of occasions when supply became a serious concern.

As HWP was involved with the UK E443 reactor which was made critical in early November 1956 and therefore well ahead on delivery with the AE443, they would be expected to be well versed on the reactor design criteria as defined by the UKAEA (Harwell), and this turned out to be so and little trouble was experienced in this area. However, subsequent to the E443 reactor being made critical several necessary modifications to the AE443 design became apparent, and these are discussed in a later section of this report.

6.0 AAEC STAFF EMPLOYED ON THE AE443 PROJECT - UK.

By June 1955 a significant number of AAEC staff had taken up residence at the Atomic Energy Research Establishment (AERE), Harwell. These could be divided at that time into two categories; those related to assisting with the formulation of a research program and related facilities, and those directly involved with the AE443 Project. This paper is concerned with the staff in the latter category.

Table 2. lists those people who were employed on the AE443 Project. In broad terms the work fell into two categories; those engaged upon the procurement of components to build the AE443 reactor, and those acquiring knowledge and experience to put it together and to operate it in a safe and efficient manner. In order to achieve the latter, staff were attached to the E443 project. The listing is divided into two periods. The first period was mainly taken up with getting orders placed for the reactor components. At the beginning Bill Roberts attempted to carry the greater part of the load and allow me to carry on part time attached to the E443 design team, but the workload associated with getting the orders placed by HWP with the suppliers was too much, so I was moved to full time on the AE443 project and stayed on it until the end of 1957. The late George Page was employed full time on the procurement of the instrumentation for the reactor until about mid 1957 when he returned to Australia, and his place was taken by John Parry. Geoff Tingate was attached to the E443 team and was concerned with reactor operational procedures. Colin McKenzie was attached to the physics section and was engaged upon reactor start up. Don George and Ken Cooke were attached to the E443 project on the construction site, where Don was concerned with the electrical side of component installations and Ken with the mechanical. Likewise the late C.A.(Charles) Logan was engaged on E443 plant operation.

In early 1956 the foundations for the reactor at Lucas Heights were commenced, and by mid 1956 some components, including the structural steel work from W.Germany, had arrived at site. At this stage those people concerned with the construction of the reactor had either moved back to Lucas Heights or were in the process of doing so. Bill Roberts commenced work at the site in May 1956 to take charge of the construction of the reactor and associated buildings, leaving myself in charge of procurement in the UK. The Chief Scientist, Mr C.N. Watson-Munro moved to Lucas Heights in early November, about the time the E443 reactor was made critical, leaving Dr Dalton in charge of all AAEC staff in the UK. Doug Ebeling joined the AE443 (UK) Project team in the second phase shortly after Bill Robert's departure, as did Bob Carlson a little later.

7.0 PROCUREMENT OPERATION.

Whilst the AE443 was a replica of the UK E443 so far as the design was concerned, it still required the full treatment on procurement, and over six hundred orders were placed with UK, W.German, and Australian suppliers. By far the majority of orders were placed with UK firms, but several important items were placed in W.Germany. These included the upper and lower annular shields, the aluminium tank top shield, several heat exchangers including the heavy water coolers, and the top and bottom steel structures with their casings with M.A.N.. They also supplied the boring and alignment templates. Several stainless steel vessels were manufactured in W.Germany; namely, the heavy water storage tank and expansion vessel. I believe these were the first nuclear plant components manufactured in this country, and the first off fabrication of stainless steel to such high standards. Some difficulties were encountered with welding this material to meet the required specification, and as a result we were given an insight into the high degree of co-operation which existed between the manufacturing industry, the research establishments, and the universities. We were also fortunate in that the Chief Inspector at HWP was a former welding instructor at the UKAEA (Risley). As a result the problems were sorted out with a minimum of delay.
No doubt the most demanding task for the AAEC project staff was the maintaining of the progress schedule for each component. On numerous occasions items which appeared to be well on target on delivery could become a critical item. In some cases this was due to problems encountered during manufacture. In the case of the top shielding manufactured in W.Germany, distortion problems arose when pouring the molten lead in situ in the lower annular shield and the aluminium tank top shield. These are rather complicated components, constructed of a steel box in each case lined with 2 mm of cadmium; 4in. of lead with cast-in cooling pipes; the remainder being filled with concrete. The initial promised delivery for these items was October 1956, and the final shipping dates were January and February 1957 respectively. Cases such as these required personal visits to the works by myself and the HWP Project Leader to argue our case for delivery to slot in with site construction. Other areas which gave considerable concern were those components related to stainless steel fabrication and castings where the presence of inclusions and porosity did not meet specification. The main circulating pumps were in this category because of porous impeller castings supplied to the pump manufacturer, but by jumping the queue, we were able to get supply of one pump for erection purposes to use as a template for the piping in the main heavy water circuit on site.
Some firms were more competent than others in fabricating stainless steel components, and this could lead to the overloading of these suppliers with an adverse effect on delivery. In one case which was concerned with the supply of fabricated stainless steel piping, the supplier repeatedly reported to HWP that they were on schedule on delivery almost up to the date of promised supply. We were informed that this was not the case, and subsequent to a visit to the supplier, our order was split between other branches of the same firm in order to get delivery in a reasonable time. This was done with the help of the UKAEA (Risley).

8.0 DESIGN MODIFICATIONS.

Throughout the period of the AE443 Project we were fortunate to be in a position where we could incorporate design modifications in the AE443 reactor as they became apparent during the manufacturing, construction, and commissioning stages of the E443 reactor. The majority of these modifications dealt with detailed design and manufacture and do not require further comment, but two design modifications could be of interest.

During construction of the E443 reactor it was found that there was insufficient space between the reactor top plate and the aluminium tank top shield to allow access to the vertical experimental holes in way of cables,apparatus, etc.. The E443 reactor top plate was raised by 10 inches, and the AE443 by 14 inches. For the latter, this involved an additional 10 inch cast iron ring and 4 inches of steel fixed to the underside of the top plate to give a clearance of 24 inches instead of 10 inches as originally planned..

The other design modification was concerned with the coarse control arms. These take the form of cylindrical controllers containing the operating mechanism terminating in blades of the signal-arm type, and it was with the blade design that the AAEC requested modification before taking delivery from the supplier. This was related to the design of the blade to withstand lateral forces imposed by the circulating heavy water during reactor operation. Evidence of some degree of blade vibration became apparent during the early operation of the E443 reactor, and on examination of the completed control arms for the AE443 the request was made to add lateral strength to the blade. After initial opposition from the supplier to strengthen and stiffen the blades this modification was carried out.

9.0 COST.

A more detailed and comprehensive cost account for this item could possibly be found in the AAEC files. This account covers only the HWP contract and is based on an estimate made at the end of July 1957. At this stage it contains a contingency of 2.0% for materials and a 25.0% contingency on erection.

	Pounds Sterling.
1. Materials delivered F.O.B. UK Port packed for shipment. Goods of Australian origin delivered to site.	584,000
2. Estimated cost of erection of plant at site - excluding site supervision.	152,650
3. HWP design, procurement, and direct charges, including site supervision.	217,600
Total Estimated Cost -	954,250

To this must be added the remaining AAEC costs such as shipping, civil works, and other customer costs.

A recent publication (6) gives an approximate cost of $4 million, presumably in $A.(1958), for the total cost. If a discount rate of 8.0% p.a is assumed over the 30 year period 1958 - 88, the present worth value is $40 million. The replacement value would no doubt be significantly higher, and this topic may be covered in a subsequent paper at this Symposium.

10. REFLECTION.

Writing this report has meant turning the clock back thirty years and brushing aside quite a few cobwebs. In doing so one cannot help but reflect on events in this period and make comparison under current conditions. The AE443 team worked in a less restrictive environment and so were able to get on with the work in hand with a minimum of interference. Evidence is to hand to show that this practice worked as the final product conforms to the engineering and regulatory requirements for safe and reliable plant operation. If we were to assess the situation today to build a similar plant, could we justify the additional costs in real terms, which have been imposed with the use of current practices in order to produce a safe and reliable plant?

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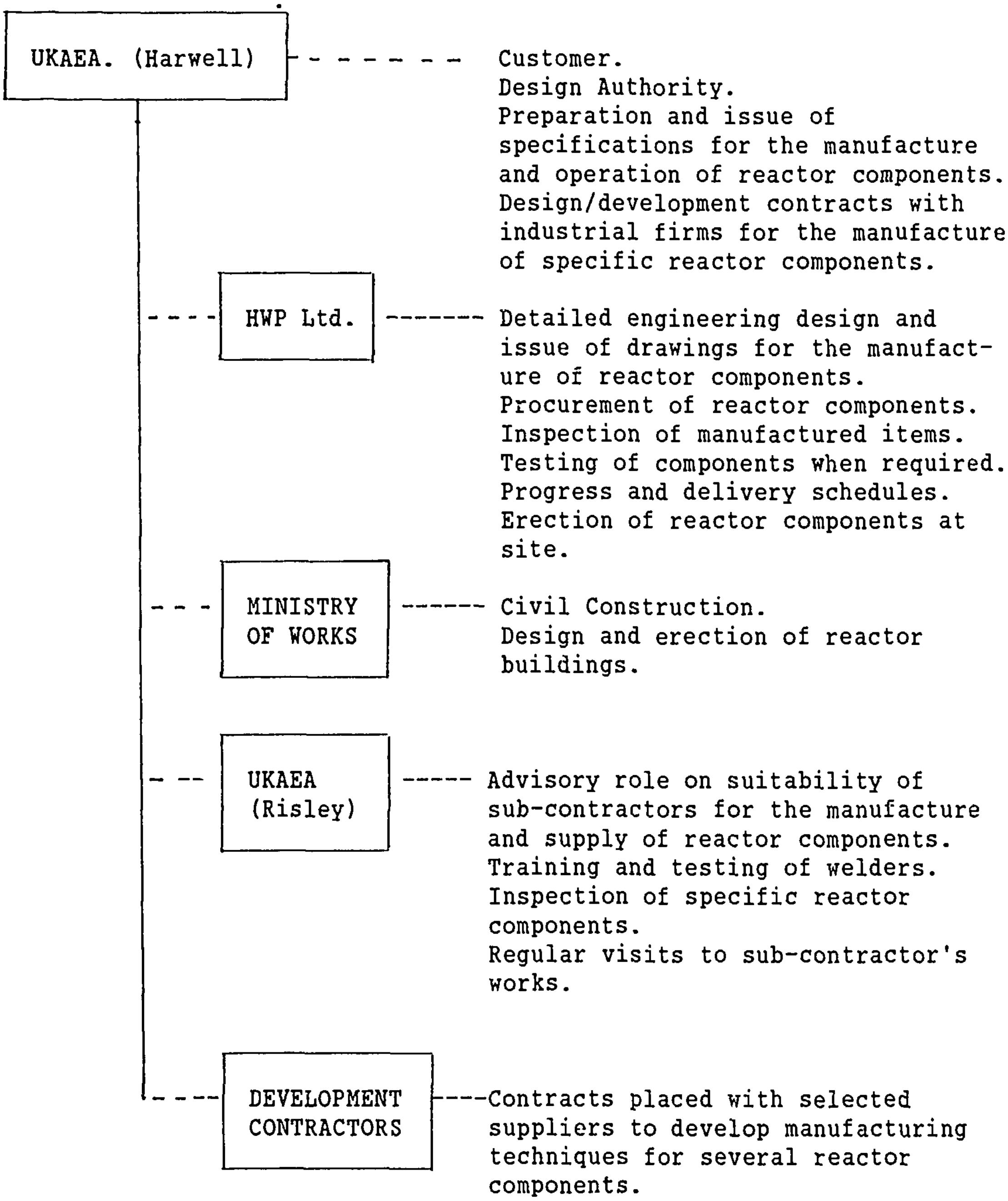
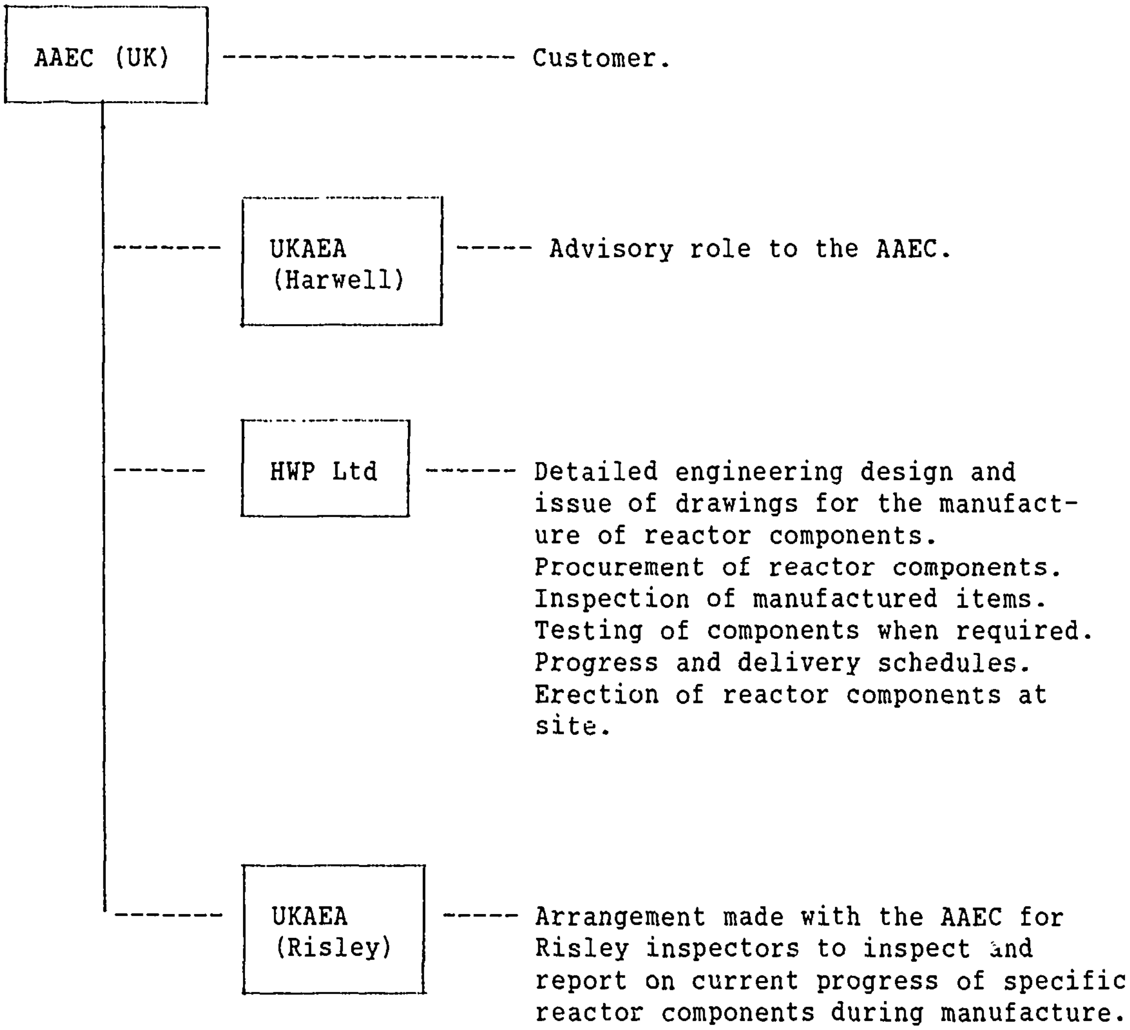
FIGURE 1 UKAEA (E443) ORGANIZATION.



UKAEA. (Harwell)	Customer. Design Authority. Preparation and issue of specifications for the manufacture and operation of reactor components. Design/development contracts with industrial firms for the manufacture of specific reactor components.
HWP Ltd.	Detailed engineering design and issue of drawings for the manufacture of reactor components. Procurement of reactor components. Inspection of manufactured items. Testing of components when required. Progress and delivery schedules. Erection of reactor components at site.
MINISTRY OF WORKS	Civil Construction. Design and erection of reactor buildings.
UKAEA (Risley)	Advisory role on suitability of sub-contractors for the manufacture and supply of reactor components. Training and testing of welders. Inspection of specific reactor components. Regular visits to sub-contractor's works.
DEVELOPMENT CONTRACTORS	Contracts placed with selected suppliers to develop manufacturing techniques for several reactor components.

FIGURE 2 AAEC (AE443) ORGANIZATION UK



AAEC (UK) ------------------ Customer.

UKAEA (Harwell) ----- Advisory role to the AAEC.

HWP Ltd ------ Detailed engineering design and issue of drawings for the manufacture of reactor components.
Procurement of reactor components.
Inspection of manufactured items.
Testing of components when required.
Progress and delivery schedules.
Erection of reactor components at site.

UKAEA (Risley) ----- Arrangement made with the AAEC for Risley inspectors to inspect and report on current progress of specific reactor components during manufacture.

TABLE 1

CHRONOLOGICAL ORDER OF EVENTS OF INTEREST.

1949 - Industrial Atomic Energy Policy Committee (IAEPC) set up. (Advisory role to Commonwealth Govt.)

April 1952 - IAEPC replaced by the Atomic Energy Policy Committee.

Nov. 1952 - Members (3) of the AAEC selected.

Jan. 1953 - Uranium mining began at Rum Jungle.

April 1953 - Royal assent given to the Atomic Energy Act. AAEC Office at Coogee, Sydney, set up shortly after.

1954 - First uranium oxide produced at Rum Jungle.

1954 - Arrangements concluded with the UK for access to information. As a result the AAEC was able to maintain its own research team at Harwell.

June 1955 - Order placed with Head Wrightson Processes Ltd. London, for a Heavy Water Reactor to the same design as the UK reactor E443 (DIDO).

Oct. 1955 - Contract awarded to Hutcherson Bros. Pty Ltd.,for the erection of the reactor buildings and for the laboratory buildings at Lucas Heights. The first pegs driven in the site at Lucas Heights.

Feb. 1956 - Foundations for HIFAR reactor were commenced.

Nov. 1956 - UK reactor DIDO made critical.

Jan. 1958 - HIFAR reactor made critical.

April 1958 - The AAEC Research Establishment was officially opened by the Prime Minister.

Jan. 1960 - HIFAR reactor commenced routine full power operation.

TABLE 2.

AAEC (AE443) PERSONNEL - U.K.

1ST PHASE: U.K. June 1955 - April 1956

HIFAR

W.H Roberts - O.I.C
F.H.Carr
G.Page

DIDO

G.A.Tingate - Operational Procedure
C.McKenzie - Physics
D.George - Site Construction
K.J.Cooke - Site Construction
C.A.Logan - Site Reactor Operation

2ND PHASE: U.K. April 1956 - Dec. 1957

HIFAR

F.H.Carr - O.I.C.
D.R.Ebeling
R.Carlson
G.Page
J.Parry (Part Time)
G.A.Tingate

DIDO

G.A.Tingate - Operational Procedures
C.McKenzie - Physics - Start up.

HIFAR

ASPECTS OF CONSTRUCTION

UNITED KINGDOM AND AUSTRALIA

by

K.J. Cooke

By the time that I joined the Australian Atomic Energy Commission (AAEC) at Harwell in the UK on June 20,1955 the decision to build a high flux research reactor at Lucas Heights, near Sydney, had already been made and the prototype reactor had been selected. It was the E443 reactor (later to be named DIDO - from D2O - the moderator /coolant) which was then under construction at Harwell.

As the previous speaker, Frank Carr, has explained a project management team had been established to bring the Australian reactor into fruition. I, as part of that team, initially was assigned to oversee the mechanical aspects of construction of E443 with a view to learning as much as possible from that project so as best to be able to assist in the realization of the Australian reactor, later to be named HIFAR (High Flux Australian Reactor). My colleague, overseeing the electrical aspects, was one Donald W. George, who I'm sure, is very well known to you. We both were attached to the UK Ministry of Works (MOW) who were constructing E443 for the United Kingdom Atomic Energy Authority (UKAEA).

In early December 1955 I was transferred to Australia and established an office at the Headquarters of the Commission at 45 Beach Street, Coogee. There I worked in association with the Technical Secretary, Ian Bissett and both of us reported administratively to the Chairman, Sir Jack Stevens. Until then, Ian had been the sole liaison officer in Australia handling the development of the Research Establishment (RE) at Lucas Heights where HIFAR was to be built. Henceforth, I liaised on HIFAR matters, with project management reporting to the Senior Engineer, Bill Roberts, at Harwell. Ian covered the rest of the site with project management reporting to the Chief Scientist, Charles Watson-Munro, who also was at Harwell.

Earlier a firm of architects, Stephenson and Turner (S&T), had been commissioned by AAEC, on a percentage-of-cost fee basis, to design and supervise the construction of the laboratories and other facilities which comprised the RE. A firm of builders, Hutcherson Brothers (HB), also had been selected. They were to carry out the construction work on a cost-plus-management fee basis. The firm of Head Wrightson Processes (HWP) had, as Frank Carr has explained, contracted directly with the AAEC for construction of the "nuclear" systems of HIFAR and HB constructed the rest. Both S&T and HB utilized the services of sub-contractors for portions of the work.

When first I visited the site in early December 1955 it had been cleared and fenced and a Site Office had been established. (With minor modifications it exists today.) The excavation for HIFAR foundations had been commenced.

Early in 1956 I relocated from Coogee to the Site Office thus establishing the first presence of AAEC at the RE. Ian Bisset remained at Coogee to maintain communications with AAEC project management staff at Harwell and to liaise with S&T at their offices in North Sydney.

We commenced regular progress meetings. These were attended by AAEC, S&T and HB and reported to the senior project management team at Harwell in the UK. Diagrams of the Project Management Organization are shown in the attached Figures. Figure 1 shows the organization from the beginning of the project in mid-1955 through to mid-1956 when project management control shifted from the UK to Australia with the return of senior staff. Figure 2 shows the organization from then until completion in 1958.

Back again to early 1956; it soon became evident that the various avenues, streets, lanes and places at the RE required names and the site itself needed an identity.

Ian Bisset requested guidance from the Harwell group but this was not forthcoming; that is, not with the promptness he had expected. My guess was that they were too busy with the pragmatism of getting the reactor and laboratories established to be bothered with such trivia as "names".

Well, Ian in his inimitable fashion, took the matter unto himself. He didn't know much about nuclear science, or the people involved. So, he got hold of a "Who's Who in Atomic Energy" and, one evening, sat down with a site plan and put names on it - the more important the thoroughfare, the more important the name it got. To my knowledge, none of his selections was questioned.

Then came the ultimate problem of a name for the site. Ian sought the aid of the high-brow intellect of the Secretary of the AAEC, Pat Greenland, who went to work on the problem with great diligence. With the name "DIDO" to tempt his fertile brain he discovered, in his scholastic research of the classics, that DIDO'S lover's name was "AENEAS". Eureka!, he proclaimed, the name shall be thus: "Atomic Energy Nuclear Establishment At Sydney".

Well, Pat researched further and found that AENEAS died in a sea of flames. That portent did not appeal to him so the site was named simply - the Research Establishment (RE).

Early in 1956 S&T began letting various local supply contracts, through HB, for materials and components for HIFAR. All "critical" items were ordered in Europe, as Frank Carr has explained, but as many items as practicable were obtained locally. This, as you will appreciate, posed some difficulties. Australian Standards differed from the British Standards employed on E443 in the UK - steel sections were different, electrical specifications were different and, of course, our climate was different - so, some design changes were necessary.

As a minor example, the DIDO containment building is dark whereas it was considered that HIFAR'S should be light to reduce the heat load from the Australian sun on the air conditioning system. Hence, a different specification for the building paint was required.

On site, some of the difficulties experienced included flooding of the foundation excavations by the spring rains and placement of the steel sealing membrane in the reactor building floor.

This membrane was intended to be flat so that it would have intimate contact both with the underlying concrete and the subsequent overlay to form part of the containment barrier. A bituminous underlay caused some contamination of the welding and the thin steel plates buckled from the stresses induced by welding. However, this was overcome by weighting with heavy drums and cutting and rewelding as required to relieve stresses.

Some excitement developed on December 19, 1956 when bushfires swept the area from New Illawarra Road, just across from the site, right up to and along the Heathcote Road, until it was brought under control some 5 km away. Fortunately, no damage was sustained on the site but the incident served to confirm the wisdom of providing dual electricity supply lines to the site.

In due course, the building and reactor structure were ready to receive the main lead-lined steel reactor vessel which weighed some 65 tonnes. This had been transported to Sydney by the British freighter, "Australind", from the UK where it was fabricated. At a dock in Wooloomooloo it was unloaded from the freighter by the "Titan" crane from Cockatoo Island Dockyard and landed on to a low-loader for transport to the site.

All of this created some interest in the media as the arrival of "Australia's first reactor" was quite a newsworthy event with "Atoms for Peace" being a theme prevalent at the time. Besides, we now had a new toy in Australia which was hungry for news - television.

Darkness overtook the transport en route to the site and an overnight stay was made at Kyeemagh, near Brighton-le-Sands. An armed guard was posted as a precaution.

Next day it was found that the load would not quite pass under the 4.5 metre clearance of the rail bridge across the then Prince's Highway (now Rawson Ave.) at Sutherland. Advantage was taken of the maximum clearance at the edge of the cambered road surface but it was still not quite enough so the transport's tires were slightly deflated to gain the extra clearance required. No further problems were experienced and the reactor vessel reached the site later that day and was installed during the following days on the awaiting reactor structure.

The biological shielding specifications called for the extensive use of "heavy" concrete. Most of this comprised normal concrete but with the use of barytes (barium sulphate) as aggregate. However, for some areas requiring more dense shielding, steel shot was used as aggregate. As will be explained by the following speakers, Bob Carlson and Doug Ebeling, experience with DIDO indicated that shot concrete should be substituted for barytes in several locations.

As I recall, no difficulty was experienced in locating a source of barytes aggregate in Australia but a source of steel shot was another story. We were not aware of such an application for steel shot and sought supplies from any place we could find - even to discarded or sub-standard ball bearings.

Ultimately a very cheap source was found in a Melbourne suburb where an iron foundry was producing cracked shot for use in the drilling of concrete. (Since then, this method has been superseded by diamond drilling techniques.)

It is a matter of some trivial interest how this steel shot was produced. A cupola furnace produced a steady stream of molten iron and a jet of compressed air blasted this some 10-15 metres through the air in a spectacular shower of droplets to fall into a shallow pool of water. The chilled shot, of course, was extremely hard and, when cracked, provided an excellent abrasive medium for concrete drilling operations.

It also is of passing interest that an amazingly simple method was used to separate the spherical shot from other irregular shapes which resulted from this crude method of production - they were simply trickled on to an inclined conveyor belt. The spherical shot rolled backwards and were collected while the irregular shapes were carried over for recycling. As required, the shot were then screened for size.

While all this "reactor" work was proceeding, construction of the containment building was progressing. A point of concern arose between the Architect (S&T) and the Builder (HB) with respect to the complex design of the curved beams for supporting the polar crane. The DIDO design had utilized British Standard sections which were unavailable in Australia so these beams had to be redesigned.

The Architect produced a design which the Builder did not like so he came up with his own design which the Architect did not like. After extensive deliberations, including securing of legal advice by both parties, it was resolved that the Architect's design should prevail and it was built accordingly. I understand it is still in use.

With closure of the containment building providing protection from the elements, the various experimental facilities were aligned with the appropriate openings in the reactor vessel by optical means (telescope and target) and then "clean conditions" were established to install the graphite reflector blocks and the aluminium tank. Meanwhile, the ancillary and auxiliary systems were being installed inside and outside the reactor building.

One of the ancillaries, the Emergency Electrical System, was modified by Don George at Bill Robert's request, to include fly-wheels on the motor-generator sets so as to ensure an uninterrupted transition from normal to emergency electricity supply.

Modifications also were made to the fuel and experimental facilities storage blocks as will be explained by the following speakers, Bob Carlson and Doug Ebeling.

As system installations were completed the meticulous task of commissioning commenced. Of special interest to the process engineers, and new to us here in Australia, were the heavy water systems.

After leak and pressure testing, these had to be dried completely of "light" (ordinary) water to prevent degradation of the heavy water when it was introduced to the systems. This was accomplished by vacuum extraction and some local freezing had to be alleviated by warming the affected regions.

A later speaker, John Farry, will cover aspects of commissioning the control and instrumentation systems leading to the start-up of HIFAR on Australia Day 1958.

The project had been executed, from initial contract letting, to reactor criticality in less than three years - a feat which most likely could not be repeated these days.

The Research Establishment, including HIFAR was officially opened less than three months later on April 18,1958 by the Prime Minister, The Rt. Hon. Robert G. Menzies.

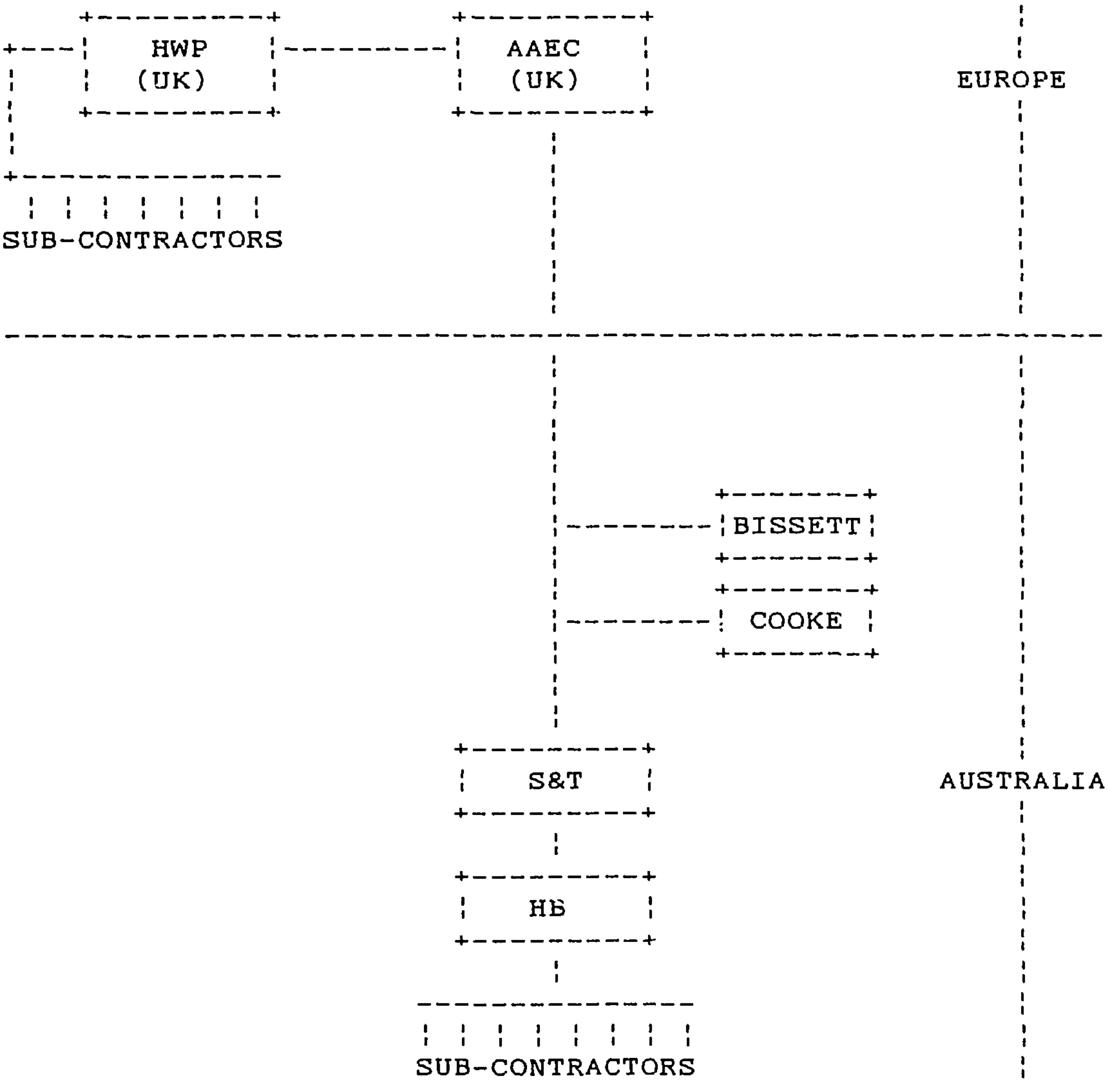

HWP
(UK)
AAEC
(UK)
EUROPE
SUB-CONTRACTORS
BISSETT
COOKE
S&T
AUSTRALIA
HB
SUB-CONTRACTORS

FIGURE 1

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    +----------+        +----------+                   ¦
+---¦   HWP    ¦--------¦   AAEC   ¦                   ¦
¦   ¦  (UK)    ¦        ¦  (UK)    ¦               EUROPE
¦   +----------+        +----------+                   ¦
¦        ¦                    ¦                        ¦
+--------------               ¦                        ¦
 ¦ ¦ ¦ ¦ ¦ ¦ ¦                ¦                        ¦
SUB-CONTRACTORS               ¦                        ¦
         ¦                    ¦                        ¦
------------------------------------------------------------
         ¦                    ¦                        ¦
    +----------+        +----------+                   ¦
    ¦   HWP    ¦--------¦   AAEC   ¦                   ¦
    ¦(SYDNEY)  ¦        ¦ (SITE)   ¦                   ¦
    +----------+        +----------+                   ¦
         ¦                    ¦                        ¦
    +----------+              ¦       +--------+       ¦
    ¦   HWP    ¦              ¦-------¦BISSETT ¦       ¦
    ¦ (SITE)   ¦              ¦       +--------+       ¦
    +----------+              ¦                        ¦
         ¦                    ¦                        ¦
  ---------------       +----------+                   ¦
  ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦       ¦   S&T    ¦              AUSTRALIA
  SUB-CONTRACTORS       +----------+                   ¦
                              ¦                        ¦
                        +----------+                   ¦
                        ¦   HB     ¦                   ¦
                        +----------+                   ¦
                              ¦                        ¦
                      ----------------                 ¦
                      ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦                  ¦
                      SUB-CONTRACTORS                  ¦
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FIGURE 2

SYMPOSIUM ON

HIFAR CONSTRUCTION & INITIAL OPERATION

SOME ASPECTS OF HIFAR DESIGN

by

R W S CARLSON & D R EBELING

March 1988

1. THE BASIS OF DESIGN

Following the conclusion of World War II and the discovery and application of nuclear fission, the United Kingdom decided in the late 'forties and early 'fifties to embark on a program to utilise nuclear energy for the generation of electricity. Reactors had been constructed to manufacture plutonium and it was logical to extend this technology to use the heat as a substitute for coal and expensive oil in a conventional Rankine steam cycle.

Because of the lack of irradiation data, the British wished to test materials and components for application in their power program. An order of magnitude higher neutron flux level was required in order to compress the time scale for testing and demonstrating the suitability of the material for long-term neutron exposure. They needed to process a relatively large volume of material as cheaply as possible.

A decision was made to utilise heavy water moderation because it meant a large lattice spacing to give room for experiments over a large volume. If D_2O could be combined with enriched fuel it meant a small fuel inventory and, therefore, a high flux over a large volume at a relatively low power output.

2. SOME BACKGROUND

Originally the British considered a design called HIPPO, based on the Canadian NRX research reactor at Chalk River, which satisfied some of the requirements and was a completed and tested design. However, the use of natural uranium raised the power level and costs which were higher than desired.

The NRX accident occurred at the time the British were considering building HIPPO and there was concern in the UK that their testing program could be delayed by the enquiry and possible doubts about the safety of the design. At about this time, enriched fuel became available to the UK and the supply of heavy water, although short, was sufficient to allow a change to be made to construct a design based on the US-developed CP-5; heavy water moderated and cooled, highly enriched, graphite reflected reactor at Argonne, near Chicago in the USA (see Figs 1 and 2). CP-5 was designed to operate at 5 MW with 17 fuel elements and achieve a peak thermal flux of 10^{14} neutrons cm^{-2} sec^{-1}. Construction of CP-5 started in 1952 and criticality was reached in February 1954. Thus, CP-5 more closely fitted the UK design basis, which had been set at achieving a peak thermal flux of ^{14} neutrons cm^{-2} sec^{-1}, at a power output of 10 MW (thermal) with 25 fuel elements.

Apart from extending the D_2O outlet pipes to stand just above the fuel element outlet ports, to avoid total loss of tank water from outlet pipe leakage, control arm drive changes and canned type primary circulating pumps, the design was basically CP-5 (see figs 3 and 4). The volume of the primary circuit was reduced to an absolute minimum because of cost and shortage of D_2O at that time and has led to a very cramped plant room. This requires dense concrete shielding to protect against the short lived 7 MeV gamma produced by the O16 - N16 reaction and decay.

Construction of DIDO commenced about 1953 and criticality was achieved in 1956. The Australian Government was fortunate to be able to purchase the design of DIDO cheaply and to take advantage of the construction of similar reactors at Harwell, Dounreay, Riso and Julich and, more importantly, observe the commissioning and early operating experience of DIDO at 10MW. Considering the great pressure on DIDO to operate to specification in 1956, the construction and operation was a credit to the UKAEA and the reactors have generally performed well over the years. Apart from a few design blemishes, such as failure of the lead thermal shield cooling water circuit pipes buried in the concrete, the design has been basically sound, but some features were able to be changed before HIFAR operated. In fact, the original design was so conservative that DIDO, PLUTO and Julich now operate at about 25 MW; some two and half times the original design power output.

In this segment of the symposium, some aspects of the HIFAR design will be described and the reasons given for departing, in a few areas, from the original DIDO design.

3. DESIGN CHANGES MADE TO HIFAR

As indicated earlier, HIFAR was able to take advantage of the early operation of DIDO to incorporate some changes before construction had advanced too far. Some of the changes made were:

- Strengthening the Biological Shield
- Coarse Control Arm Blades and Guide Fork
- Fuel Flask Weight and Other Related Matters
- Raised Height of Top Plate
- Water Cooled Fuel Storage Block
- Direct Cooling of Heavy Water Rigs (by removal of thimbles)
- Elimination of Equipment for Fuel Element Emergency Sprays
- Fuel Element Shear Flask
- Experimental Flask
- Horizontal Flask

3.1 Strengthening the Biological Shield

As a result of radiation measurements of DIDO, shielding weaknesses were found in the area of the thermal column (Fig 4) where the ion chambers are located and around the annular rings (Fig 3).

HIFAR substituted iron shot concrete instead of barytes concrete and this produced lower radiation levels at the outer surface of the biological shield, particularly in the vicinity of the Control Room.

3.2 Coarse Control Arm Blades and Guide Fork

HIFAR staff expressed some concern about the lateral strength and stiffness of the long control arm blade, particularly when buffeted by the outward flow of heavy water when the arms passed through the zone of the fuel element heavy water outlet ports (Fig 3). We insisted to the designers, Hobson's of Wolverhampton, that the top and bottom flanges be strengthened to reduce stresses and be made stiffer (Fig 5). Our position was vindicated when the cladding failed where it joined the pivot block following vibration tests in the DIDO Active Handling Bay.

At about this time, another safety significant problem occurred at the pivot block guide fork (Fig 6). It was discovered that the different coefficient of expansion between the stainless steel wearing strip on the inside of the guide fork and the fork itself acted in a bimetallic fashion, which closed the gap when heated, thus causing the pivot block of the arm to seize. This effect was eliminated by fitting a stainless steel compensating strip, similar to the wearing strip, on the outside of the guide fork.

3.3 Fuel Flask Weight and Related Matters

The upper body of the original DIDO fuel handling flask was found to be seriously deficient in shielding capacity when the first irradiated fuel element was unloaded. Since the flask weight of about 16-17 tonnes was well within the 20 tonne reactor crane capacity, the shielding weakness was corrected by welding a steel cone over the upper flask body and filling it with lead shot, but keeping the total weight just below 20 tonne.

Head Wrightsons were advised of this problem and they altered the shape of the flask (Fig 7) for the PLUTO reactor to add more lead and made the flask shape for HIFAR the same. The increased load took the weight of the PLUTO flask to 23 tonnes which was unacceptable because PLUTO has a 25 tonne crane. However they forgot that the HIFAR crane capacity was only 20 tonnes and proceeded to supply essentially a PLUTO shape flask. Quite by accident, the weight was checked by R W S Carlson who discovered the error just before lead was due to be poured into the conical sections. The solution finally agreed, was to place a 4" layer of high strength temperature resistent concrete on the outside of the cones before pouring lead. This reduced the weight to just under 20 tonnes.

Another change concerned the emergency flooding connection. This was originally provided on the DIDO flask as an emergency air cooling port should an element become stuck during insertion into the DIDO air cooled storage block. The connection on the HIFAR flask was raised and local shielding increased because shielding weaknesses and radiation shine out the tube occurred at DIDO.

The other items of interest concerned the mechanically operated grab. Two steel fingers are pivotted to lock on to and release from a mushroom attachment screwed into the fuel element shield plug. The fingers on the DIDO flask opened during a fuel unload resulting in an element being dropped from the full up position onto the plenum chamber. Fortunately no detectable damage was done to the nozzle boxes but Harwell immediatley changed the mechanical grab to a pneumatically operated arrangement. This incident occurred during manufacture of the HIFAR flasks and after extensive tests with the shield plug and muchroom, it was decided to continue with the mechanically operated grab. In 30 years over 9,000 operations have been completed without ever dropping an element. The other change made at HIFAR was to the original grab open/closed microswitch wire which tended to lose the correct tension for winding and unwinding. A rearrangement providing constant tension was added and this has successfully operated for nearly 30 years. Generally speaking, the fuel handling flasks have functioned very well over their 30 year life time.

3.4 Raised Height of Top Plate

On the original design drawings for DIDO the space between the under-surface of the top plate and the master plate was very small (Fig 3) and to gain access to equipment, both the inner and outer rigs would have to be removed at shutdowns. To avoid this situation, DIDO was able to increase its space by some 10", however HIFAR was able to increase it to about 24" which considerably improved maintenance access.

3.5 Water Cooled Fuel Storage Block

The original DIDO fuel storage block was air cooled. HIFAR staff were concerned about gamma heating of the concrete shield and decided to change to a water cooled block (Fig 8). This decision proved to be very successful as it avoided the costs and complexity of emergency water cooling flooding following loss of air and the subsequent removal of water to restore conditions to normal.

3.6 Direct Cooling of Heavy Water Rigs

The original design of DIDO provided for a light water experimental cooling circuit to provide coolant for both vertical and horizontal rigs. The general clutter of pipes under the top plate area combined with the potential for introducing light water into the heavy water, or flooding the top plate area, plus the need to shield the pipes from N16 gammas and activated corrosion products, lead HIFAR staff to conclude that direct cooling of rigs in the heavy water by placing holes in the unperforated thimbles would provide the necessary heat sink and be a far safer and simpler proposition. Experience to date has vindicated this decision.

3.7 Elimination of Equipment for Fuel Element Emergency Sprays

The original fuel elements for DIDO contained a small spray nozzle just above the fuel plates, fed by a small tube through the shield plug for decay heat removal during loss of coolant. These tubes were supplied by 25 rubber tubes from a water cooling system. They provided considerable clutter at the master plate area of the core and as the small bore holes in the nozzle easily blocked and the flow was practically negligable, it was decided not to install this equipment on HIFAR.

3.8 Fuel Element Shear Flask

The original fuel cycle envisaged irradiated elements residing in the No 1 Storage Block for some weeks, followed by transfer to an air cooled No 2 Storage Block in the Active Handling Bay for further decay. At this point each element was to be raised into a Shear Flask placed above a Dounreay transport flask located in a pit near the No 2 Block. Two horizontal shear blades were designed to remove the nozzle and upper aluminium assembly from the fuel box, which would then drop into a hole in the 25 hole Dounreay flask.

This arrangement was not successful. Shear plates sometimes broke, sometimes sheared in the wrong place and were difficult to remove, particularly if, as on one occasion, an irradiated element was stuck in the body. It was decided at HIFAR not to proceed with this arrangement, but to develop an underwater saw to cut away the unwanted attachments, leaving the fuel box only as a gamma irradiation source for subsequent storage. This approach has operated successfully for some 28 years and Fig 9 shows the flask used at HIFAR to rough shear the shield plug from the element before finally sawing away the unwanted aluminium components from the fuel box.

3.9 Experimental Flask

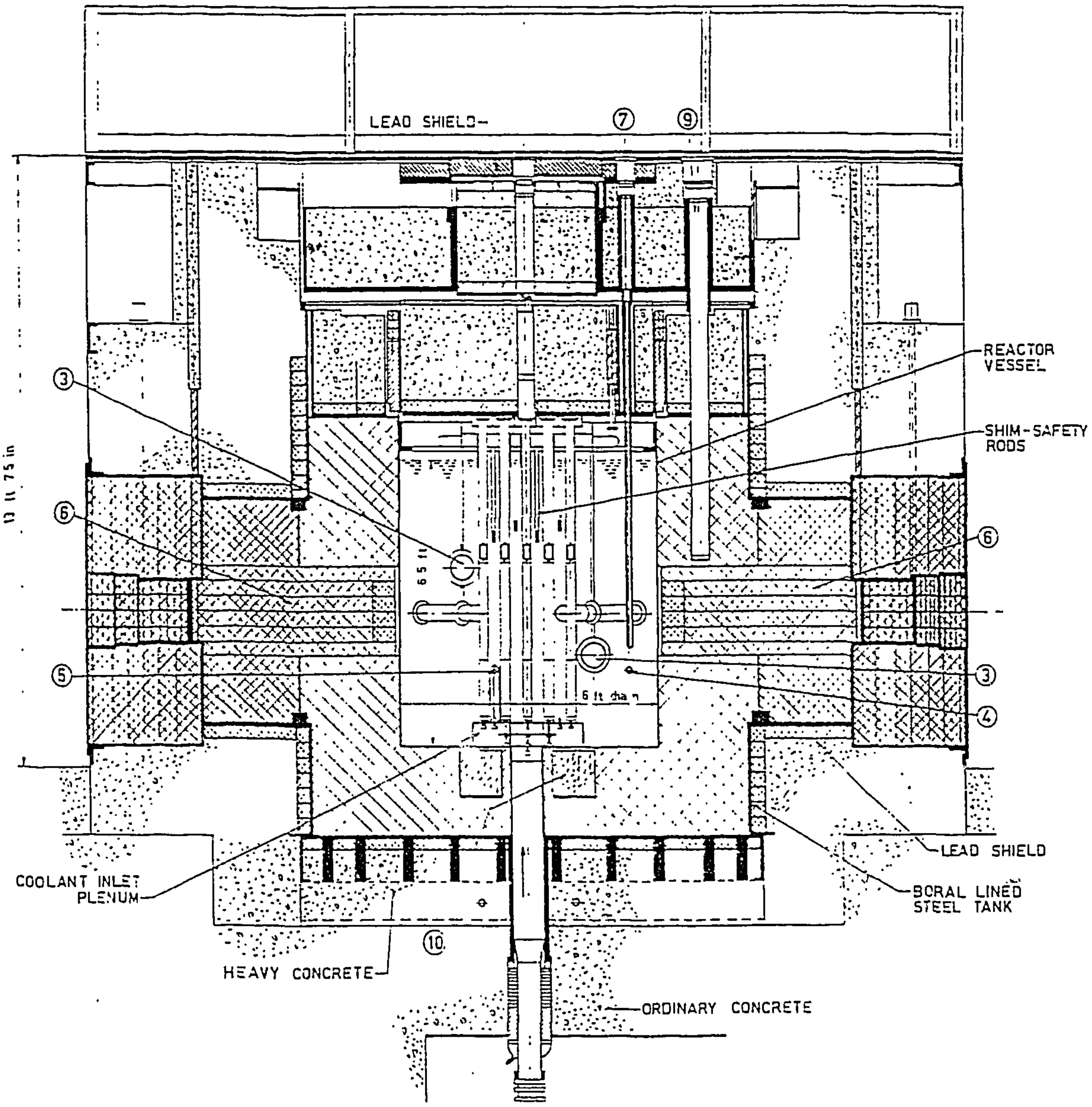
A flask was designed for DIDO based on the fuel element flask design consisting of a stainless steel and lead shield. This was estimated to cost £30,000 to construct and only £8,500 was available in the budget. Since experiments were much less active than fuel elements, the shielding could be completely redesigned to be made of cast iron; aluminium spray coated. This design tendered at £7,900 and was fully successful for about 25 years, removing and inserting experiments in the vertical facilities.

3.10 Horizontal Flask

Another component in the DIDO active handling cycle was a flask for loading and removing horizontal rigs. Such a flask was provided for HIFAR, again constructed of cast iron, but its use was abandoned because of the difficulty of locating it on the reactor shield face without having to remove nearby experimental equipment and the problem of lining it up accurately with the hole accepting the equipment. Experience has shown that the provision of shielding muffs over the end of radioactive equipment, distance and speed of handling achieved the objective in a simpler, safer and less costly fashion.

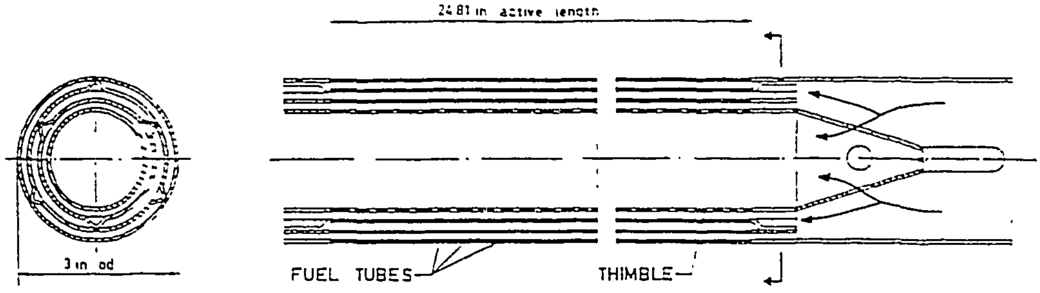
The fact that the DIDO class reactors have operated safely and efficiently for over 30 years at power levels up to 2½ times the design level and well beyond their original design life times is testimonial to the general soundness and conservatism of the original design. As can be expected, some design problems have arisen, but these have been solved at HIFAR eg, repairs of the lead shield cooling coils. In looking at the overall success of the design, the one area where simplification could have been of significant benefit is in materials handling. The relatively complex shielded and remotely operated equipment for safely transporting small but highly radioactive components for further processing, is a costly and time consuming burden borne by the reactor and its staff over the years. The relative simplicity of active handling in a swimming pool reactor would be a strong factor in any future decision to replace HIFAR when it reaches the end of its useful life.

Fig 1

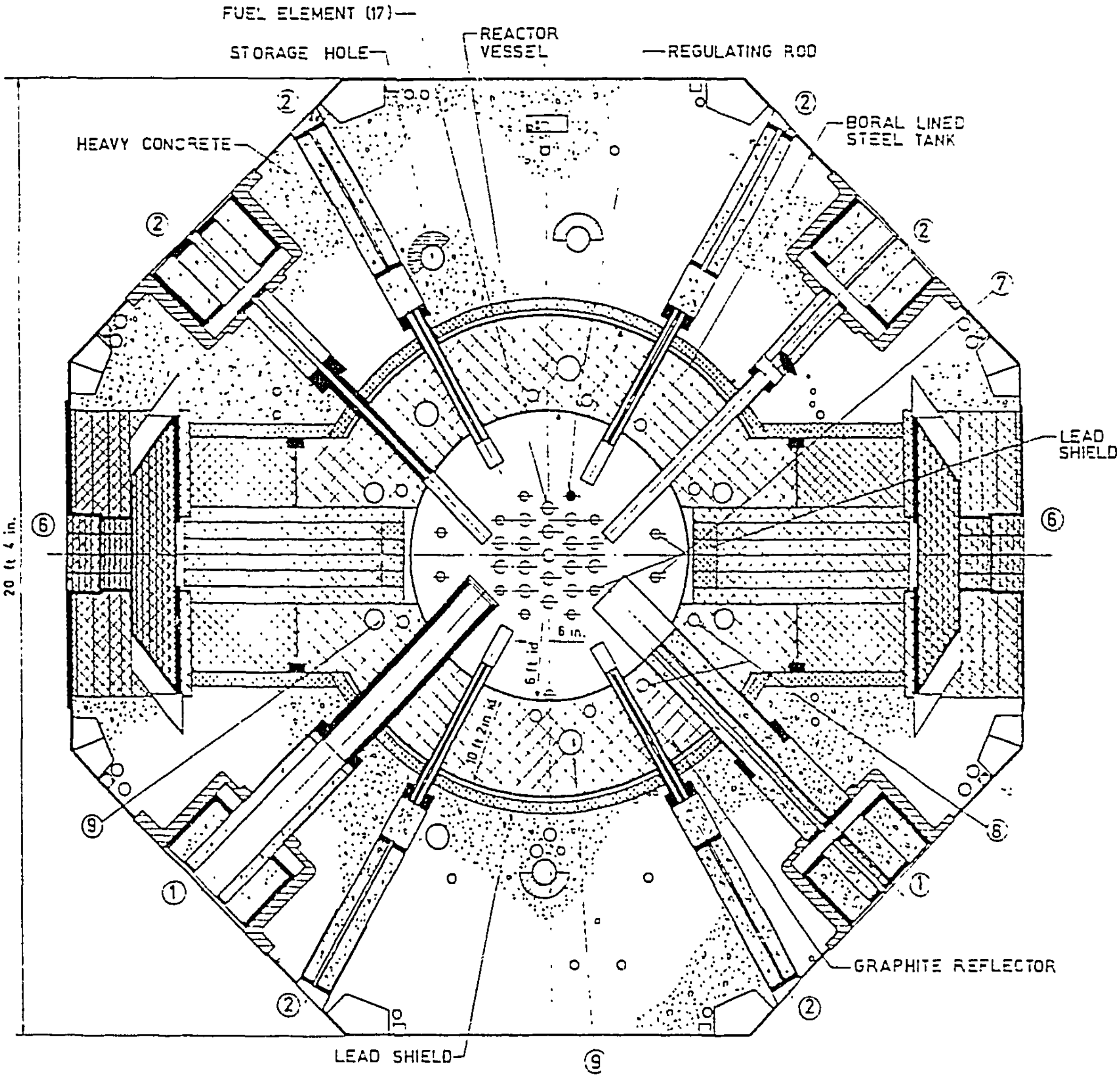


VERTICAL SECTION REACTOR CP-5

Fig 2



FUEL ELEMENT



HORIZONTAL SECTION REACTOR CP-5

Fig 3

REFLECTOR AND ALUMINIUM TANK

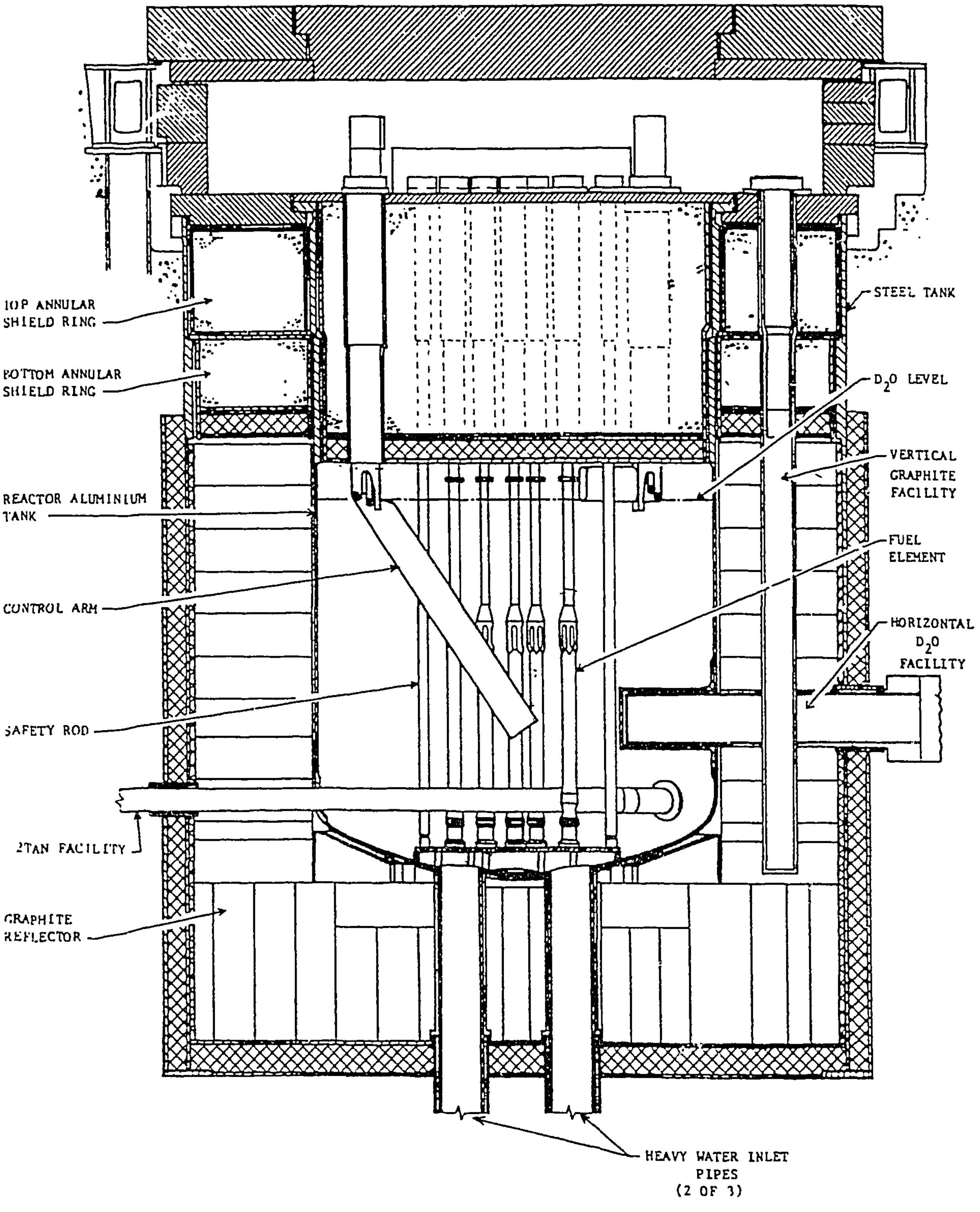
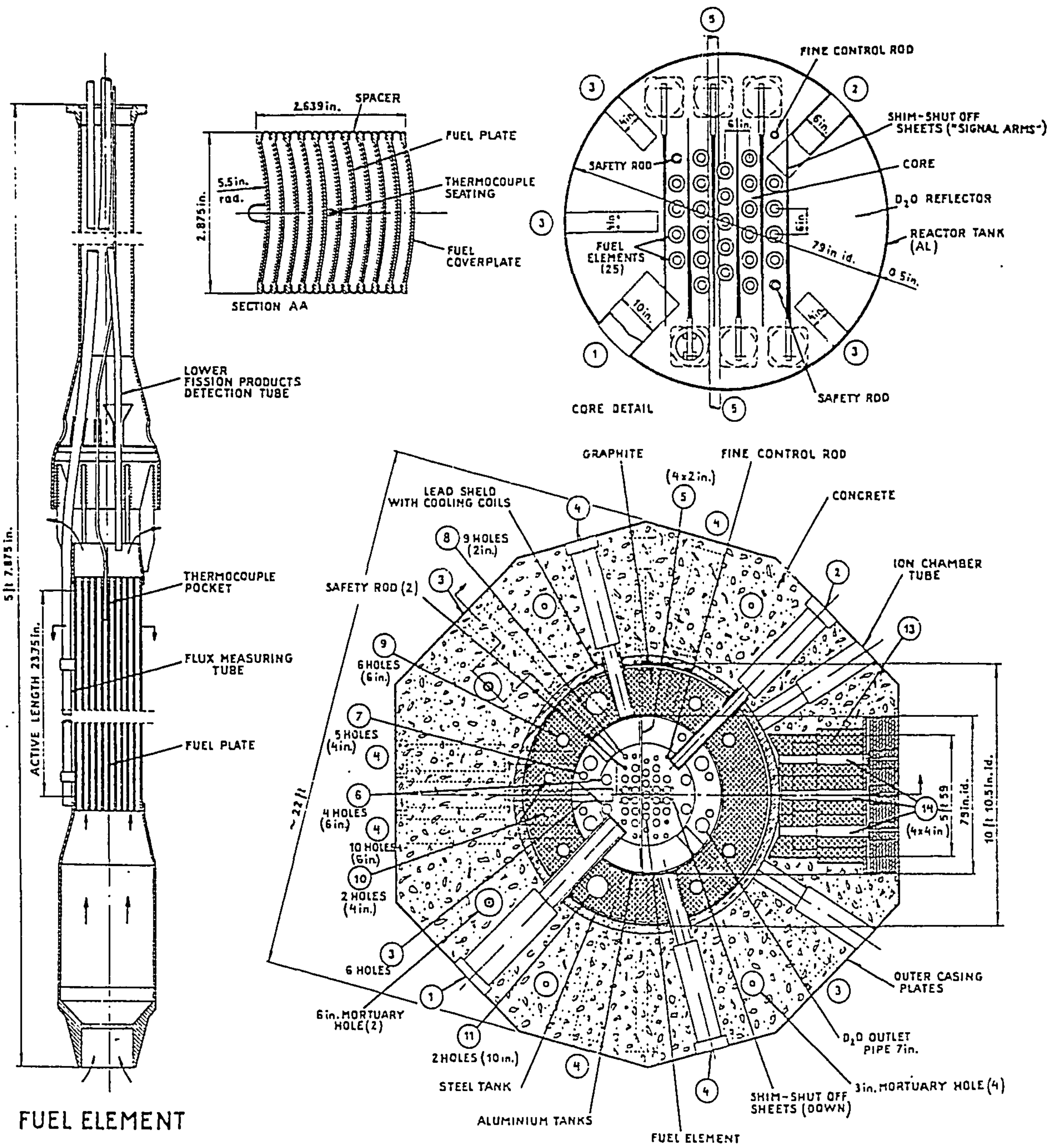


Fig 4



FUEL ELEMENT

HORIZONTAL SECTION DIDO REACTOR

CONTROL ARM BLADE

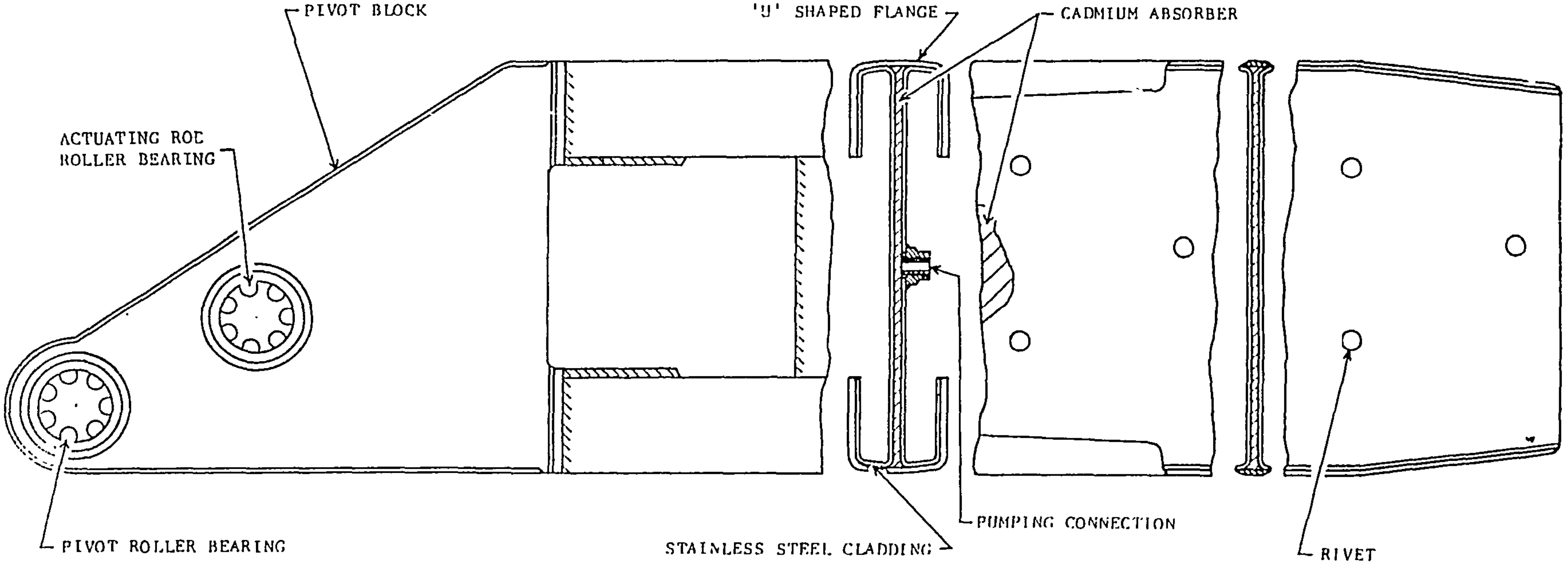


Fig 5

Fig 6

CONTROL ARM ASSEMBLY

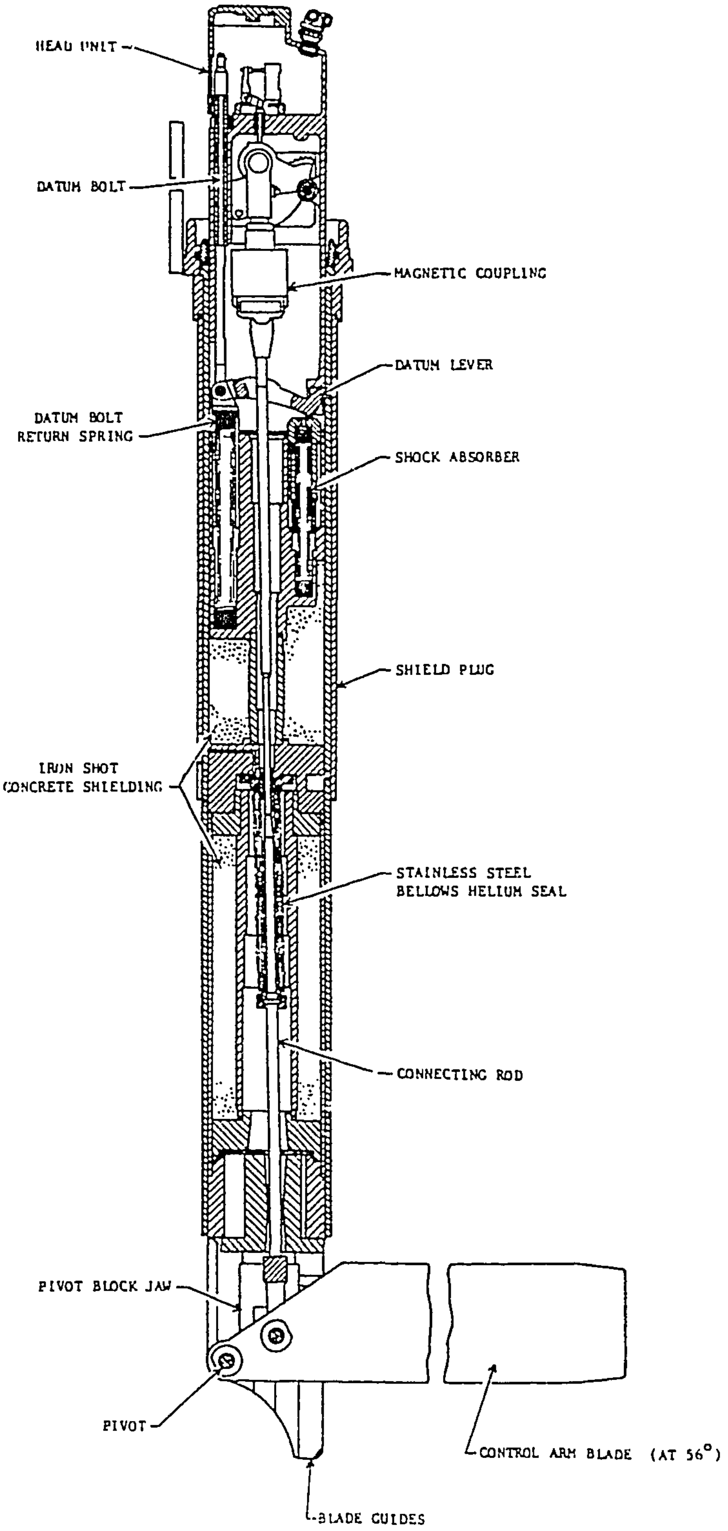
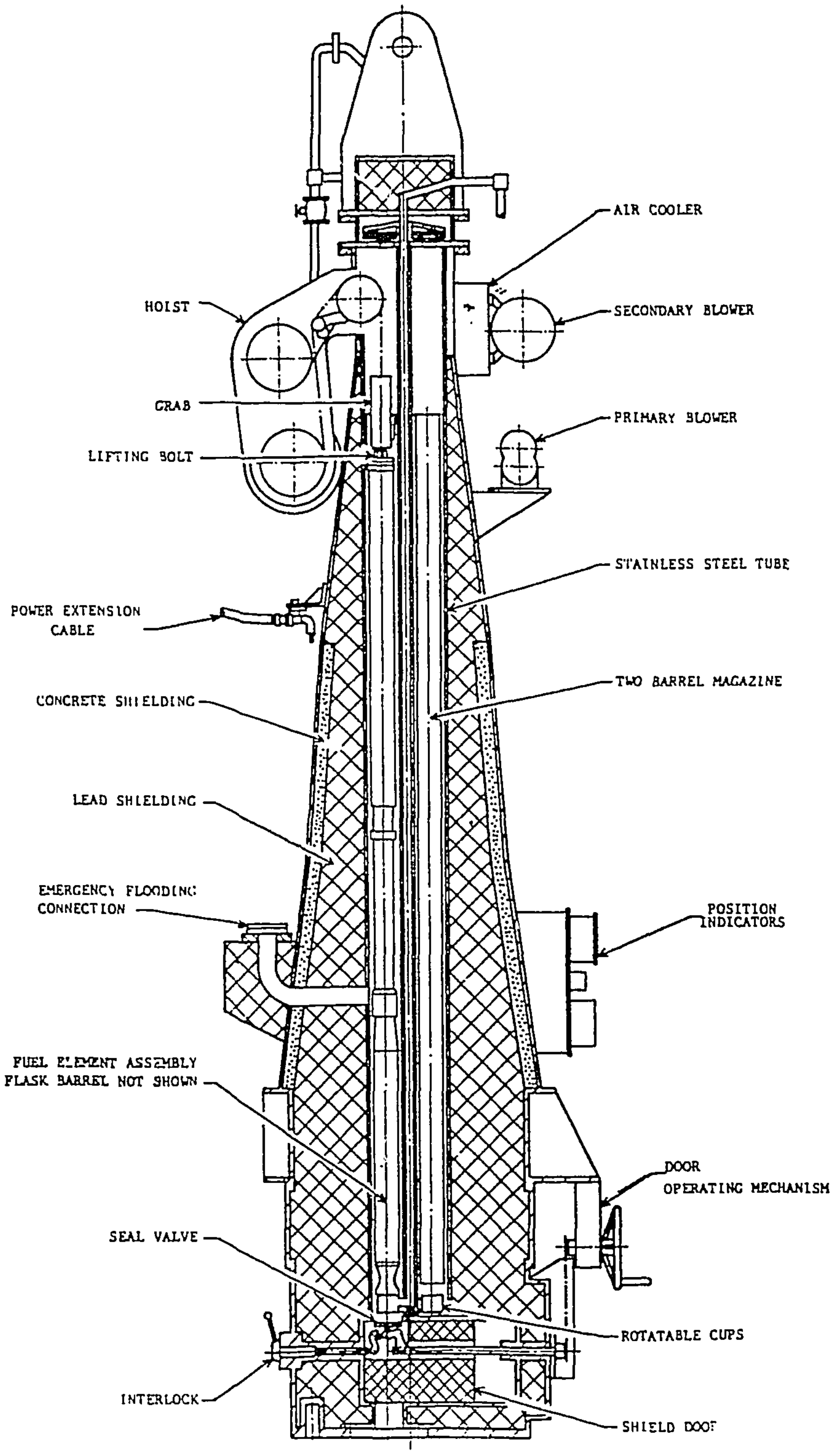


Fig 7

FUEL ELEMENT LOAD/UNLOAD FLASK



NO.1 STORAGE BLOCK VERTICAL SECTION

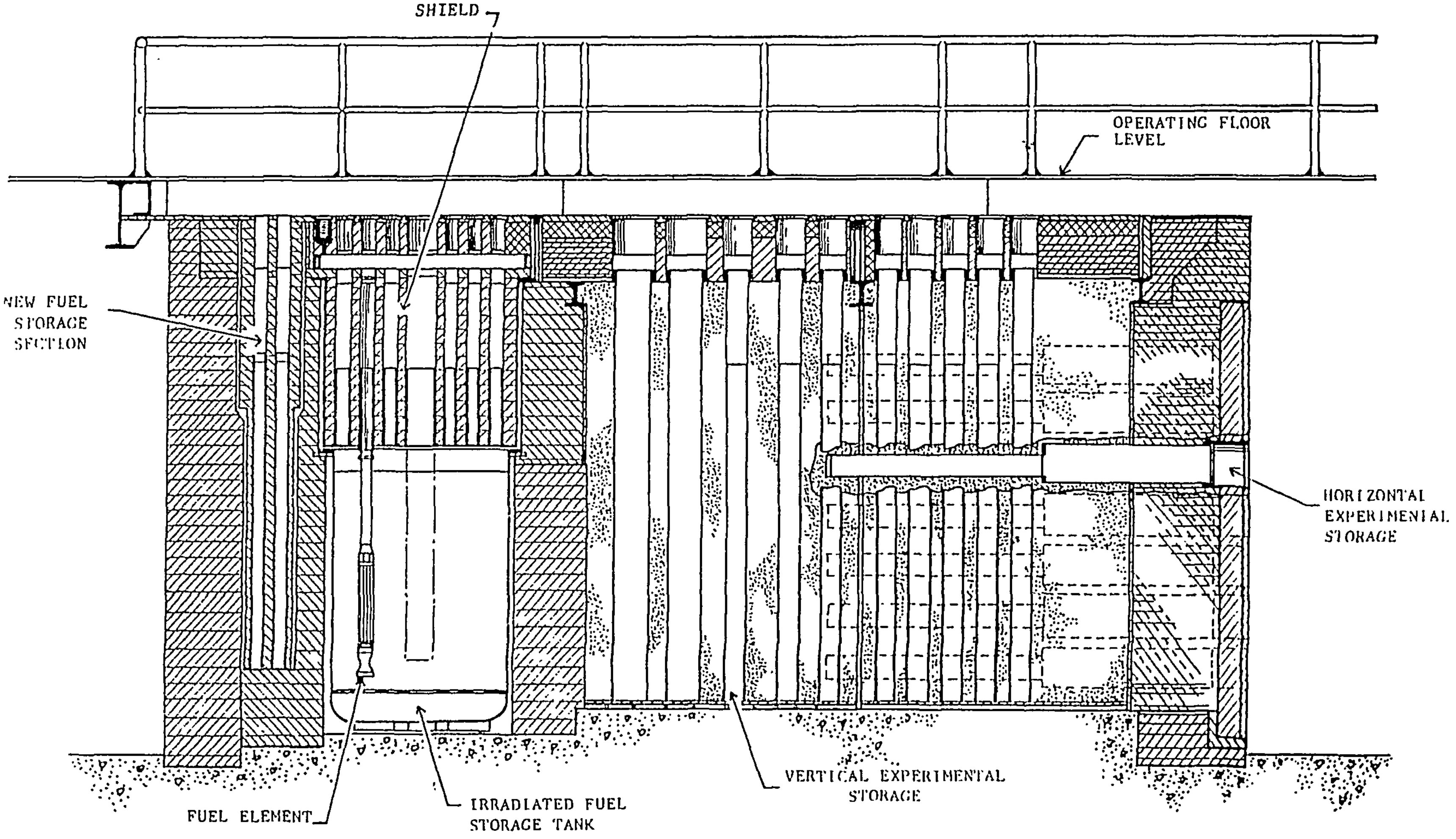
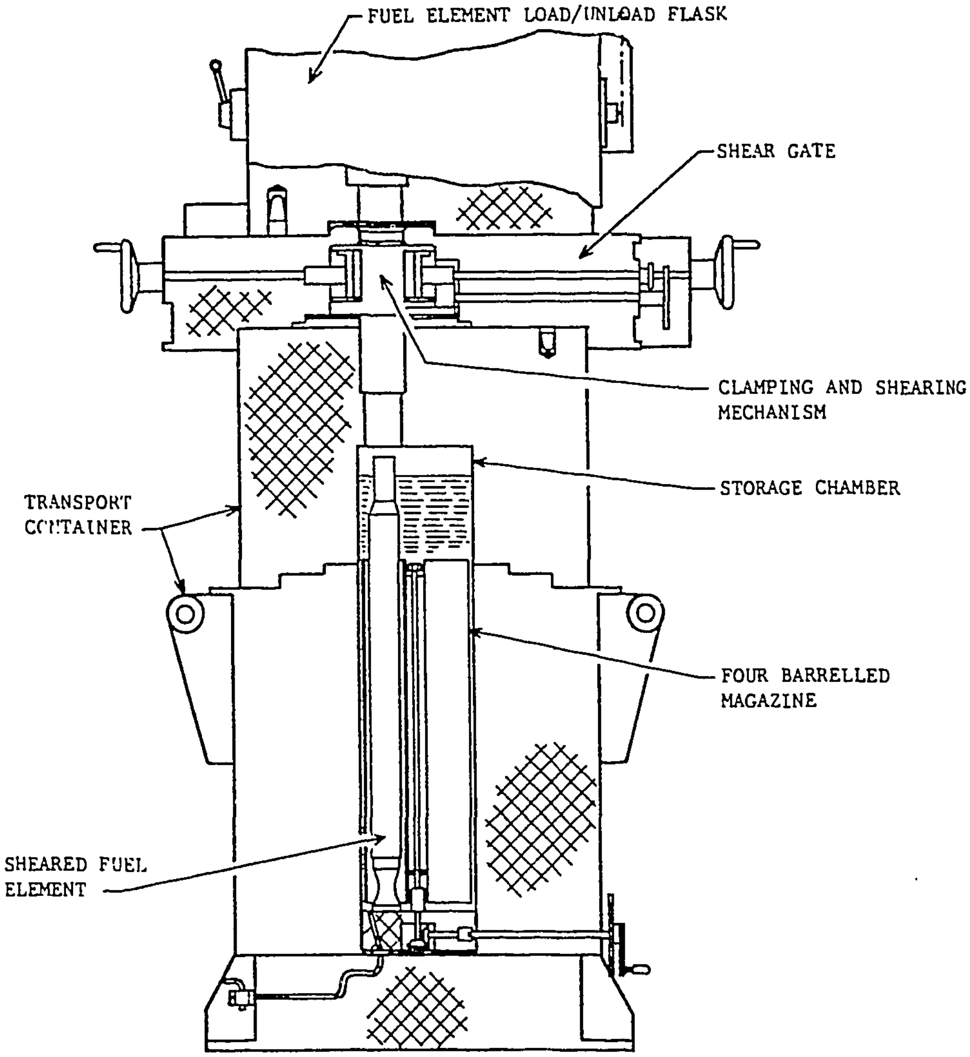


Fig 8

Fig 9

FUEL ELEMENT SHEAR AND TRANSPORT FLASK



INSTRUMENTATION AND CONTROL ASPECTS OF HIFAR

by

J. Parry

March 1988

Introduction: It is not possible in a brief review to describe the instrument configuration of HIFAR in detail. The purpose of these notes and the associated discussion is to give some of the historical background to the construction project, to indicate modifications necessary for early low power operation and to offer some comments on the design philosophies of the times.

The Installed Instrumentation: In common with the major mechanical contracts, the placement of orders for HIFAR instruments followed the procedures for the UK DIDO reactor. Mr George Page, a New Zealander, was appointed as senior officer for instrumentation and control in the Australian group assembling at Harwell in mid 1955. George Page had an extensive background and detailed knowledge of the measurement techniques relating to the important physical parameters such as temperature, pressure, flow etc. He also possessed the capacity for meticulous attention to detail necessary for complex contracts such as those involved in the HIFAR project. He was assisted in the field of neutronic measurements and electronics by the author.

The latter part of 1955 was occupied with familiarisation with the DIDO system and discussions with the Harwell personnel responsible for the UK project. The firms involved in the HIFAR instrumentation contracts and already manufacturing equipment for DIDO were George Kent for the conventional instruments, EKCO Electronics for the neutronic equipment and safety circuits and Hobsons Engineering for the control absorbers. Over the next year regular progress meetings were held both with the individual instruments firms and periodically , with their representatives and the prime contractor, Headwrightson Processes. At these meetings matters such as the maintenance of time schedules, the necessary quality compliance aspects and proving tests were closely monitored. During this period close contact was maintained with the DIDO project team and many potential difficulties with the Australian project were avoided by this fortunate collaboration.

Following the DIDO startup and completion of the essential aspects of contract monitoring the Australian staff involved with the HIFAR project returned to Lucas Heights during 1957. When the construction of HIFAR had reached the appropriate stage, representatives of the UK contracting firm (Mr D. Sylvester for George Kent and Mr R. Davis for EKCO Electronics) worked with the local sub-contractor on the installation of the control room equipment and the extensive wiring runs necessary within the control room, and to the various instrument locations within the reactor complex. Again the highest quality standards were demanded; for example, high temperature mineral insulated cable was used extensively. The close of 1957 was involved with checking out detailed test schedules and proving runs of the instrumentation before acceptance from the contractors.

Startup Instrumentation: The permanent instrumentation discussed above was designed for routine reactor operation at a nominal 10 Megawatts. It is a characteristic of heavy water reactors, such as HIFAR, that they develop a strong "built-in" neutron source after a period of full power operation due to photoneutron reactions of the fission product gamma rays on the deuterium in the moderator. The neutron flux therefore never falls below that equivalent to a few watts even after extended shutdown periods and the designed instrumentation is not required to cope below this level.

For the initial reactor startup and the first months of low power operation, even if a portable neutron source was located near the core, the equivalent power levels were far below those expected for the built-in instruments. Typically these early neutron flux levels corresponded to power levels of microwatts to some hundreds of milliwatts. It was therefore necessary to modify and supplement the existing equipment for the initial startup and this early period of operation. The requirements for this supplementary instrumentation were determined by Dr Colin McKenzie, the reactor physicist who had assisted in the DIDO startup, and by the author. Several of the "shutdown amplifiers" in the installed instrumentation were electronically modified to enhance the sensitivity and ion chambers temporarily located close to the reactor core. However the main additions were extra channels of pulse counting equipment. The use of neutron counters (both boron trifluoride and fission chambers) rather than mean current ion chambers provided many orders of magnitude enhancement in sensitivity. These counters were fed to several linear and several logarithmic pulse counting channels thus providing duplicated control and automatic shutdown facilities.

Safety System Design: The HIFAR instrumentation essentially performed three main functions. It provided startup interlock circuits which ensured that essential pre-startup conditions were met before reactor operation could begin. It provided for measurement and display of all the important reactor state parameters for the control of the plant. Finally it monitored important reactor variables and provided automatic plant shutdown if these moved outside safe operating regimes.

The principles to be followed in the design of reactor protective systems have now been standardised and accepted internationally (at least by the western nations). In the mid 1950s when the DIDO design originated these principles were in the evolutionary stage. Looking now at the original HIFAR design as it was before the recent refurbishment program, it appears that it would not meet the modern requirement for complete separation of control and protective functions. However, other important safety concepts such as redundancy, diversity etc. can be seen in the original design. Overall, it comes across as a very carefully thought out and executed system.

The safety circuits were implemented using proven PMG type electromagnetic relays, probably the most reliable technology available at the time. The monitoring contacts were arrayed in two separate circuits, the primary and secondary "guard lines". The distinction between these was that the primary line contained the original actuator and the secondary line relied on a slave contact. In the safe condition all contacts were closed providing a complete electrical circuit in each of the guard lines and permitting the holding electromagnets on the control absorbers to be energised. The control absorbers could then be withdrawn from the core during startup. Violating any of the safe operating conditions caused a contact to open in each line. An open circuit in either of the guard lines initiated an automatic shutdown.

Most of the important safety concepts currently accepted can be found to some extent in the original design, although the implementation of these concepts is not as clear cut as would be expected in recent designs. The monitored parameters employed diversity; for example a potential power excursion would be detected by rate of change of neutron flux, level of neutron flux and fuel element temperature. Where electronic instruments were involved in safety monitoring, and 100% reliability could not be guaranteed, redundancy (multiple channels) was employed. To avoid single instrument failure causing unnecessary shutdowns, the principle of coincidence was included with the redundant channels leading to the well known "two out of three" majority voting systems. In addition to these design aspects the high standards of quality control demanded, and the attention to detail in such matters as relay contact materials and ratings, has paid off in a system which has proved to be extremely reliable and efficient over many years of safe operation.

HIFAR COMMISSIONING & OPERATION

(1955 - 1962)

G. A. TINGATE

1. INTRODUCTION

It is 6 years since I retired from the AAEC and about 25 since I was associated with HIFAR. On the occasion of the anniversary of the first criticality on Australia Day 1958, it is appropriate to place on record an appreciation of the contributions of all who were associated with the design, supply, construction, commissioning and operation of HIFAR and its many irradiation rigs over the years. My personal thanks must go especially to the hundred or so members of Reactor Operations Group during my 5 years with HIFAR, many of whom were called upon to break new ground in a new technology. Credit is also due to those responsible for the operation and maintenance of HIFAR over the subsequent 25 years, particularly in view of the fact that the useful life originally specified for the DIDO type reactors was 25 years. This figure was based on amortisation considerations rather on technical grounds, as evidenced by the fact that HIFAR is still alive and well, and looks set for successful operation to the end of the present century.

From 1949 to 1955 I was a Project Engineer in the Design and Construction Department of the State Electricity Commission of Victoria. The late W. H. (Bill) Roberts was a member of the same department during this period, and although I knew him well I did not work directly with him. Towards the end of 1954 he joined the AAEC and proceeded with his family to Harwell. Shortly afterwards I was interviewed in Melbourne by Charles Watson-Munro and Alan Wilson, resulting in an appointment which took me and my wife to Harwell in June 1955.

2. HARWELL AND DIDO (1955-57)

On arrival at the Atomic Energy Research Establishment at Harwell I was allocated to Bill Robert's team and attached to the UKAEA Engineering group. By that time DIDO had been under construction for about a year, but many aspects, including the handling flasks and storage blocks, were still being finalised. Tests and reviews were also under way on many other features of the reactor proper, and the results were consolidated progressively in manuals for the benefit of operating staff. One test rig was a mock up of the reactor tank and core with dummy fuel elements. Ordinary water was circulated in order to study turbulence in the tank, vibration of control arms and other effects. As a result the fuel boxes were reinforced and the fuel element outlet port configuration was altered in order to reduce the turbulence. Lateral stiffeners were also added to the control arms. Another test was of the emergency water sprays which were incorporated in the fuel elements at that time.

Theoretical investigations were also carried out to establish whether various aspects of DIDO were inherently safe, with a view to minimising operating restrictions and increasing the power above 10 MW at some future date. The approach was to assume the worst case and calculate the resulting temperatures etc. under the most pessimistic assumptions. In a surprisingly large number of cases the results were favourable, making it unnecessary to refine the investigations further. One notable example was to assume that the heavy water was lost from the fuel elements but not from the tank proper. It was shown that the fission product decay heat would be conducted safely to the outer box of the fuel element following a sudden shut down from 10 MW. The results of such calculations were not always so clear cut. For instance it appeared that gamma heating in the DIDO air-cooled fuel element storage block might result in excessive concrete temperatures. Thermocouples were therefore installed, but the temperatures turned out to be innocuous enough in service. This 'scare' was partly instrumental in the decision to provide a water-cooled storage block for HIFAR.

In mid 1956 I was advised that I would be in charge of Reactor Operations Group on my return to Australia. I was immediately transferred on attachment to DIDO, which was undergoing final commissioning and testing prior to the loading of the heavy water and first fuel elements. By that time the late C. A. (Charlie) Logan had been on attachment to DIDO for some six months. Colin McKenzie was attached to the UKAEA Reactor Physics team preparing for the criticality measurements. Criticality was achieved in November 1956. In the meantime Bill Roberts had returned to Lucas Heights, where the construction of HIFAR was running about one year behind that of DIDO.

During the period of my attachment DIDO was commissioned, routine full power operation was established, and the first irradiation rigs were loaded. The DIDO staff kept us well informed of major developments, and clearly welcomed the opportunity to compare notes and ideas with independent observers. Something like 300 modifications were mooted in the light of experience, and the construction schedule at Lucas Heights allowed about 150 to be incorporated into HIFAR. Close contact was maintained throughout with the staff at Lucas Heights, and virtually no construction time was lost because of the changes. One notable exception was the shielding of the thermal column. Measurements on DIDO revealed areas of minor weakness just as that zone of HIFAR was about to be poured. This was held up for a few days while details were being worked out as to where iron shot concrete should be substituted. At the time of my departure from DIDO in August 1957 a number of rigs had been loaded, and a rather elaborate water-cooled rig was being prepared for one of the vertical facilities. The cooling circuit external to the reactor was quite extensive, and lead bricks were being stacked as shielding. One or two such rigs might be accommodated without undue congestion, but it was clear that the number would have to be kept to a minimum, and avoided if possible in HIFAR.

3. HIFAR (1957-1962)

3.1 Commissioning and criticality

At the time of my arrival at Lucas Heights at the end of September 1957, construction was proceeding vigorously under the general coordination and control of Bill Roberts and his staff. Several contractors and sub-contractors were working at the HIFAR site, including the main reactor contractor, Head Wrightson Processes, and the building contractor, Hutcherson Brothers. Many of the HIFAR shift and day personnel had been recruited and had been on site for some time. The reactor steel building was essentially complete, the reactor steel tank was in place, and an enclosure was being constructed around the top of the reactor to provide clean conditions. The reactor aluminium tank was installed less than 3 weeks later, on 17th October.

Over the next few weeks responsibilities fell more and more on AAEC staff in anticipation of the loading of the heavy water and fuel, and the first approach to criticality. The final preparation of the reactor was carried out entirely by AAEC staff, and called for expertise in a wide range of disciplines. Several had returned from Harwell, including John Parry and the late George Page (Control and Instrumentation), Lloyd Smythe (Analytical Chemistry), Bob Fry (Health Physics), Bill Wright (Fuel Elements) and Colin McKenzie (Criticality). Even with this support the criticality date could not have been met but for the long hours worked by all. Each person remained on the job until the day's assignment was completed, whether at 5 pm or 3 am. No amount of coordination or preparation could have substituted for the continuity and momentum generated in this way.

3.2 Calibration of HIFAR

During most of 1958 and 1959 HIFAR was operated at a power of 1 watt for reactivity and other calibrations. At this power accurate but time consuming measurements are possible without undue secondary influences such as fuel depletion and the build up of fission product poisons. The reactivity effects of various materials in the more important irradiation facilities are of particular interest to Reactor Operations when assessing various loading configurations, and the results were examined from this point of view by the late Bob Wyber. During this phase much of the attention of HIFAR day staff was directed towards the many irradiation rigs being designed and manufactured on site. Most of these were not intended to be loaded until after full power operation was achieved, though two collimators were loaded in June 1959.

3.3 Early Irradiation Rigs

In the course of preliminary discussions with the various Irradiation Officers, it soon became clear that the materials used in many of the proposed rigs were suitable for direct immersion in the heavy water in the reactor aluminium tank. It was thus possible to avoid external water cooling systems for rigs in the vertical heavy water facilities by fitting them with suitably perforated liners. Most of the Isotopes rigs fell into this category. Brief particulars of some of the first rigs loaded into HIFAR are given in the following table.

RIG	DESCRIPTION	FACILITY	IRRADIATION OFFICER	DATE LOADED
X2	Collimator	4H1	Terry Sabine	18-6-59
X3	"	4H2	" "	"
X22	HTGC fuel	2V3	Brian Hickman	2-2-60
X19	" "	4V2	" "	19-2-60
X17	UKAEA	E2	Joe Bell	22-2-60
X18	"	A3	" "	"
X15	Cobalt	2V5	Gerald Newman	19-5-60
X13	"	2V2	" "	"

3.4 Operation of HIFAR at power

At the conclusion of the calibrations the power was raised in steps with a view to commencing routine 10 MW operation by the beginning of 1960. The Reactor Shift Superintendents had been interviewed some months earlier, leading to the appointment of Bill Cawsey, the late Peter Crooks, Ivan Mayer, Tom Stokie, Bernie Toner and Tony Wood. During the first weeks of 1960 shift supervision was undertaken by staff who had been responsible for various aspects of the commissioning and calibration of HIFAR to that point. They included Bob Carlson, Alan Marks, Colin McKenzie, George Page, John Parry, John Symonds and myself. The arrival times of the Reactor Shift Superintendents were such that Bob Carlson had to continue in this capacity until the beginning of 1961. During the early years of routine operation the late John Sinclair was largely responsible for the programming of HIFAR. John, Uldis Barda, Andy Bicevskis, Nat Burnett and Keith Tognetti carried out various Engineering investigations and collaborated with users and Project Engineers on new irradiation rigs.

With the commencement of full power operation a large amount of new information became readily available. Much of this could be obtained at any time, but some was only possible while starting up or shutting down. The reactor was usually shut down in a different way each time, for instance to test a particular trip or to record the effects of the various controls, such as the control reversal function. Independent estimates of the true reactor power were obtained by carrying out heat balances on both the heavy water and the light water circuits. Measurements were also made of the equilibrium temperatures of fuel elements unloaded at various times after shut down. These established that the emergency water sprays need not be used if the fuel is changed on the day following shut down, as was usual. Measurements were made of the shine from open experimental holes on top of the reactor during shut down, to explore the possibility of loading new rigs without a flask. The levels of radiation were much less than estimated, particularly from the hollow fuel element facilities.

4. THE STATE OF THE ART IN THE 1950's

As mentioned earlier, many of the assessments of DIDO and HIFAR were carried out in the first instance on pessimistic assumptions, which is reassuring enough when the results fall within acceptable limits. When they do not, restrictions and controls are often imposed which are unduly stringent. It is possible to eliminate or tone down some of these by making the appropriate measurements in service, but not when safety measures are intended to cover some hypothetical power surge or other highly abnormal behaviour. The usual attitude in the 1950's was to insist on a reactor trip function as a protection against each and every such contingency. A more rational line was adopted by the management of one overseas research reactor which was built at much the same time as DIDO. In addition to the full reactor trip function a power set-back function was provided, which could reduce the power to say 10% in about 15 seconds. Comprehensive transient studies were carried out on proposed loops and other experiments, and the power set-back function was sufficient in place of nearly all of the full trip functions which would have been required in other reactors at that time. As many as 100 such full trip functions might be installed at any one time in the one reactor. Ironically most of the trips occurring during the operation of those reactors stemmed from instrumentation faults and false readings.

Shut downs due to instrumentation were not a significant problem in HIFAR, partly because of fewer trip functions and possibly because the instrumentation was not so up-to-date and was therefore relatively free of teething troubles. The general approach adopted for DIDO and HIFAR was adequate for operation at 10 MW with the type of fuel elements etc. originally used. It clearly left much room for improvement before powers of 20 MW of more could be considered seriously. Even at these high ratings there should be some scope for minimising the number of trip functions through appropriate analyses.

Current HIFAR Operations, N.A. Parsons

and

The HIFAR Refurbishing Program, M.R. Allen

(A Joint Presentation)

CURRENT HIFAR OPERATIONS

by

N A PARSONS

March 1988

1. INTRODUCTION

> "The creation of ANSTO as the successor to the Australian Atomic Energy Commission in early 1987 was recognition that Australia's needs in nuclear matters have changed. The Organisation now operates under the new Australian Nuclear Science and Technology Organisation Act 1987, it has a new Board, and it has been moved to a different portfolio. The statutory functions and powers of the Organisation are prescribed in the ANSTO Act."

The above paragraph is an extract from the ANSTO plan of December 1987 which defines the corporate environment of HIFAR. Amongst other things, the plan emphasised HIFAR as a key national facility, and identified HIFAR operations and facility upgrading as activities within an outward looking nuclear technology program. This paper outlines the present operation of HIFAR within that program.

2. ORGANISATION

One outcome of the corporate plan was the transfer of HIFAR from the engineering service area of ANSTO to the research and output area. Responsibility for HIFAR operation now lies within the new Reactor Division, which has the activities given in Table 1 and the organisation shown in Figure 1. It can be seen that the HIFAR operating organisation consists of three main sections responsible for operations, utilisation and engineering respectively. Also in the Division are sections for HIFAR services and assessments, nuclear research and other nuclear technology associated work and for marketing.

In addition to the organisation for the reactor, there is a separate organisation for safety overview. The ANSTO act put in place of the Regulatory Bureau the Nuclear Safety Bureau as a separate arm of ANSTO with responsibility, amongst other things, for monitoring and review of HIFAR. Whilst the Bureau has access to the Minister, responsibility for the operation of the reactor lies with the Executive Director of ANSTO, and is delegated by him to the line management.

3. CURRENT SAFETY CASE

Until 1986 the major work on HIFAR safety was the HIFAR Safety Document of 1972 which, together with the 1982 supplement, comprised the safety analysis report for the reactor. The supplement took account of the changes to the reactor since 1972, and postulated that the reactor was safe and that it met the Interim Siting Criteria of the AAEC. The plant changes of particular relevance then included:

- Emergency Core Cooling Systems (ECCS), where automatic ECCS had been provided to give compliance with the ISC single fault criteria during a LOCA.

- Containment Isolation Systems (CIS) which were provided to confirm assumptions of redundancy made in HSD Section 7.10.7.

- Space Conditioner System (SCS) which had been improved in a number of ways, notably the provision of automatic controls which preclude a possible need for manual control during a LOCA.

- No 1 Storage Block where amongst other things pipework modifications now preclude simultaneous loss of storage block coolant and containment breach.

- Nozzle flow straighteners installed in the reactor tank remove the need for special constraints on the power of peripheral elements.

- Reactor Building insulation, where the original flammable material has been replaced by non-flammable insulation to reduce the fire risk.

- Standby Diesel fuel pipes, where modifications, together with load transfers to other diesel alternators, reduced the risk and consequences of fire damage to the power distribution system.

However, the Safety Document and Supplement used deterministic arguments conforming to the criteria of the ISC. In 1982 the Commission had not formally withdrawn the ISC, which remained for guidance, but a new set of criteria was promulgated by the Regulatory Bureau. These criteria, which are still current, are largely probabilistic and a study to produce the matching safety argument for within-plant failures was completed by a special technical group in 1986 (Report of the HIFAR Safety Analysis Working Party Task (b) Group, DR22). The results of the study are summarised in Figure 2. In a subsequent paper, F D Nicholson (1987: RD/TN108) has concluded that all of the fault sequences examined in DR22 "either comply fully with the ... requirement of the Regulatory Bureau principles document ... or whose likelihoods and consequences are sufficiently small for compliance ... to be claimed." Mr Nicholson's interpretation of som of the principles is given in Figure 3.

Subject, as always, to review of the work so far, it now remains to be demonstrated that there is similar compliance for sequences due to external initiating events. In the meantime the work to 1982 was judged sufficient to recommend that the restrictions in land usage beyond the 1.6 Km exclusion zone be lifted.

4. PLANT CHANGES

In common with other MTRs, HIFAR is subject to continuous change not only to update safety and to modernise, but also to adapt the reactor to changing demands. In the last decade some 54 major and 340 minor modifications have been registered. The current rate is 50 a year. While there have been some cancellations there remain some 50 changes in hand for practical completion and over one hundred awaiting formal completion. In addition to the large tasks comprising the refurbishing program to be dealt with by Mr Allen in his paper, current changes include:

- The RCB crane equipment
- New nucleonic instruments.
- Remote starting of main circulators.
- Personnel monitor.

Changes to the crane include the fitting of a new reserve brake scheduled for this calendar year, and, as a separate matter, the provision of remote control by radio transmitted pulse coded signals. The first is a safety related change that will provide redundant braking even under overload conditions. The second is intended to increase the efficiency of operations, but it also has the potential additional benefits of safer handling and reduced radiation dose to staff.

The original nucleonic instruments have given continuous service for the full life of the reactor, but the lack of spare parts has at last become critical. The shutdown amplifiers and period meters are being replaced, the amplifiers to be replaced by excess flux trip units. The new instruments will have the same nuclear trip performance as the old ones, but are expected to provide additional self checking, interlocking and operating features and conveniences. Installation of these instruments is expected next financial year.

With the introduction of a new data acquisition system as a major element of the refurbishment, there is less need for continuous manning of outside plant. However, if the operator is withdrawn, it is prudent to arrange for rapid restarts of main circulators if the reactor is not to poison out after temporary losses of main power supply. New starters are being installed on all main circulators with provision for operation from the reactor control room.

HIFAR has two personnel airlocks and hand and clothing monitors (Nuclear Enterprises Type CM6) are installed at both of these. Instructions require their use by staff leaving the Containment Building, but the instruction is not enforceable. The decision was taken to purchase a walk-through (portal-type) monitor to be installed at the airlock which carries the most traffic. Experience in its use may justify the purchase of a second monitor at a later date. The selected unit is the Nuclear Enterprises type IPM 7 monitor. The monitor has been delivered and is now being installed together with a swinging gate barrier. The installation is adjacent to a change/wash room at the entrance to the Building 40 airlock.

These and other changes will make the reactor easier to operate and will provide extra protection. On the other hand an increase in complexity is inevitable. For example Table 3 compares the engineered safety features now with the original designs and indicates that the number of systems has increased by a factor of 3. This trade off of simple or automatic operation with more complex plant tends to shift the pressure of work from the operating to the maintenance staff.

5. USAGE

The reactor operating statistics for 1988 are given in Table 2. They are typical for a year that does not include a refit. The number of trips is above average due to an intermittent fault in the control reversal system.

The largest single change to reactor capacity was the introduction of the hollow fuel elements in the 1960s, firstly the MK3 and now the MK4 (see Figure 4). This single change increased the irradiation capacity of the reactor by 25 50 mm diameter high flux facilities that are important revenue generators for ANSTO. Overall utilisation of the 81 facilities has been steady at 45-50% occupation. The present loading is given in the schedule for operating program 365 reproduced here as Table 4.

While the main demand for irradiations is for isotope production, ANSTO is now providing commercial irradiation services direct to industry. These services include neutron transmutation of doping of silicon in special rigs in the low flux irradiation facilities in the graphite reflector. The rigs and handling equipment can handle silicon ingots from 40 mm diameter to 127 mm diameter and up to 600 mm long, and irradiate them in 6VGR facilities. The present capacity is between 2 and 4 tonnes per annum, depending on the diameter of the ingots.

Trial irradiations were completed in 1986 and commercial irradiation started at the beginning of 1987. The flux monitoring is intended to be by SPNDS. These were recently installed and calibration and commissioning of the associated instrumentation is now in hand. In the meantime irradiations have proceeded on the basis of foil irradiations and product quality checks.

These irradiation rigs have proven to be useful for other irradiations and are currently used for the activation of sand and of mineral samples for neutron activation analysis, when not in use for silicon.

Turning to beam work, visitors to the reactor will see a number of developments in place especially the 6H facility. ANSTO has also supported investment in new instruments notably a new small angle scattering machine to be installed at a 4H facility by the Storage Block.

6. REACTOR CONDITION

The reactor itself has remained remarkably sound as far as can be determined by visual inspections. The reactor tank and heavy water circuit were last inspected in 1985 and a detailed report on this and the other inspections that year is given in O/TN48. With minor exceptions the reactor systems were found to be in good order and no evidence of deterioration of the tank since 1979 was indicated.

An exception is the shield cooling system which was damaged early in the life of the reactor and partially repaired in the late 1960s. No further deterioration has been observed and the balanced circulation system installed at the time remains in service.

Inspections of the containment building shell carried out in 1982 revealed that at a number of points rain water and condensation had been trapped in pockets formed by the steel work and local severe corrosion of the steel had taken place. A repair program was set in place, and is now complete, together with the repainting of the whole structure.

The main heavy water circulators are giving good service after a period of unreliability in the 1970s. In March last year the main circulator in position No 3 was removed from service for reconditioning. Taking into account that the pump has been in service since 1977, it was found to be in fair condition. The wear on the rotor bearings was well within the limit and no damage due to wear in the bearings was found on the stator or pump casing. The upper thrust bearing was well worn and the pads had deep grooves on the bearing faces. The stator is in good condition and megger test results were within the normal limits. The only damage was to the binding materials and plastic separation rods due to the longer than usual exposure to radiation. This is the second circulator to exceed the design service life by a significant period. In 1986 the last circulator to be removed was still servicable after 8 years service. The high reliability achieved is evidence of the effectiveness of the changes to maintenance procedures made in early/mid 1970s to overcome the bearing failures experienced at that time.

The information from these two units suggests that the optimum period between refits is now about seven years, which is the equivalent of 5 years continuous operation.

The McLaren diesel has failed. Last year routine tests of the original standby diesel gave indications of a cylinder fracture that required the diesel to be taken out of service. In view of the imminence of the new standby supply system (see paper by Mr Allen) the decision was taken to dispense with the machine in favour of a mobile diesel alternator as an expedient until the new supply system was commissioned. No repair has been attempted.

Following a detailed survey of the polar crane by Plant Subsection an assessment was made of the bridge structure with respect to fatigue. The results showed that fatigue presents no problem. However, it was considered prudent to engage an independent body for future routine surveys of all cranes in the HIFAR complex that are used to handle irradiated fuel. The current contract is with Lloyd's Register of Shipping Inspection Services.

7. PUBLIC RELATIONS

HIFAR continues to be an exhibit of interest to most visitors to the Laboratories, both official and private. However, last year a wider audience was reached through the enterprise of Channel 10 and the breakfast show "Good Morning Australia". The duration of the broadcast was two hours and it was transmitted live with the anchor team inside the RCB. The exercise involved about 30 people from the television company.

The outside broadcast van was stationed inside the building by the vehicle airlock, and cables were run to the antenna on a nearby roof.

8. CONCLUSION

In conclusion, while there have been a number of changes to the plant, a number of plant repairs have been necessary, and safety is subject to continuous review, the reactor appears to be in good shape and surprisingly little change to the reactor itself has been necessary. It continues to be in good order and the present condition justifies the judgement, selection and work of 30 years ago. Our challenge now at HIFAR is to manage the operation to meet the changing demands of nuclear science and of industry and at the same time maintain the highest standards of safety at an acceptable cost.

TABLE 1 - REACTORS DIVISION SPECIFIC ACTIVITIES

- Safe and efficient operation of the reactor HIFAR as a national facility to produce radioisotopes and provide irradiation facilities for basic and applied research;
- Maintenance of the necessary competence in nuclear reactor and related technology to support the continued safe operation of HIFAR and to provide expert advice to government;
- Upgrading of the neutron beam and other facilities on HIFAR, making them available to ANSTO and external users for the exploitation of the possible applications of neutron techniques in industry, medicine and other fields;
- Contributing, through the Australian School of Nuclear Technology (ASNT), to the education and training of people from Australia and overseas in nuclear science and technology;
- Operation and maintenance of the No 1 Hot Cells facility for use by HIFAR and other ANSTO units;
- Development and application of reliability and risk engineering techniques for the benefit of ANSTO, industry and the general Australian community;
- Radiation Shielding calculations and general nuclear safety appraisals as required for the benefit of ANSTO, external bodies and government;
- Maintaining a regularly updated data base of information relating to reactor and related technology as a source for advice to government and industry;
- Research and development to support the above activities and responsibilities.

TABLE 2 - OPERATING STATISTICS 1978

Reactor Availability	Hours	%
Time in the period	8,736	100.0
Scheduled shutdown	1,137	13.0
Unscheduled shutdown	132	1.5
Total time not operating	1,269	14.5
Total time operating	7,467	85.5
Full power availability	7,434	85.1
Number of trips from full power	67	
Number of poison-outs	2	

Fuel Usage	
Number of fuel elements used	54
U-235 consumption	3,812 gs

Absorber Usage	
Number of CCAs changed	NIL

Consumables Usage	
Heavy Water added	501 kgs
Helium usage	722 m^3
Light Water usage	96,611 m^3

Irradiation and Collimator Services

Number of industrial and medical targets irradiated:

Self-service rigs	1172
In-pile rigs	772
Collimator usage	17,601 hrs
NTD Si Production	1,684 kgs

Note:

Date refers to 13 complete operating programs.

TABLE 3

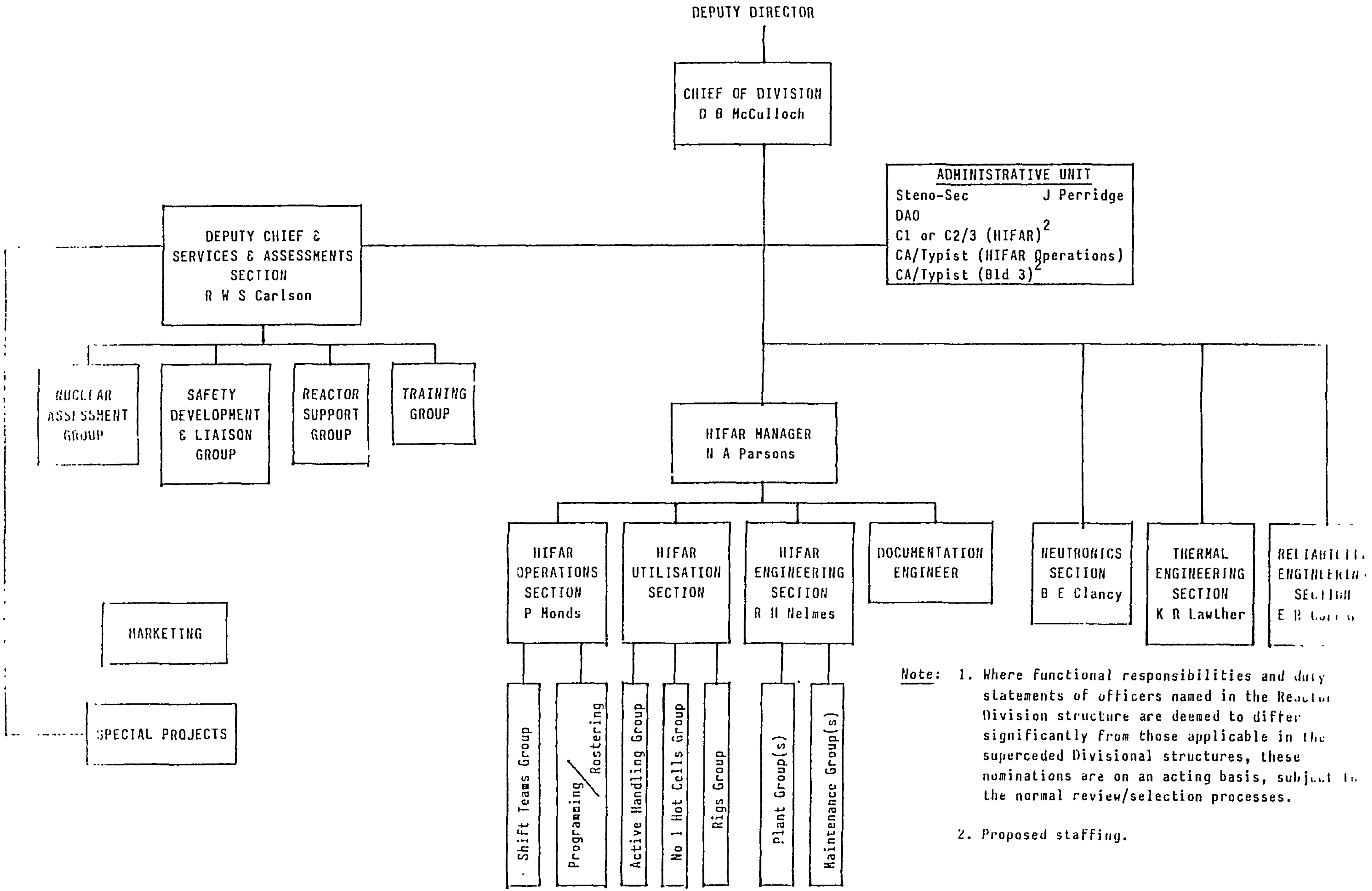
ENGINEERED SAFETY FEATURE SYSTEMS
(excluding reactor shutdown systems)

		Number of Systems	
		1958	1988
1.	**Containment**		
	Containment Isolation	1	2
	Containment Cooling	1	3
2.	**Core Cooling**		
	ECCS	0	2
3.	**Power**	1	3
		3	10

TABLE 4
RIG LOADING OP365

RIG	FACILITY	DESCRIPTION
1. Vertical Heavy Water Facilities		
X-45	6V-1	Cobalt Irradiation
X-94	2V-7	Cobalt Irradiation
X-98	2V-1	Cobalt Irradiation
X-99	2V-2	Cobalt Irradiation
X-101	2V-6	Cobalt Irradiation
X-106	6V-2	Isotope Cakestand
X-111	2V-5	Cobalt Irradiation
X-151/2	2V-4	Cobalt Irradiation
X-177	4V-4	Aluminium Corrosion
2. Vertical Graphite Facilities		
X-208	6VGR-1	Silicon Rig
X-208	6VGR-2	Silicon Rig
X-208	6VGR-3	Silicon Rig
X-208	6VGR-4	Silicon Rig
X-208	6VGR-5	Silicon Rig
X-208	6VGR-6	Silicon Rig
3. Hollow Fuel Element Rigs		
X-183/12	D3	Isotopes Cakestand
X-183/4	C2	Isotopes Cakestand
X-183/6	B4	Isotopes Cakestand
X-183/5	C4	Isotopes Cakestand
X-183/10	B3	Isotopes Cakestand
X-183/8	D4	Isotopes Cakestand
X-183/9	B5	Dummy Cans
X-210	B1	Dummy Rig
X-195	E4	University of NSW Bubble Rig
4. Horizontal Heavy Water Facilities		
X-2	4H-1	Collimator)
X-3	4H-2	Collimator)
X-21/2	4H-5	Collimator)
X-33	4H-3	Isotope Self Service)
X-34	4H-4	Isotope Self Service) assumed negligible
X-41/2	6H	Collimator)
X-48/3	10H	Collimator)
X-82/4	2-Tan	Collimator Face 3/4)
X-166/1	2-Tan	Collimator Face 8/9)
X-176/1	4H-6	ACS Self Service
5. Horizontal Graphite Facilities		
X-6	6HGR-4	ACS Self Service
X-7	6HGR-5	Isotope Self Service

FIGURE 1
REACTORS DIVISION - INTERIM ORGANISATION, 1 MARCH 1988



Note: 1. Where functional responsibilities and duty statements of officers named in the Reactor Division structure are deemed to differ significantly from those applicable in the superceded Divisional structures, these nominations are on an acting basis, subject to the normal review/selection processes.

2. Proposed staffing.

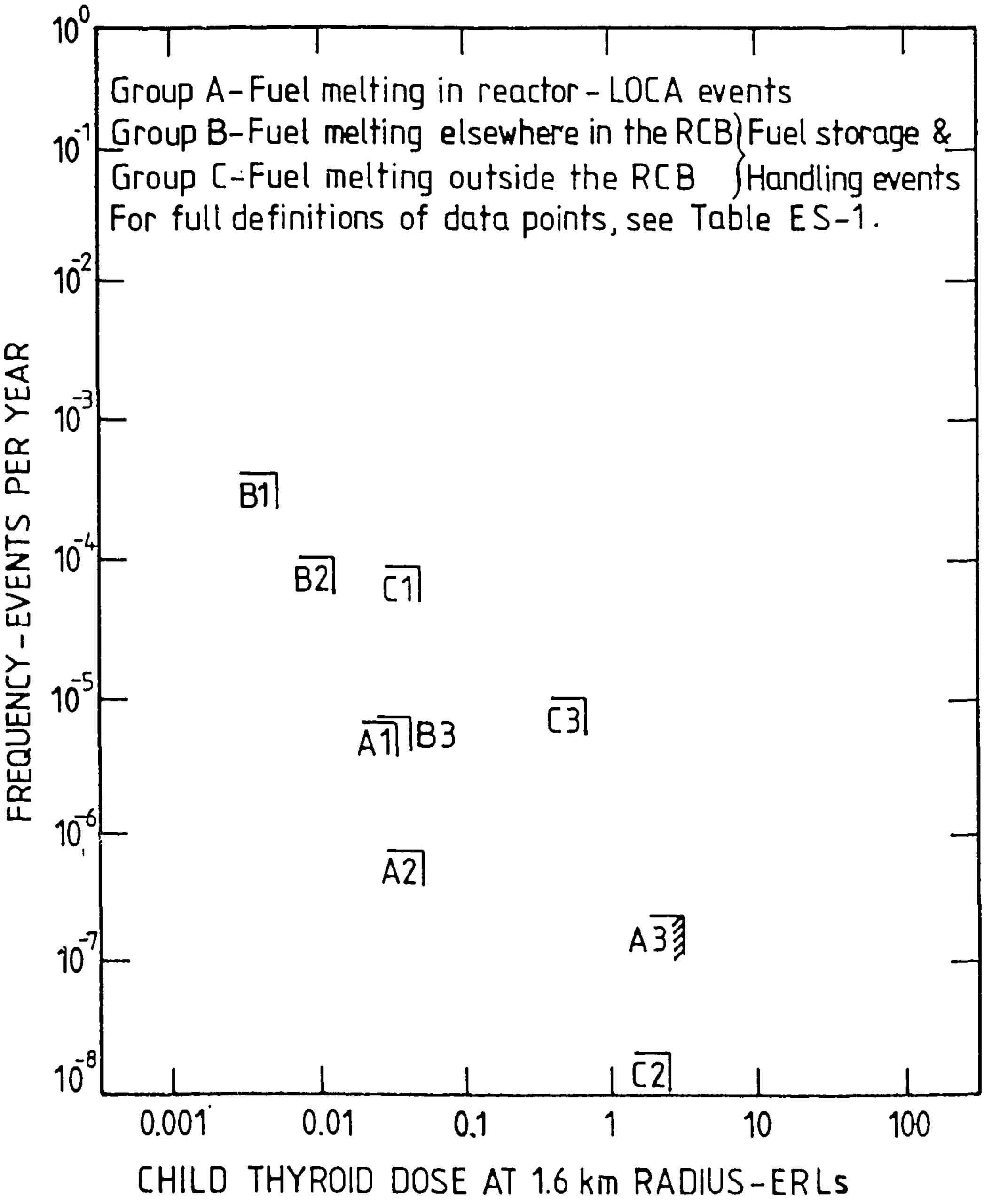


Figure 2 Frequency and consequences of accidents
(Report of HSAWP Task (b) Group)

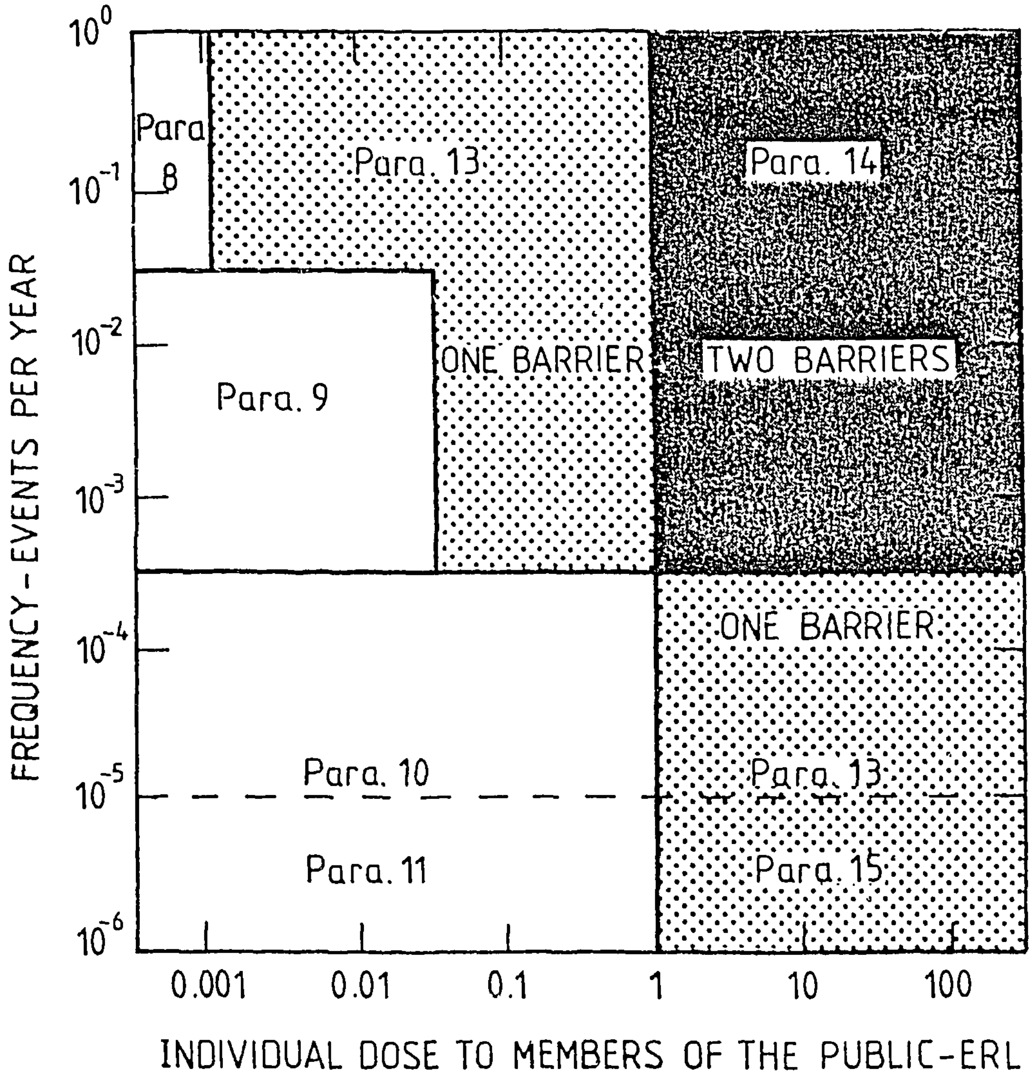
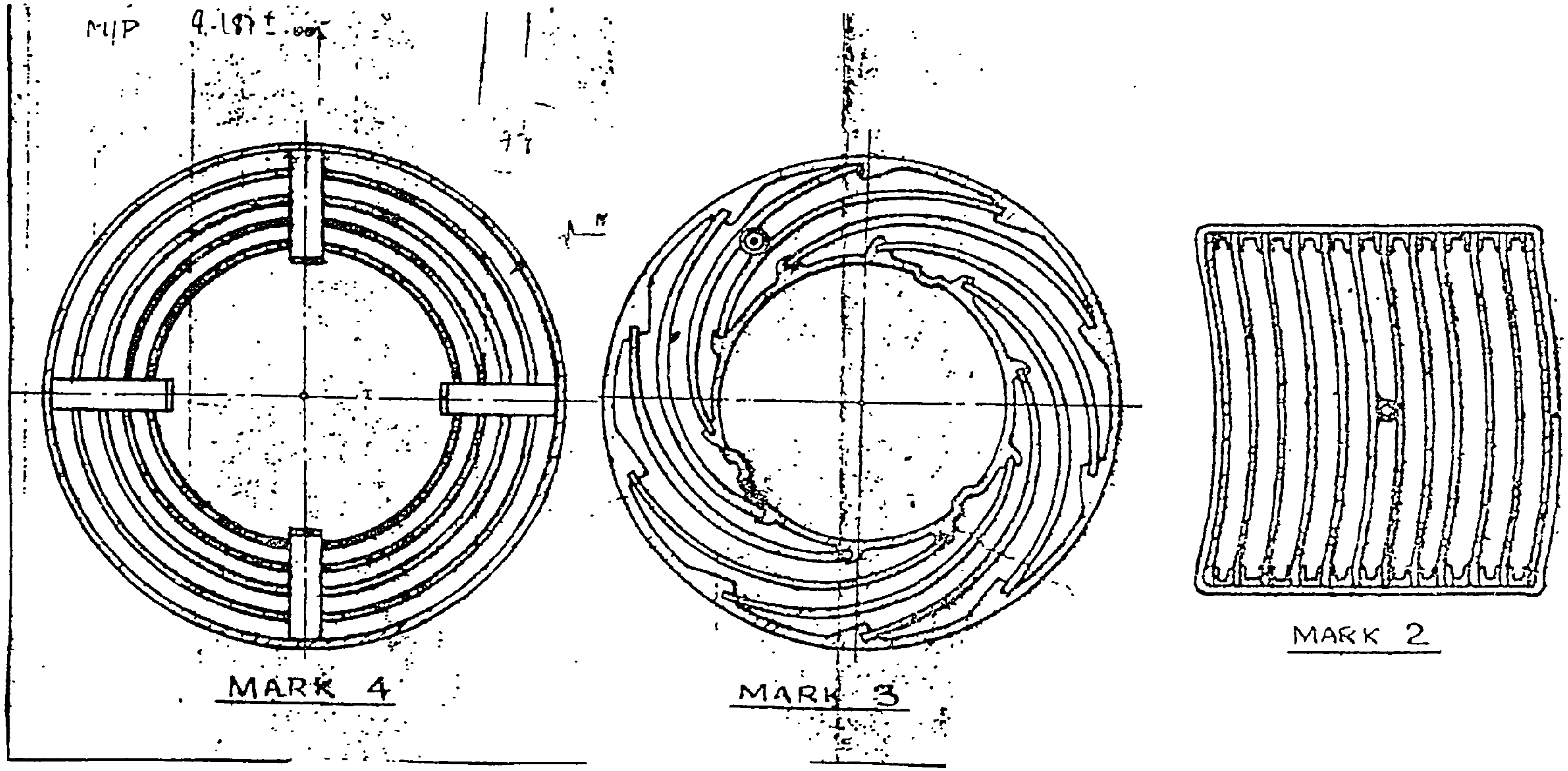


Figure 3 The Relationship Between the Frequency of an Event, Dose to the Public and the Protection Required by Particular Paragraphs of REGBUR MEMO/1/82 (July 1982) (RD/TN108, F D NICHOLSON 1982)



MARK 4 MARK 3 MARK 2

FIGURE 4 - CROSS SECTION OF HIFAR FUEL ELEMENTS

THE HIFAR REFURBISHING PROGRAM

M R ALLEN

26 January 1988

1. INTRODUCTION

The refurbishment of HIFAR was recommended by the National Energy Research Development and Demonstration Council (NERDEC) in a report of ANSTO (AAEC) research in 1979. A new policy proposal was submitted by ANSTO and direct government funding of $4.7 million over a five year period for safety upgrading was approved. The program effectively commenced at the end of 1981 when Siemens (Interatom) were engaged as a consultant for the program. The initial task of the consultancy was an assessment of the safety related reactor systems in order to establish the scope and relative priority of refurbishing tasks.

As a result of this study work on the following major reactor systems was proposed:

- Electrical Power Supply System (EPSS)
- Civil works
- Reactor Protection System
- Reactor Containment System
- Compressed Air Supply System
- Upgrading of Irradiated Fuel Storage
- Safety Analysis

At a later stage in the program the following tasks were added:

- Cooling Tower Replacement
- Replacement Data Acquisition System
- Seismic Modifications

The emphasis of the refurbishing program is directed at safety related systems with the original aim that on completion HIFAR should satisfy requirements for operation into the 1990s. The criteria for inclusion and the relative priority of separate tasks were based on a deterministic assessment of the existing plant using the design requirements of nuclear codes and standards. These requirements were formulated after HIFAR was designed and the majority of the codes and standards are directed to power reactors. However, whilst the magnitude of nuclear safety issues is considerably less for research reactors than for power reactors the use of design criteria of the latter has inevitably occurred in safety related modifications work. A determination of the appropriate level of this usage is a major consideration of the operators, designers and the regulatory bodies for research reactors which is accentuated for work on existing reactors of this type such as HIFAR.

The other important engineering considerations are associated with the changing design bases for nuclear plant and the increased surveillance of construction by independent nuclear regulatory bodies. It is perhaps of interest to note that when HIFAR was constructed, it was equipped with most of the essential safety systems which are characteristic of modern power reactors. However, the preferred configuration of these systems has changed in the thirty year operating period of HIFAR in order to increase the degree of confidence in the ability of the systems to withstand rare events and low probability equipment failure. As a consequence of the search for higher levels of confidence, the financial and staff resources which are necessary to effect change has increased enormously. This is graphically illustrated by a comparison of the 2-3 year initial construction period for HIFAR and the similar periods which have been necessary for relatively small scale refurbishing tasks. However, notwithstanding the desirability of some changes, the refurbishing tasks have necessitated very detailed investigations of the design features and construction methods of the existing plant and there is no doubt that the reactor construction is of a high standard which displays standards of workmanship which are not readily available in the current contract industry.

2.1 The EPSS

The existing EPSS suffers from the following characteristics in comparison with modern reactor design.

- Lack of operational and physical separation of the redundant (duplicated) plant.
- Lack of testability under operating conditions unless the reactor is in a shutdown state.
- Lack of physical and electrical separation of the cable systems.
- The original design did not address the current design bases of concern, for example seismic resistance and fire rating, to the degree which is desirable for the future role for HIFAR.
- Equipment is becoming increasingly difficult to maintain due to age and obsolescence.
- The cross-linking which is possible is complex and not easily assimilated by operators.

A new EPSS subsystem is shown in Figure 1 in line diagram form. The total EPSS system features two redundant subsystems which have identical features, apart from a standby supply for reactor experimental rigs on the 'B' subsystem.

Each subsystem is housed in separate sections of Building 70 which was constructed for the new EPSS. Separate inground trenches and separate reactor building penetrations are used for the associated cable systems.

The manufacture, installation and commissioning were controlled by quality assurance procedures which have proved demanding to ANSTO and the contractors. As a consequence of lack of standards compliance it was considered necessary to review virtually all of the equipment and to establish an 'ANSTO Type Approval' based on the documented quality assurance evidence which was available from various sources.

Most of the electrical equipment was vibration tested on a three axis vibration table in the frequency range 2 to 30 Hz at acceleration values up to 1 g. Whilst most of the equipment satisfied the criteria in their standard form it was necessary to make some modifications. The more significant changes were:

(a) the addition of a top wall fixings for pedestal type electrical cubicles;

(b) the removal of high mass items (eg transformers) from printed circuit boards;

(c) the strengthening of UPS battery racks.

The local amplification factor for acceleration can typically result in acceleration values in excess of 1 g for a ground motion acceleration of 0.2 g.

The design bases for the EPSS includes a requirement to provide electrical power following a core melting accident in HIFAR. Such an accident would result in the high radiation exposure value of about 1 C kg^{-1} in the EPSS building which is about 20 metres from the RCB. The ability of electrical equipment to survive the radiation doses has been investigated with the result that local shielding will be provided for equipment which uses micro-processor electronics. Other electronic and electrical equipment will not be shielded from nuclear radiation.

The two 300 kVA diesel-alternator units have been constructed and tested to the rules of Lloyd's Register of Shipping. The units have a mission period of seventy two hours, although diesel stop controls are provided in the emergency control room (ECR) and the site emergency operations and control centre (EOCC) to conserve fuel, in the event that the preferred (offsite) power supply would be available. The RCB, ECR and EOCC are each being equipped with an EPSS mimic diagram panel with annunciation of the EPSS with extensive alarm panels. The EOCC is one kilometre from HIFAR.

As previously reported the EPSS is comprised of two similar subsystems. Standby power supplies from each subsystem are provided to loads which have nuclear and non-nuclear safety classifications. The adherence to the IEEE type cable separation criteria within the reactor containment building is not easily achieved. These difficulties are compounded if neither fuses or circuit breakers are considered to protect associated safety circuits from all types of short-circuit transients. For HIFAR all non-nuclear safety electrical loads on the standby supply will have voltage transient isolators in addition to conventional circuit protection devices in order to limit the strict segregation requirements within this classification.

The EPSS is currently being installed whilst the reactor is operating and in a twelve month site construction period the reactor operation has not been directly affected by the work. However, this strategy has proven far more onerous than was anticipated with respect to ensuring a smooth flow of construction work. Practical completion of the EPSS is scheduled for July 1988.

2.2 Civil Works

The EPSS building (Building 70) includes new in-ground cable trenches from this building to the reactor containment building. A plan of the layout of the building is shown in Figure 2. This building provides physical separation for the equipment of the EPSS 'A' and 'B' subsystems. The two central rooms are provided for the offsite electrical supply and non-safety electrical equipment. The test loads for the diesel generators are located at the rear of the building.

2.3 The Reactor Protection System

The basic design features of the reactor protection system (RPS) have not been changed during the reactor life. The concept is based on primary and secondary guard circuits which provide redundancy within the shutdown system, but in which some instruments are used for both circuits, but separated by the provision of auxiliary contacts. The RPS provides: warnings; control reversal; restricted trip and complete trip functions. The signals are monitored by eleven relay sets and voting logic is carried out also by electromagnetic relays. The existing RPS could be improved with respect to the following features:

- lack of preferred channel independence features;
- lack of physical and electrical isolation of the sensors and cable systems within the RPS and from other electrical and mechanical systems;
- increasing obsolescence of instrumentation;
- the dated appearance of associated instrument displays in the reactor control room.

The system has, however, proved very reliabile and the significance of the safety related aspects of the above features has been investigated and assessed as adequate. A specification for the total replacement of the RPS has been prepared together with detailed cost estimates, but a final design decision to proceed has not yet been taken. Additional funding will, however, be required if a complete replacement is pursued. The ANSTO Board has supported a plan to seek additional funds as part of a modernisation program beyond the refurbishing plan.

The optimum refurbishing program of work for the RPS has not yet been established by the agreement within ANSTO. However, the refurbishing engineers favour the construction of a new split level control room attached to the RCB which would also contain the electronic racks in a secure area. A benefit of this plan would be the minimal impact on the reactor operation during construction.

2.4 The Reactor Containment System

This proposal to refurbish the HIFAR Reactor Containment Building (RCB) on the basis of safety upgrading originated from the preliminary safety study which was carried out by Siemens, the AAEC consultant for the HIFAR Refurbishing Program. The proposal recommended the installation of a fission product cleanup plant (FPCUP), with equipment redundancy, to the RCB. However, the current proposals do not include the implementation of the Siemens proposals.

The RCB containment barrier can be defined as consisting of the following systems since the overall containment barrier performance can be influenced by each system, viz:

(a) The RCB, which provides the basic structure and a controlled enclosure for normal operation and a sealed volume for accident conditions.

(b) The Containment Isolation System (CIS), which provides automatic sealing of the ventilation systems and other penetrations of the RCB for accident conditions.

(c) The Space Conditioner System (SCS) which provides RCB atmosphere cooling for both normal operating and accident conditions.

There are two main types of Reactor Containment Building system; the "vented" and the "sealed" type. For the former a RCB of low leak rate is constructed and the RCB is ventilated by extracting air through a FPCUP at a rate which ensures that the RCB is maintained at a sub-atmosphere pressure. The air flow rate must, therefore, not be less than the leak rate of the RCB. Many research reactors including other DIDO class reactors are equipped with the "vented" RCB system which has the advantage that an increase of the RCB pressure is limited by the loss of heat and air mass from the RCB thus eliminating the requirement for cooling systems such as the SCS.

ANSTO has, throughout the life of the reactor, employed the "sealed" RCB system for HIFAR. The definition of the maximum credible accident (MCA) for HIFAR in the HIFAR Safety Document (HSD) 1972 as being the full core melting in the reactor has inhibited the introduction of a "vented" RCB containment system. Recent work based on probabilistic reliability analysis (PRA) has confirmed the MCA as a design basis accident at a sufficiently high postulated frequency to require safety related equipment.

Apart from the Danish reactor DR-3 at Riso, which has a sealed RCB system and considered 50% fuel melting in the core as a design basis accident, fuel melting in the core is not considered as a design basis accident for other DIDO class reactors (DIDO, PLUTO and FRJ-2).

These three reactors have "vented" reactor building containment systems which are suitable for accidents where about twenty four hours of fuel fission product decay has occurred, because significant radioactive decay of the noble gases will occur in this period. The fission product noble gases are very difficult to filter.
Although the basic design concept for the RCB containment

barrier has never been altered during the life of HIFAR and much of the original equipment remains in service, a considerable amount of effort has been devoted to improving the quality of the various systems which comprise the RCB containment barrier.

In particular the CIS, in 1975, and the SCS, in 1970 and 1982 have been the subject of significant modification and expenditure.

A proposal was developed to relegate the SCS from the current role of post-accident pressure suppression system for the RCB. Recent work on the accidents which postulate serious fuel damage in the core has shown that the cooling effects of the thermal capacity of the reactor structure and the external surfaces of the heavy water - light water - heat exchangers can limit the internal RCB pressure. However, a pressure relief operation would be necessary during such accidents to limit the RCB pressure to 10.3 kPa (RCB design pressure) if the building leak rate should be less than 0.6% per day. Although the resulting calculated off site dose rates were less than the values accepted by the ANSTO regulations, (460 mSv cf 1,000 mSv child thyroid dose) the retention of a dynamic pressure suppression system was retained following the regulatory review process.

2.5 The Compressed Air Supply System

The preparation of a conceptual re-design of the reactor compressed air system has been completed. The design features the use of standby compressors sited within the RCB to permit the testing of the containment isolation system (which isolates the normal supply) whilst the reactor is operating. Improved reliability and verification of the isolation of the normal compressed air supply will also be provided, which is an important aspect of the sealed containment building system used for HIFAR.

2.6 Upgrading of the Irradiated Fuel Storage

Facilities for the storage of irradiated fuel elements in the HIFAR containment building are provided by a main, water-filled tank with forty eight load positions and a smaller water-filled tank with four load positions for 'leaking' fuel elements. The main irradiated fuel storage tank is cooled by recirculating water through heat exchangers which are sited outside of the reactor containment building; unlike the DIDO, PLUTO and DR3 storage blocks which are air cooled for normal operation. The 'leaking' fuel element storage tank is indirectly cooled by an internal cooling coil.

The original storage tank system was designed to provide cooling by natural convention flow through the fuel elements and the heat exchanger in the event of failure of the circulation pumps. In order to ensure good convection conditions large diameter pipes were used (150 mm bore) and the tank connections penetrated the top and bottom of the tank. During the life of HIFAR, the safety priorities have changed and the bottom pipe connection was considered as an undesirable feature because of the potential for draining the storage tank in the event of a pipe or joint failure (the concrete shielding is not watertight). Loss of water circulation was not a serious safety issue because the large thermal capacity of the water inventory would allow several hours of interruption to flow, even with maximum decay heat elements 48 hours after shutdown from 11 MW operation. The replacement tank is a double wall tank with an interwall cavity which can be sealed for leak testing, see Figure 3.

The replacement of the fuel element storage tank took place in 1985. During the re-commissioning work several pre-existing deficiencies in the cooling circuit were revealed. The heat exchangers were located on the suction side of the pumps which caused air ingress into the heat exchangers and large pressure oscillations in the circuit. The circuit outside of the RCB has been completely re-designed, improved RCB containment water seals added and comprehensively re-instrumented. The construction work has started and completion is scheduled for April 1988.

2.7 Analysis

It is now unlikely that the new Safety Analysis Report (SAR) will be written as part of the HIFAR Refurbishing Program, because of the limited benefit for the required man-power resources. A revised format for the scope of the modifications to the HIFAR Safety Document has yet to be prepared.

A safety analysis of the potential accident sequences of HIFAR has recently been completed. The task of the study group, the HIFAR Safety Analysis Working Party Task (b) Group (HSAWP(b)), was to identify and examine using probabilistic risk analysis (PRA) techniques the accidents with significant potential for off site radiation exposure. The work of the group has resulted in changes to the current safety case, in particular to the accident source term and reduced off site radiation exposure values, for accidents within the RCB. Recent work has shown that the HSAWP(b) accident sequences analyses comply with the formal probabilistic requirements of the safety principles of the Nuclear Safety Bureau, ANSTO.

2.8 Replacement Cooling Towers

A contract has been let for the construction of replacement light-water cooling towers for HIFAR, see Figure 4. Installation work will commence in June 1987 and completion is scheduled for June 1988. Six induced draft, modular type units, of reinforced fibre glass construction with PVC packing, will be installed parallel with the existing timber towers basin. The new cooling towers and the existing basin, which will be retained, are seismically qualified in order to be capable to acting as the ultimate heat sink for the emergency core cooling system, following a seismically initiated LOCA accident.

2.9 Replacement Data Acquisition System

A replacement data acquisition system (DAS) was commissioned in HIFAR in January 1988 at the end of a two year construction contract. The equipment is based on the Leeds and Northrup LN2068 master station. The master station incorporates a network of distributed computer system units based on the Motorola 68000 microprocessor. Terminals (VDU and printer) are provided in the RCB(2) and the ECR(1). The system will initially carry about 1,200 sensors. Data which is stored on hard disk will initially be retrieved for long term storage by a personal computer, but direct transfer facilities to the LHRL main frame computer will be added in the future. The components which have limited reliability (hard disk drives) have been provided with hot spares.

2.10 Seismic Modifications

A seismic study by Siemens (Interatom) concluded that the most practical method of ensuring that the HIFAR primary circuit would not be damaged by an S2 earthquake (0.23 g for HIFAR) would be to strengthen the reactor structure and the heavy water circuit. The following modifications are being implemented as part of this recommendation.

(a) Strengthening the base of the RCB stiffeners.

(b) Providing horizontal stiffening to Building 42 and installing a sliding connection to the RCB air lock. The collpase of this building is likely during an S2 event and would threaten the stability of the reactor.

(c) Preventing the heavy water pumps from sliding off their supports in the plant room.

(d) Welding the beams supporting the secondary cooling pipework to the main reactor support columns.

(e) Providing cross bracing for the supports of vessel 1V4 to avoid secondary damage in the D_2O plant room.

In addition the following modifications are also being implemented in order to harden the ECCS against seismic degradation of performance.

(f) Providing a horizontal support to the upper part of the main secondary cooling pipe in the pump house.

(g) Providing tension bars in one section of the pump house long wall to provide lateral stiffening.

(h) Supporting masonry walls in pump house.

(i) Supporting ECCS cabinets to prevent sliding and tilting.

(j) Repositioning racks presently fixed to masonry walls in the pump house.

3. SUMMARY

The refurbishing program was originally planned in 1982 to cover a five year period and in view of the limited development of the proposals at this date the progress has been satisfactory. The inclusion of the Cooling Towers and Data Acquisition System in the program has had the effect of extending the required funding and timescale of the program.

The investigations of reactor systems which are important to safety have shown that HIFAR does not have significant deficiencies with respect to the basic plant design features with the possible exception of the EPSS and seismic resistance. The radiological consequences of rare event reactor accidents resulting from in-plant causes have been examined for the existing plant and found to be well within the limits of the safety criteria.

However, the reactor does contain old equipment in safety related plant and an on-going program of plant monitoring and replacement is essential if HIFAR is to maintain the current safety status, although at a lower level of activity than is current for this refurbishing program.

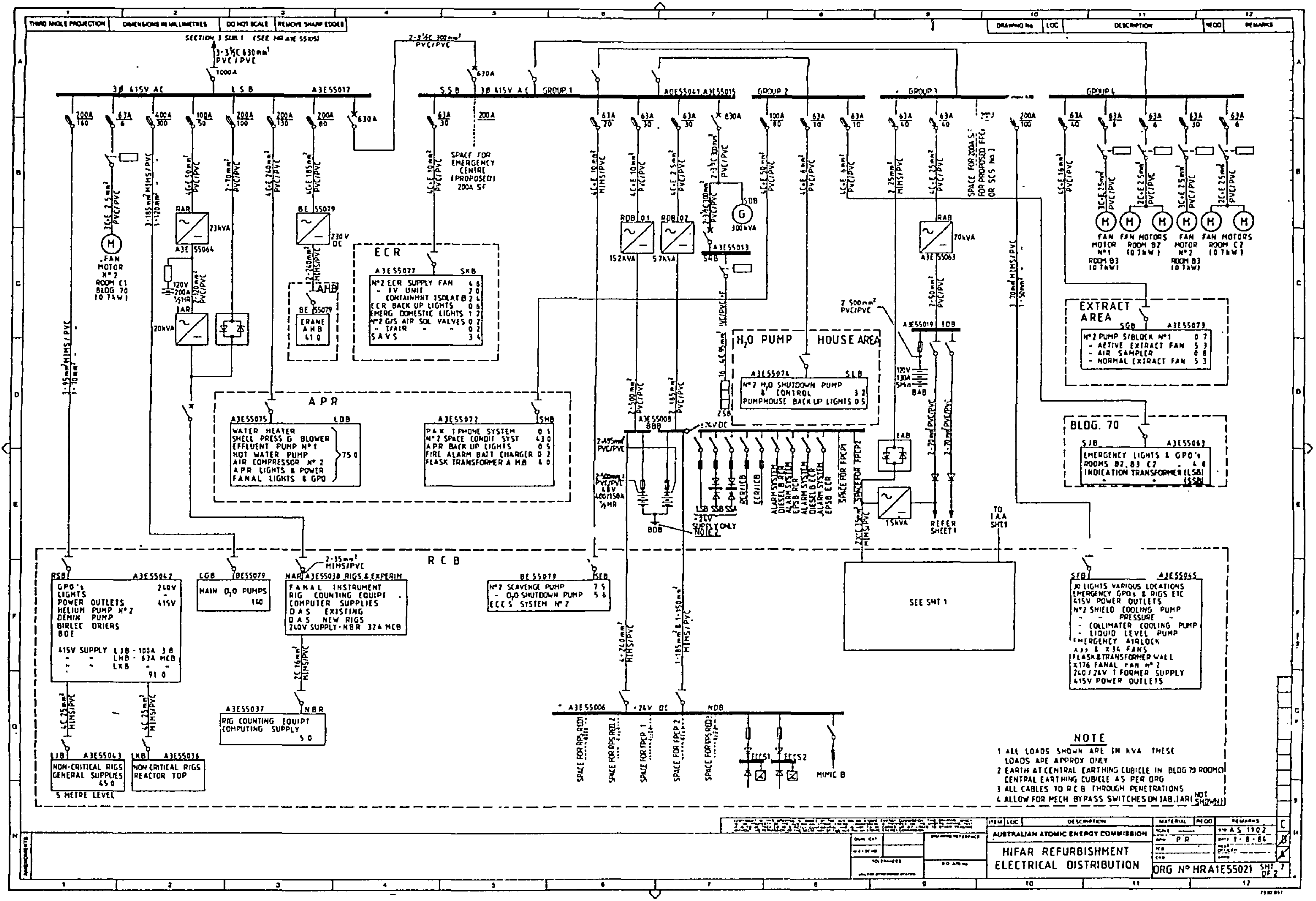

THIRD ANGLE PROJECTION
DIMENSIONS IN MILLIMETRES
DO NOT SCALE
REMOVE SHARP EDGES
SECTION 3 SUB 1 (SEE HR A1E 55105)
3-3½C 630mm² PVC/PVC
1000A
3Ø 415V AC LSB A3E55017
2-3½C 300mm² PVC/PVC
630A
SSB 3Ø 415V AC GROUP 1 A0E55041, A3E55015
GROUP 2
GROUP 3
GROUP 4
SPACE FOR EMERGENCY CENTRE (PROPOSED) 200A SF
SPACE FOR 200A S.F. FOR PROPOSED FFC, OR SCS No 3
FAN MOTOR No 2 ROOM C1 BLDG 70 (0.7kW)
RAR 23kVA A3E 55064
IAR 20kVA
120V 200A ½HR
BE 55079 230V DC
AHB
BE 55079 CRANE AHB 41.0
ECR
A3E55077 SKB
No 2 ECR SUPPLY FAN 6.6
- TV UNIT 2.0
CONTAINMNT ISOLAT B 2.6
ECR BACK UP LIGHTS 0.6
EMERG DOMESTIC LIGHTS 1.2
No 2 G/S AIR SOL VALVES 0.2
- I/AIR - - 0.2
SAVS 3.4
RDB 01 152kVA
RDB 02 57kVA
SDB 300kVA
A3E55013 SHB
FAN MOTOR No 1 ROOM B3 (0.7kW)
FAN MOTORS ROOM B2 (0.7kW)
FAN MOTOR No 2 ROOM B3 (0.7kW)
FAN MOTORS ROOM C2 (0.7kW)
RAB 70kVA A3E 55063
EXTRACT AREA
SGB A3E55073
No 2 PUMP S/BLOCK No 1 0.7
- ACTIVE EXTRACT FAN 5.3
- AIR SAMPLER 0.8
- NORMAL EXTRACT FAN 5.3
H₂O PUMP HOUSE AREA
A3E55074 SLB
No 2 H₂O SHUTDOWN PUMP & CONTROL 3.2
PUMPHOUSE BACK UP LIGHTS 0.5
A3E55019 IDB
120V 130A 5Min BAB
IAB
15kVA
REFER SHEET 1
TO IAA SHT 1
BLDG. 70
SJB A3E55063
EMERGENCY LIGHTS & GPO's ROOMS B2, B3, C2 4.6
INDICATION TRANSFORMER (LSB) (SSB)
APR
A3E55075 LDB
WATER HEATER
SHELL PRESS G BLOWER
EFFLUENT PUMP No 1
HOT WATER PUMP
AIR COMPRESSOR No 2
APR LIGHTS & POWER
FANAL LIGHTS & GPO
75.0
A3E55072 SHB
PAX 1 PHONE SYSTEM 0.1
No 2 SPACE CONDIT SYST 43.0
APR BACK UP LIGHTS 0.5
FIRE ALARM BATT CHARGER 0.2
FLASK TRANSFORMER A HB 4.0
A3E55008 BBB
±24V DC
48V 400/150A ½HR
BDB
+24V SUPPLY ONLY
NOTE 2
LSB SSB SSA
ECR/LCB
ECR/LCB
ALARM SYSTEM DIESEL B BTR
ALARM SYSTEM EPSB RCR
ALARM SYSTEM DIESEL B ECR
ALARM SYSTEM EPSB ECR
SPACE FOR FPCP1
SPACE FOR FPCP2
RCB
RSB A3E55042
GPO's 240V
LIGHTS
POWER OUTLETS 415V
HELIUM PUMP No 2
DEMIN PUMP
BIRLEC DRIERS
BOE
415V SUPPLY LJB - 100A 3Ø
- - LHB - 63A MCB
- - LKB
91.0
LGB BE55079
MAIN D₂O PUMPS 140
NAR A3E55038 RIGS & EXPERIM
FANAL INSTRUMENT
RIG COUNTING EQUIPT
COMPUTER SUPPLIES
DAS EXISTING
DAS NEW RIGS
240V SUPPLY - NBR 32A MCB
BE 55079 SEB
No 2 SCAVENGE PUMP 7.5
- D₂O SHUTDOWN PUMP 5.6
ECCS SYSTEM No 2
SEE SHT 1
SFB A3E55045
30 LIGHTS VARIOUS LOCATIONS
EMERGENCY GPOs & RIGS ETC
415V POWER OUTLETS
No 2 SHIELD COOLING PUMP
- - PRESSURE -
- COLLIMATER COOLING PUMP
- LIQUID LEVEL PUMP
EMERGENCY AIRLOCK
X33 & X34 FANS
FLASK & TRANSFORMER WALL
X176 FANAL FAN No 2
240/24V T FORMER SUPPLY
415V POWER OUTLETS
A3E55037 NBR
RIG COUNTING EQUIPT COMPUTING SUPPLY 5.0
LJB A3E55043
NON-CRITICAL RIGS GENERAL SUPPLIES 45.0
5 METRE LEVEL
LKB A3E55036
NON CRITICAL RIGS REACTOR TOP
A3E55006 +24V DC NDB
SPACE FOR RPS RED 1
SPACE FOR RPS RED 2
SPACE FOR FPCP 1
SPACE FOR FPCP 2
SPACE FOR RPS RED 3
ECCS 1
ECCS 2
MIMIC B
NOTE
1 ALL LOADS SHOWN ARE IN kVA. THESE LOADS ARE APPROX ONLY
2 EARTH AT CENTRAL EARTHING CUBICLE IN BLDG 70 ROOM C1 CENTRAL EARTHING CUBICLE AS PER DRG
3 ALL CABLES TO RCB THROUGH PENETRATIONS
4 ALLOW FOR MECH BYPASS SWITCHES ON IAB, IAR (NOT SHOWN)
AUSTRALIAN ATOMIC ENERGY COMMISSION
HIFAR REFURBISHMENT ELECTRICAL DISTRIBUTION
DRG No HRA1E55021 SHT 2 OF 2
AS 1102
1-8-86
AMENDMENTS

Figure 1

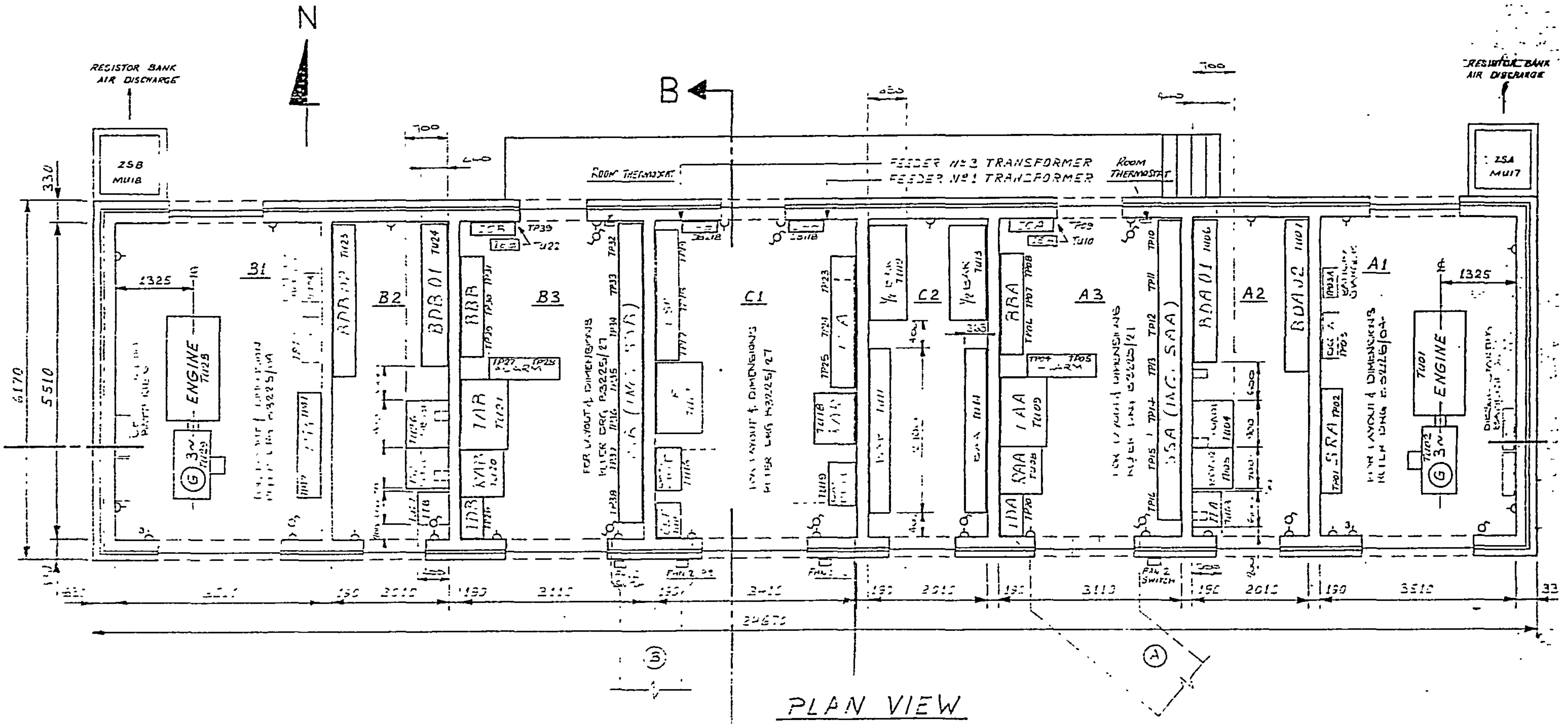

N
B
RESISTOR BANK AIR DISCHARGE
ZSB MU18
ZSA MU17
FEEDER No 2 TRANSFORMER
FEEDER No 1 TRANSFORMER
ROOM THERMOSTAT
B1
B2
B3
C1
C2
A3
A2
A1
ENGINE TU28
G 3~ TU29
ENGINE TU01
G 3~ TU02
BDB 02 TU25
BDB 01 TU24
BBB
IAB TU21
KAB TU20
IDB
BDA 01 TU06
BDA 02 TU07
SSA (INC. SAA)
SRA
BBA
IAA TU09
SAA TU08
IDA
½ BAK TU13
½ BAK TU12
FOR LAYOUT & DIMENSIONS REFER DRG B3225/27
FOR LAYOUT & DIMENSIONS REFER DRG B3225/21
FOR LAYOUT & DIMENSIONS REFER DRG B3226/04
FOR LAYOUT & DIMENSIONS REFER DRG B3225/04
6170
5510
330
1325
24670
3510
2010
3110
150
A
B
PLAN VIEW

Figure 2

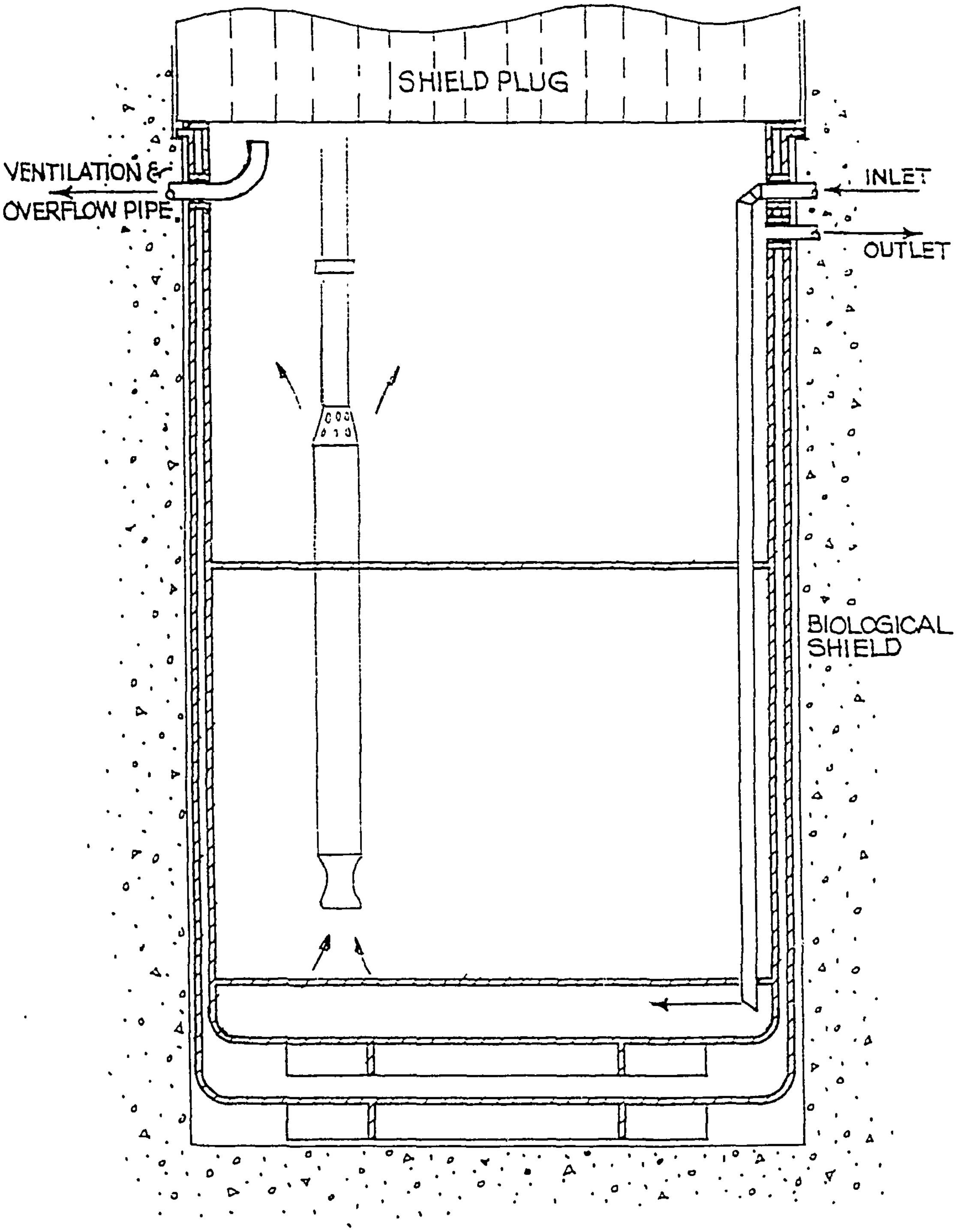


Figure 3

NO1 STORAGE BLOCK DIAGRAM - DOUBLE TANK UNIT

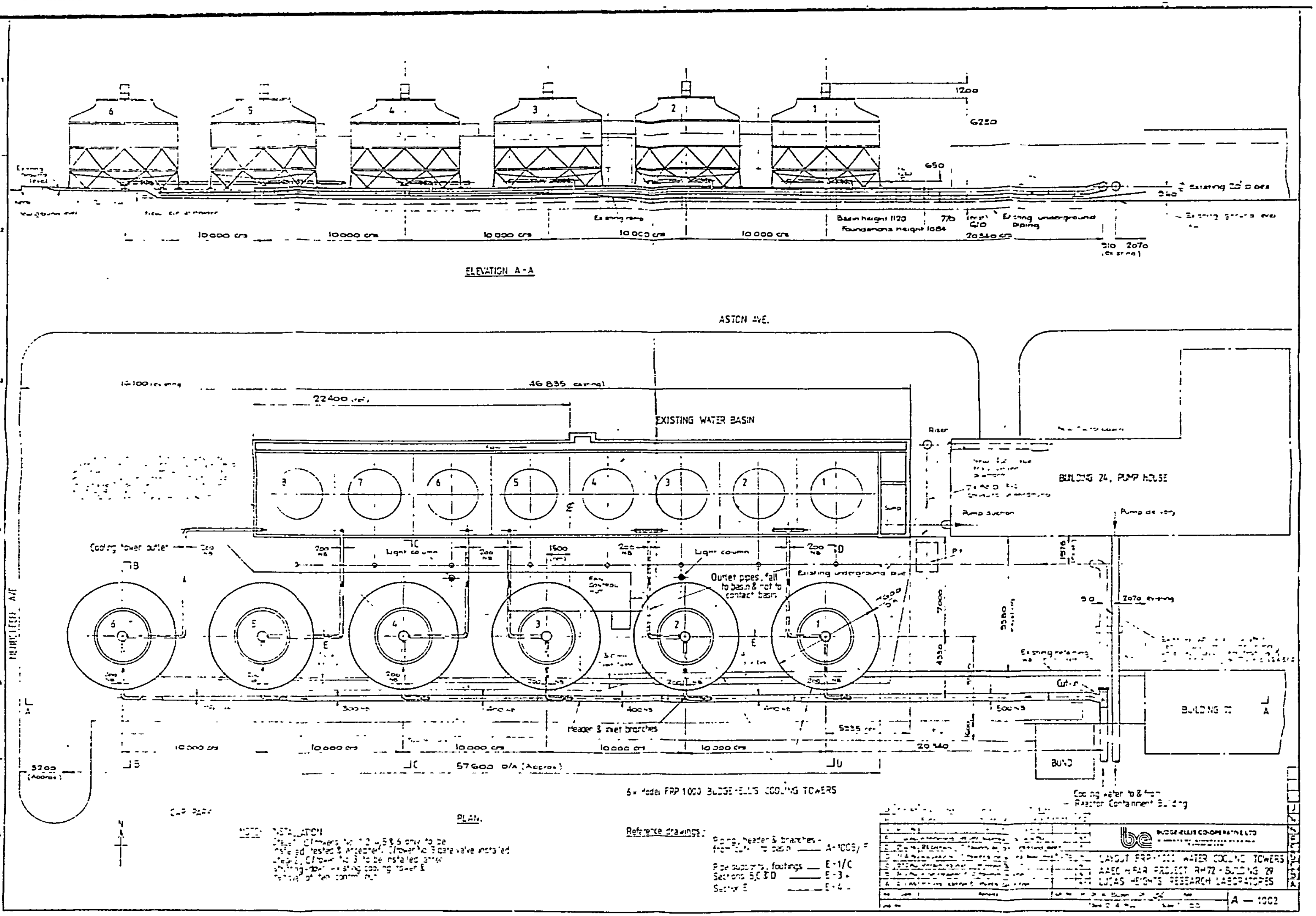
ELEVATION A-A
10 000 crs
10 000 crs
10 000 crs
10 000 crs
10 000 crs
Basin height 1120
Foundations height 1084
1200
6250
650
770
610
20 540 crs
510 2070
Existing underground piping
Existing 20" pipes
ASTON AVE.
EXISTING WATER BASIN
46 835 (existing)
22400 (ref)
16100 (existing)
BUILDING 24, PUMP HOUSE
Riser
Sump
Pump suction
Pump delivery
Cooling tower outlet
Light column
Outlet pipes, fall to basin & not to contact basin
Existing underground pipe
Header & inlet branches
57600 o/A (Approx)
5200 (Approx)
20 540
7000
4330
9580
1500
2070 existing
BUND
BUILDING 77
Cooling water to & from Reactor Containment Building
CAR PARK
6 x Model FRP 1000 BUDGE-ELLIS COOLING TOWERS
PLAN.
NOTE: INSTALLATION
Reference drawings:
Piping, header & branches - from pump to basin — A-1005/F
Pipe supports, footings — E-1/C
Sections B,C & D — E-3
Section E — E-4
BUDGE-ELLIS CO-OPERATIVE LTD
LAYOUT FRP-1000 WATER COOLING TOWERS
AAEC HIFAR PROJECT RH72 - BUILDING 29
LUCAS HEIGHTS RESEARCH LABORATORIES
A — 1002

Figure 4