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Reactor System Defects in Royal
Navy Nuclear Powered Submarines
Cause and Strategic Deployment Aspects

Client: Greenpeace

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CLIENT: GREENPEACE UK

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REACTOR SYSTEM DEFECTS IN ROYAL NAVY NUCLEAR POWERED SUBMARINES

Summary

This report reviews the current operational readiness and condition of the Royal Navy Valiant/Churchill SSN (attack) and Polaris SSBN (missile) nuclear powered submarine squadrons. Since the Ministry of Defence adopts a stance of neither confirming or denying claims relating to its nuclear submarine fleet, the report relies upon allegations and information that cannot be corroborated, although the authenticity of certain of the sources should not be doubted.

In late 1989 a major defect was discovered in the nuclear reactor system of SSN HMS Warspite whilst this boat was undergoing extensive refitting and nuclear refuelling. Shortly following this discovery and by Christmas of 1989, all of the boats of the Valiant/Churchill squadron had returned to port and since that time none of these boats has put to sea under nuclear power. In about February 1990, the Ministry of Defence acknowledged that a defect existed in Warspite that all other boats of the squadron were to be inspected. Thereafter in July, 1990 the Ministry announced that HMS Conqueror was to be paid off and scrapped, then in November/October that Churchill and Warspite were to be withdrawn for the final stages of their refits and scrapped. In October it was reported that the crews of HMS Valiant were to be stood down because of her imminent scrapping, it was rumoured that Courageous was destined for the same fate and that HMS Swiftsure and Sovereign were to be withdrawn from service and mothballed.

The Ministry of Defence has stated that the withdrawal of these nuclear powered submarines, officially three boats but more probably seven in total, has been possible by the easing of East-West tensions and in accord with the 'Options for Change' policy review. Others have speculated that this sudden withdrawal of an entire class of nuclear powered submarines has been necessitated by the discovery of the major defect extant in the reactor system of HMS Warspite. They reason that the defect is of a generic, design-related nature that is present or potentially present in all submarines powered by the first development series of the P1 pressurised water reactor. Whatever, the scrapping and possible mothballing of the seven boats reduces the total Royal Navy fleet to 11 nuclear powered SSN boats, a reduction of 40%.

The first series of P1 reactor is also installed in the four Polaris class nuclear deterrent submarines. Of late the pattern of operation of these submarines has changed, with one boat HMS Renown being retained in refit at Rosyth some eighteen months overdue, a second boat HMS Revenge has undergone extensive reactor compartment work whilst laid up at Faslane since February of this year, and with the third boat HMS Repulse reportedly in such unseaworthy condition that she has only managed 6 weeks of operational service during the last two years. It seems that the only fully operational Polaris submarine is HMS Resolution and reliable sources state that her reactor system has yet to be thoroughly inspected. Resolution is believed to have been on patrol for some 15 weeks (compared to a normal patrol period of 10 to 12 weeks).

In other words, the conclusion drawn is that the Polaris boat reactor systems are also beset with the same reactor defect that has grounded the Valiant/Churchill squadron. The pattern of SSBN boat movements has been disrupted of late, the maintenance of the submarine nuclear deterrent has required ad-hoc measures, such as hurriedly making Revenge seaworthy to replace Resolution on patrol, which may have impinged on the all important nuclear safety. If, as it is alleged by some sources, HMS Resolution has yet to be thoroughly inspected for the reactor defect then there must exist a greater risk of accident whilst this boat is in continuing operation, although the MoD have quite categorically stated that all nuclear powered submarines at sea are not at risk of accident.

Introduction

In July of this year the Secretary of State for Defence announced the retirement of the Valiant/Churchill class nuclear powered attack submarine (SSN) HMS Conqueror. In the November two other Valiant/Churchill class submarines, HMS Churchill and HMS Warspite, were scrapped before completion of their major refits at the Rosyth and Devonport Royal Dockyards. These three boats are now awaiting decommissioning.(see Note 1)

The reason given by the Secretary of State was that the withdrawal of these submarines was within the general framework of the "Options for Change" defence policy review brought about by easing of past East-West tensions. Others (Ref 1,2,3) claim the reason for the withdrawal of these submarines to have arisen directly from the discovery of a serious and design-generic defect discovered in the reactor system of HMS Warspite.

Submarine Nuclear Reactor System

Royal Navy nuclear powered submarines are fitted with one of two reactor designs. The earlier boats, including the Valiant/Churchill and Polaris class squadrons (and possibly the first two boats of the Swiftsure class - HMS Swiftsure and Sovereign) have the so-called series P1 pressurised water reactor (PWR) installed, later boats have the Rolls Royce designed series P2 reactor.(Note 2)

The Trident submarines now under construction will each be equipped with a reactor of a new design.

Operation - Embrittlement and Cracks

The reactor primary coolant circuit is subject to progressive embrittlement of the steel and, separately, the development of cracking in the body of the steel, particularly at joints and welds where the coolant circuit piping enters the reactor pressure vessel. In combination, these two forms of material degradation place the reactor primary coolant circuit at increasing risk of abrupt and catastrophic failure as the reactor system ages in service operation.(Note 3)

The presence of developed cracks within any part of the pressurised reactor coolant circuit places the submarine at risk of total loss at sea. This is because an abrupt failure of the coolant circuit would result in a loss of coolant into the reactor compartment. Unlike the civil PWR installation where the secondary containment building (the large dome-like outer building) is of sufficient volume to permit a large reduction of pressure as the escaping coolant flashes into steam into the secondary building where it is contained, the submarine reactor compartment is cramped and of insufficient over-volume to permit any significant degree of steam depressurisation. Hence, a major loss of coolant accident in the reactor compartment of a submerged or surfaced nuclear submarine would, undoubtedly, result in failure of the reactor compartment fore and aft bulkheads and, possibly, pressure hull of the submarine leading to total loss of the boat.

Obviously, for reasons of nuclear, crew and public safety any boat that has a threatening defect within the reactor system should not be not certified as seaworthy. The means by which each submarine reactor system is certified as safe are not open to independent scrutiny since this is undertaken by the Ministry of Defence Nuclear Powered Warships Committee which is not publicly accountable, neither publishing its procedures or findings.(Note 8)

Crack in the Reactor System of HMS Warspite

Details of the extent and location of the cracking discovered in HMS Warspite during the mid stages of her Devonport refit have not been published by the MoD. However, several reliable sources quite independently indicate the defect to be in or around one of the four connections of the primary coolant circuit to the reactor pressure vessel.

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During the lengthy refit of each submarine it is possible to replace pipes and components of the primary coolant circuit by first decontaminating the internal surfaces of the pipework of radioactive crud, isolating the outward coolant circuit from the reactor pressure vessel by closing of the main isolating valves (MIVs), and then cutting out that section of piping under strict radiological management. Scouring the inner surfaces of the coolant circuit reduces the levels of radioactivity emanating from deposits of surface oxides (crud) that have accumulated during reactor operation, further attenuation of radioactive emissions is achieved by localised shielding and maintaining the circuit full of water. The general policy to minimise radiation dose to refit workers is to cut out defective components and replace anew, rather than to undertake repairs in-situ.

However, replacement of the reactor pressure vessel is not practical because of its large size, the level of radioactivity and the complexity and permanency of the jointing to the coolant circuit. In fact, this central component of the nuclear system is designed as a one-off lifetime component of the submarine. Accordingly, any faults or defects found in the reactor pressure vessel have to be repaired in-situ. However, the repair of faults to the reactor pressure vessel, or to pipes entering or in close proximity to the pressure vessel, is not immediately practicable during a routine refit.(Note 4)

In other words, repairing the reactor pressure vessel in-situ within a submarine would be a highly specialised, unplanned for and hitherto untried operation. Removal of the vessel for repairs or replacement is not considered to be cost effective.

Seaworthiness of the Valiant/Churchill and Polaris Squadrons

Since the integrity of the reactor pressure vessel has to be absolutely assured for nuclear and crew safety, it is believed that the Nuclear Safety Certificate has been withdrawn from all boats of the Valiant/Churchill squadron.

The reactor defect was first reported to have been discovered on HMS Warspite during her refit in Devonport in the last quarter of 1989 - the existence of the defect was acknowledged by the Ministry of Defence in February of 1990. However, another source (Ref 4) has stated that the same defect was found on HMS Valiant during her refit of 1987.

SSN Valiant/Churchill Squadron

The Ministry of Defence will neither deny or confirm that the P1 reactor submarines are each beset with this defect (Ref 5) and, particularly, the Ministry denies that the defect was the reason for the decision to scrap this particular boat (Ref 6). However, the choice of the three Valiant/Churchill boats recently scrapped seems at odds with the relatively straightforward logic of this squadron's operation and, moreover, provides an interesting insight into the reasoning why these particular boats of the Valiant/Churchill squadron have been withdrawn from service.

First, consider the annual cost of maintaining a SSN submarine at sea which, accounting for the two rotating crews, is reckoned to be a relatively modest £4.4M. The major cost of maintaining a nuclear powered submarine is encountered in the refuelling and refitting of the submarine which occurs at about every six to seven years and which costs about £100M per submarine. Another factor to consider is that submarines undergoing refit and refuelling are withdrawn from operational service for about two or more years.

Secondly, consider the SSN submarines that have been withdrawn with respect to their position in the time programme of their individual refit cycles. Considered in terms of cost commitment and operational availability, the most obvious candidate for scrapping would be HMS Valiant. This boat is scheduled for refitting next year, she will have to withdraw from service for about two years and refitting and refuelling will incur costs of upwards £100M. The least obvious candidates for scrapping are HMS Warspite and Churchill since both of these boats were at the closing stages of their refit cycle - both these boats had, at the time of the announcement for scrapping, incurred considerable sums of expenditure (about £180M), although if they had been allowed to complete refitting(Note 7) their subsequent operation would not be unduly costly at about an annual operating cost of £4.4M for each boat. The decision to scrap Warspite and Churchill incurs a loss of about £180M, together with additional cancellation charges, since little can be salvaged from the refit of each boat.

Put simply, the Ministry of Defence has chosen to withdraw the two most recently re-equipped and refitted boats from service (Warspite, Churchill) together with Conqueror which would be due for refitting in about two years hence, choosing to leave the last two boats of the class in service when shortly each of these boats will require time consuming and expensive refitting - the commissioning refit dates for Royal Navy nuclear powered submarines are shown by **FIGURE 4**.

SSBN Polaris Squadron

The SSBN Polaris squadron comprises the four ballistic missile armed boats HMS Resolution, Renown, Revenge and Repulse. Each of these boats is fitted with a virtually identical reactor system (P1) as the Valiant/Churchill class and the boats are of about the same age (commissioned in 1967 to 1969). Of these Polaris boats only one, HMS Resolution is believed to be fully operational.(Note 5)

Another factor to be considered is the design life of the SSBN submarine reactor systems. Although the Ministry of Defence will not state a specific design life (Ref 9), the general consensus is that reactor plant design life is between 20 to 25 years. However, delays in the Trident SSBN replacement programme will now, if the nuclear deterrent is to be maintained continuously in place, require all of the Polaris squadron to remain in operation to the mid-1990s, and some Polaris boats to 1998 before the full complement of Trident submarines is operational. In fact, the increasing rate of closures of civil (landside) PWR nuclear power stations demonstrate that this type of reactor has failed to reach the intended design life, with a significant number of PWRs in the United States being closed down well before 20 years service has been achieved.

HMS Resolution last put to sea on a missile armed patrol in or about the second week of July, 1990 and has yet to return from patrol. Interestingly, Resolution has now been on patrol for some 15 weeks (as of 30 November, 1990) compared to the past SSBN patrol pattern of 10 to 12 weeks. In fact, the length of Resolution's patrol can be extended by at least three to four weeks since, and if the nuclear deterrent is to be continuously maintained, it is necessary for the so-called 'swap' boat to prepare for sea, run sea trials for about a week in preparation, return and take on board missiles at Coulport (2 to 3 days), and then proceed to and take up station (most probably in Arctic Circle waters - about one week). Once the swap boat is deployed on station, Resolution can commence her homeward voyage (about 1 week).

Clearly something is amiss with the Polaris squadron.

Speculation is that for months neither Repulse nor Revenge satisfied the nuclear safety requirements in terms of the so-called Nuclear Safety Certificate which, until issued, does not permit a nuclear powered submarine to sail on active duty. It is believed (Ref 2) that HMS Resolution has yet to undergo a full reactor system inspection(Note 6) to determine if a reactor defect common to at least the Warspite and Churchill exists and that Rolls Royce (the manufacturers of the P1 reactor system) have recently engaged a firm of consultants to prepare a scheme of remotely handled reactor pressure vessel repairs for boats of the Polaris squadron.

However, it now seems that Revenge is preparing for patrol and that Resolution will return shortly. After nine months of lying alongside undergoing repairs in the reactor compartment, HMS Revenge moved from Faslane to the missile arming berth at Coulport on 27 November, 1990. Then, late on Wednesday evening, 28 November, she slipped her moorings and put to sea from Coulport, returning there on the morning of 1 December, thus completing about two full days of sea trials. She then departed again after dusk on 2 December, returning 24 hours later. On 4 December Revenge was observed loading missiles at the Coulport berth.

It is unusual for a Polaris submarine to operate directly from Coulport since sea trials are usually run from Faslane. Also, to arm at Coulport without first undergoing a longer period (of at least one week) of sea trials, particularly following such a long lay up period, departs from the regular pattern of SSBN operation. As previously noted, these unusual and somewhat hurried movements suggest that extraordinary measures are now being adopted to maintain the submarine nuclear deterrent.(Note 9)

In summary: Of the four Polaris SSBN boats HMS Renown is currently laid up undergoing a major refit which is now believed to be eighteen months overdue. HMS Repulse seems to be in an unseaworthy condition with this boat only undertaking about six weeks patrol during the last two years. Thus the SSBN squadron is now reliant upon just two boats, with the Resolution currently out on patrol, but with her reactor system yet to be thoroughly inspected, and the Revenge about to set out on patrol following an unusually long lay up period for repairs at Faslane.

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NOTES

1 DECOMMISSIONING

The recent Ministry of Defence announcements are to pay off the submarine boats which, in Royal Navy jargon means that these boats are to be withdrawn from active service. This involves standing down the crews of about 130 men for each boat and removal of sensitive (non-nuclear) navigation and other equipment. Each boat is then prepared for an extended period of 'storage' afloat awaiting nuclear decommissioning.

Decommissioning a nuclear powered submarine is likely to follow three, although not distinctly separate, stages.

The greater part of the overall radioactive inventory is in the reactor fuel. The fuel is replaced about every six to seven years during the refit of the submarine and defuelling the reactor would be an early stage operation in the decommissioning process. Defuelling during decommissioning would not significantly vary from the routine refuelling undertaken during submarine refits, although a special berth is required and this may not be immediately available due to the servicing and refuelling requirements of other nuclear-powered submarines in fleet service - for example, Conqueror (paid off in about July, 1990) might have to wait upwards of at least half a year for defuelling of the intensely radioactive irradiated fuel. Defuelling the other two paid off boats (Warspite and Churchill) may be delayed further on the basis that their new fuel cores would not be extensively irradiated and hence would not present the same degree of hazard should an accident involving a release to atmosphere occur during the storage afloat period.

Once the fuel has been removed the next stage of decommissioning is likely to involve decontamination of the internal surfaces of the reactor coolant circuit to remove activated crud and, thereafter, removal of (radio)active hardware. Decontamination scouring is necessary to reduce the radiation dose to workers who will be required to remove radioactive and radioactively-contaminated components from the submarine reactor compartment. The extent of decontamination for decommissioning is likely to be greater than for a routine refit, the scouring fluids may be discharged to the marine environment following filtration and treatment, and activated and contaminated components removed from the reactor compartment may also require additional decontamination and treatment.

For this second stage of decommissioning the same specialised facilities of the major refits, that is a custom berth and plant that can handle the intensely radioactive fuel and activated/contaminated components, will be required. The distinction between decommissioning and refitting operations includes the scale of decontamination scouring required prior to the opening up of the reactor primary coolant circuit; the very much larger volumes and variety of radioactive waste and (radio)active equipment removed; and the packaging and storage of these wastes.

Stages 1 and 2 of decommissioning will be necessary shortly following the laying up of each submarine boat, that is with Stage 1 defuelling taking place as soon as practicably possible (within months) and Stage 2 within a few years of the lay up. Not all of the radioactive components will be removed during these initial stages, very certainly the reactor pressure vessel will remain, with the pressuriser and main isolation valves, ion exchange columns, together with other activated and/or heavily contaminated equipment.

The final route, means and destiny for the remaining radioactive components of a nuclear powered submarine are not at all certain at this time. In evidence to the House of Commons Defence Select Committee (1989), the Ministry of Defence stated its preferred route of scuttling the submarine hull at sea, but recently (1990), the International Maritime Organisation (the London Dumping Convention) endorsed its resolve to prohibit the dumping of military equipment to sea. Also, the final disposal option for radioactive wastes generated by the civil nuclear industry has yet to be determined and, even when the type and location of the UK national facility (NIREX) is finalised, such will not be available until at least year 2010 or 2015. Until this facility is finalised the complete decommissioning nuclear powered submarines cannot proceed since information is not available on the transportation routes, the maximum package sizes and package radioactive inventories.

Until the UK radioactive waste management strategy is resolved in such practical detail, the partly decommissioned submarines will have to be laid up afloat. This will require preparing the submarine reactor compartment and hull for an uncertain period afloat until the final and complete decommissioning operation can be completed.

This, in fact, is the current situation with Dreadnought. This boat was withdrawn from service in about 1981, defuelled and partially decommissioned at the Chatham Royal Dockyard and then, in about 1983, she was towed to Rosyth where she remains afloat today. Volumes of radioactive material and components removed during the partial decommissioning of Dreadnought remain in store at Chatham and the hull at Rosyth is subject to regular monitoring which indicates a gradual spreading of the radioactivity from the reactor compartment into the general areas of the boat.

2 SUBMARINE REACTOR SYSTEM

Royal Navy nuclear powered submarines are each fitted with a single, pressurised water reactor (PWR) of about $30MW_e$ power rating. The reactor is fuelled with approximately 700kg of highly enriched (93 to 97% U^{235}) uranium fuel which is sufficient to provide nuclear power for about six to eight years of fleet operation.

The reactor pressure vessel is directly linked to a primary coolant circuit, heat is drawn from the reactor pressure vessel to raise steam in a separate circuit via two steam generators, with this steam being passed through to sets of turbo-alternators which provide electrical power for the propulsion system and general boat services. To suppress boiling in the reactor primary coolant circuit this circuit, together with the reactor pressure vessel, operates at extremely high pressure, at about 3,000 lbf/in^2 (3000 pounds per square inch or 200 bar). FIGURE 1 is a schematic showing the general system arrangement of the power and propulsion equipment of a nuclear powered submarine.

The reactor pressure vessel, primary coolant circuit, steam generators and other auxiliary equipment such as the pressuriser, coolant pumps and ion-exchange equipment, are all located in an isolated reactor compartment which is situated in the mid-stern section of the submarine. FIGURE 1 shows the general machinery and reactor spaces of a Royal Navy submarine, FIGURES 2 and 3 show the reactor compartment and equipment locations which are typical of the Valiant and Polaris classes of nuclear powered submarines.

During operation, the highly enriched fuel contained within the core of the reactor generates an abundance of neutrons. As well as maintaining the reactor fuel fission process, the neutron flux irradiates or activates the reactor pressure vessel and nearby components with, as a result of this irradiation, these components being activated and rendered radioactive. In addition, the primary coolant water scours out and circulates small particles of oxides (crud) from the reactor internals which deposit and/or bind into other components of the primary coolant circuit so that these components become active by contamination with radioactive crud.

It is believed that the nuclear powered submarine fleet is fitted with two developments of the PWR marine reactor originally developed by the United States. The first reactor type is installed in all boats dating up to the first two boats of the Swiftsure squadron, thereafter later boats run with a substantially modified reactor system - the Royal Navy landside base HMS Vulcan in Scotland operates two prototype or proving reactors in advance of the actual submarine reactor running hours, although the earlier P1 prototype reactor operating for the earlier boats closed down several years ago. The awaited Trident or Vanguard class SSBNs (and the SSN 20 or W class hunter killer submarines) are to replace the Polaris squadron are to be fitted with a a new design of reactor referred to as PWR2.

3 CRACK GROWTH AND EMBRITTLEMENT - CATASTROPHIC FAILURE

Over its prolonged service life the steel forming the body of the reactor pressure vessel becomes embrittled. The embrittlement results both from the high level of neutron bombardment emanating from the nuclear processes underway within the reactor core and, to a lesser extent, from a composite of thermal heating, cycling and related processes which are generally referred to as thermo-hydraulic.

Irradiation of the reactor pressure vessel body is progressive and this in turn results in a raising of the temperature threshold below which the steel acts as a brittle material and above which as a ductile material. At all times the reactor pressure must operate above brittle/ductile temperature threshold if its failure performance is to be maintained reliable.

A new, unirradiated pressure vessel will perform as a ductile and reliable engineering structure from very low temperatures whereas the steels deployed in a reactor pressure vessel of 20 to 25 years service age exhibit a brittle/ductile temperature much elevated to the region of 110°C or more.

A second and interconnected degradation phenomenon of steel linked to embrittlement is the presence and development of flaws and cracks within the body of the steel. It is virtually impossible to produce any engineered fabrication free of minute cracks. Such flaws often occur at welded junctions or where there is a high concentration of internal stress at either the manufacturing and assembly processes for the components, or where slightly dissimilar metals are in intimate contact - where such flaws and cracks occur repetitively in similar or identical fabrications then the defects is considered to be generic to the design.

During operation of the pressure vessel extant cracks can extend and, also, new cracks may form and develop. Locations known to be cracked at manufacturer are regularly monitored for crack development and the whole of the pressure vessel is routinely scanned (by eddy current and sonic means) for new crack formation. Such regular monitoring is necessary because although during the first phase of crack development is steady and progressive, to a great extent predictable, a crack can reach a critical size at which further growth is abrupt, unlimited and catastrophic.

The combination of steel embrittlement and crack growth to the critical size may result in quite expected and total, catastrophic failure of the structure. Example of such a failure, referred to as abrupt or fast brittle fracture, resulted in the total loss of several Comet aircraft during the 1950s. In the Comet fuselage a small rectangular navigation window developed cracks at the corners which, with the pressurised metal skin operating below the brittle/ductile temperature threshold at cruising altitude, resulted in the abrupt and then totally unforeseeable loss of a number of aircraft.

As previously noted, reactor pressure vessels operate at high pressure and become progressively more embrittled during long service. Although in normal operation the reactor vessel operates at a temperature above the brittle/ductile threshold, the problem is that when the reactor is closed down rapidly because of some unrelated fault, the temperature may descend rapidly whereas the pressure level reduction may lag in time - in other words, a SCRAM of a reactor may result in the cooling reactor pressure vessel entering the brittle regime whilst still highly pressurised - it is at this point that the reactor pressure vessel is most at risk of catastrophic failure.

The problem here is that small defects extant in the body of the steel, or at highly stressed areas such as joints and welds, may prompt rapid and catastrophic failure of the local steel. Over the life of the pressure vessel any original defect or crack will grow, as the pressure vessel is stressed and cycled, but there occurs a point when the geometry and length of the crack is such that further lengthening of the crack occurs very rapidly (instantaneously). This is known as the critical crack length which relates to the geometry of the engineering component.

Essentially, the risk of a crack catastrophically failing relates to its length, the force applied (the reactor pressure) and the lack of ductility (embrittlement) of the steel - the embrittlement of steel is temporarily reduced when the steel is operated at elevated temperature and there is a distinctive brittle/ductile temperature threshold regime. However, as the steel embrittles the brittle/ductile temperature threshold elevates reducing the margin between ductile (safe) and brittle (uncertain) operation of the reactor pressure vessel.

In other words, as the reactor pressure vessel increases in age (hours of irradiation operation), extant cracks progress in length; the steel embrittles and the temperature threshold above which the steel acts in a ductile way increases towards the operating regime. This results in difficulties in operating the reactor, particularly at close down when the reactor operating temperature can rapidly descend whereas the coolant pressure remains high - here the reactor pressure vessel steel may enter the brittle regime whilst still charged at high pressure.

Brittle failure of pressure vessels is relatively well understood and repairs to and eradication of cracks is possible for conventional pressure vessels. The problem with the reactor pressure vessel is that, because of the irradiation the steel is rendered radioactive, working nearby and directly on the pressure vessel is very difficult in radiological terms - the cramped conditions of a submarine reactor compartment add a further dimension of difficulty to such repair work. In fact, of the nuclear power installation on board a submarine the reactor pressure vessel is a lifetime component - whereas other components of the primary coolant circuit can be replaced during the refit, components (including the reactor pressure vessel) beyond the main isolating valves are not accessible other than for relatively minor repairs.

It is believed that the crack discovered on HMS Warspite is located at the junction of a main coolant pipe spigot with the reactor pressure vessel (that is beyond the MIV) and that, furthermore, the crack is related to the specific design and material of the spigot junction. In other words, the defect or crack is design-related and likely to be generic to all reactor systems of this design. Warspite was the first of the P1 reactor boats to undergo a fourth refit so, in this respect, she is the lead boat - such a defect found on Warspite is, in all probability, likely to occur on other reactor systems of this type.

4 REPAIRS TO THE REACTOR PRESSURE VESSEL

This is because the reactor pressure vessel is itself radioactive (unlike the coolant circuit piping which is radioactive by virtue of the presence of radioactive crud contaminants and not necessary radioactive itself). Because of the high levels of radioactivity emanating from the reactor pressure vessel the vessel is totally encapsulated in dense radiation shielding

Accordingly, for repairs the pressure vessel has to be drained and access to the outer surfaces of the vessel necessitates removal of the dense polythene radiation shielding. Such repairs would have to be completed remotely by robotic equipment specifically tailored for the task - it is understood that such specialised equipment has not been developed at this time.

5 CONDITION OF THE POLARIS SQUADRON

At this time HMS Renown is undergoing refit at the Rosyth Royal Dockyard and is about eighteen months overdue in completing the refit - this boat is not currently available for operational deployment.

HMS Revenge has been tied up at Faslane since February to 27 November, 1990 undergoing inspection and repairs within the reactor compartment - this boat is not believed to be in a full seaworthy condition.

HMS Repulse is believed (Ref 2) to have undertaken six to eight weeks of operational deployment at sea within the last two years - there is some doubt as to the seaworthy state of this boat.

6 INSPECTION OF HMS RESOLUTION REACTOR SYSTEM

The Ministry of Defence have stated that each of the Resolution class boats has been inspected in common with other nuclear powered submarines (Ref 9) but the detail of these inspections is not at all clear. Some (Ref 2) have good reason to believe that the <u>full</u> inspection necessitated by the Warspite defect has not be undertaken on Resolution and that the inspections referred to be the MoD are the routine reactor inspections undertaken prior to sea operation and which are carried out without necessity to defuel the reactor.

7 STATE OF COMPLETION OF WARSPITE AND CHURCHILL REFITS

The Ministry of Defence (Ref 9) state that Warspite had been in refit for two and one half years at the time of the decision to pay her off (1 November, 1990), and that the specified work was virtually complete, refuelling had been completed and the testing and setting work was well in hand. In fact, Warspite had been undocked when the decision to pay her off was made.

Churchill had been in refit for one year and four months when she was paid off (29 October, 1990) and her refit was about two thirds complete and she had been refuelled.

The Ministry of Defence is now in negotiation with the two refitting contractors (DML and BTL) on the final settlement of the cancellation charges.

8 REGULATION AND LICENSING SUBMARINE NUCLEAR REACTORS

Ministry of Defence nuclear plant is not subject to the Nuclear Installations Act 1965 but, instead, regulated and controlled by the Nuclear Powered Warship Committee. It is believed that this committee includes seven civilian members who are drawn from directly involved companies such as Rolls Royce who manufacture and are responsible for the development of the submarine reactor systems. Civil nuclear installations are regulated and licensed by the independent Nuclear Installations Inspectorate who apply the criteria of 'acceptable risk v tolerable consequences' to determine nuclear safety and, unlike military plant, civil nuclear installations are subject to public scrutiny via Public Inquiries and the licensing reviews published regularly by the Nuclear Installations Inspectorate.

9 HMS REVENGE PATROL

Adding to the unusual SSBN movements of late is that it is rumoured that wives of the Revenge crew have been informed that husbands will not return until February or March 1991, which suggests another long patrol.

REFERENCES

1	Observer	Series of articles in the Observer claiming the reason for withdrawal of the SSN submarines to relate to the discovery of a serious defect in the reactor system of HMS Warspite - 11, 18 November 1990
2	McFall J	Statements made by Mr John McFall, Member for Dumbarton, relating to the condition of submarine boat reactors in both the Valiant SSN and Polaris SSBN squadrons - 10 November, 1990
3	Guardian	Article of 19 November 1990
4	Anon	Letter dated 16 November, 1990 received from a serving submariner relating defects in HMS Valiant and the Polaris squadron
5	HofC	Defence Committee Session, 28 November 1990 - questions and answers to Ministry of Defence officials
6	HMSO	Answer to the Parliamentary Question placed by M O'Neil, Member for Clackmannan on 15, November 1990 for which the Answer stated "A range of factors were taken into account before deciding which submarines to decommission to achieve the lower force level of about 16 boats including age, capability, material state and cost of maintenance and operation. All of these factors are relevant in the case of HMS Warspite"
7	Anon	Private conversation of 27 November, 1990 with a consultant engaged in the non-destructive testing industry
8	Sunday Times	Article of 18 November 1990
9	MoD	MoD Response to written questions, D/DGSR(Sec)/631/7, House of Commons Defence Committee

REACTOR PRIMARY CIRCUIT | STEAM SECONDARY CIRCUIT

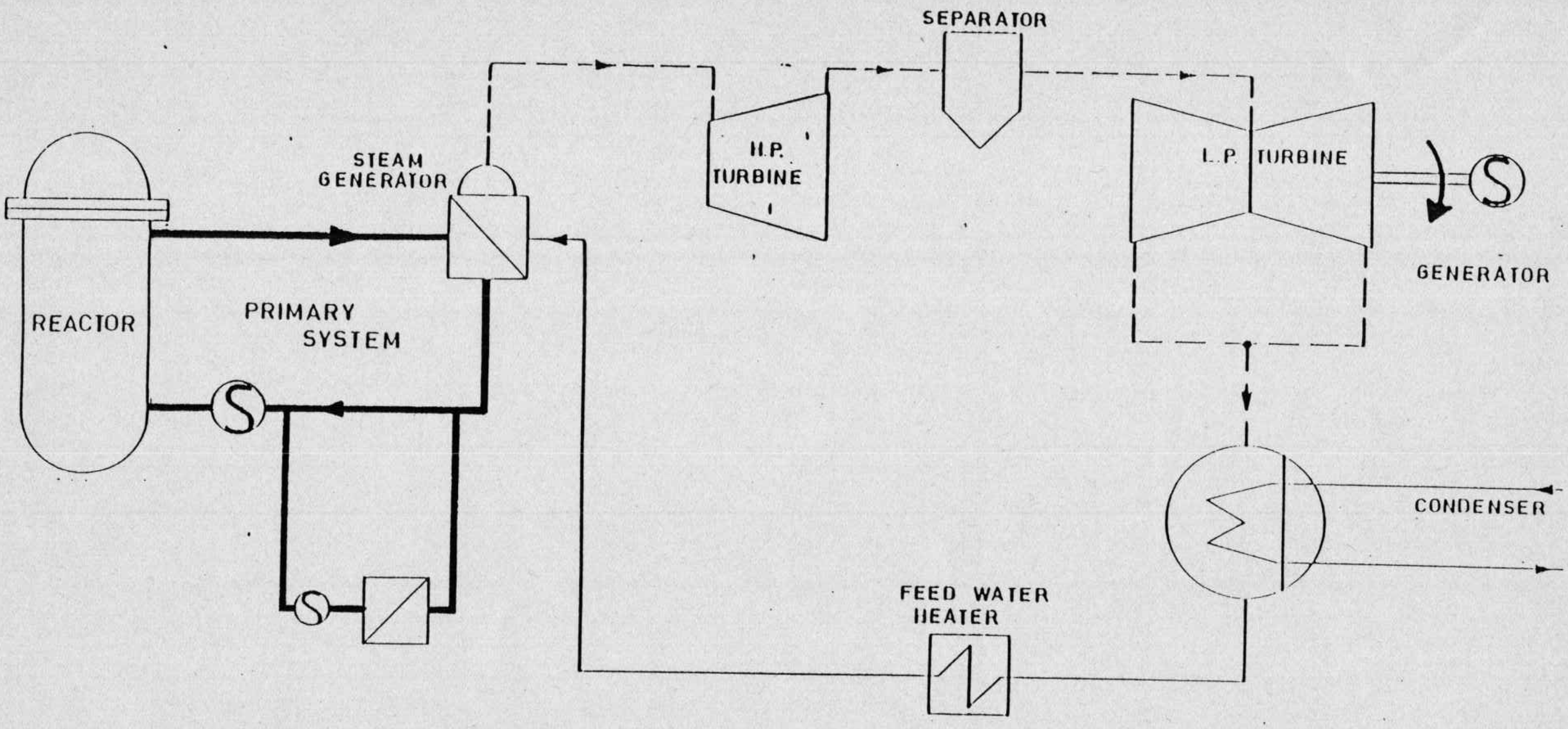
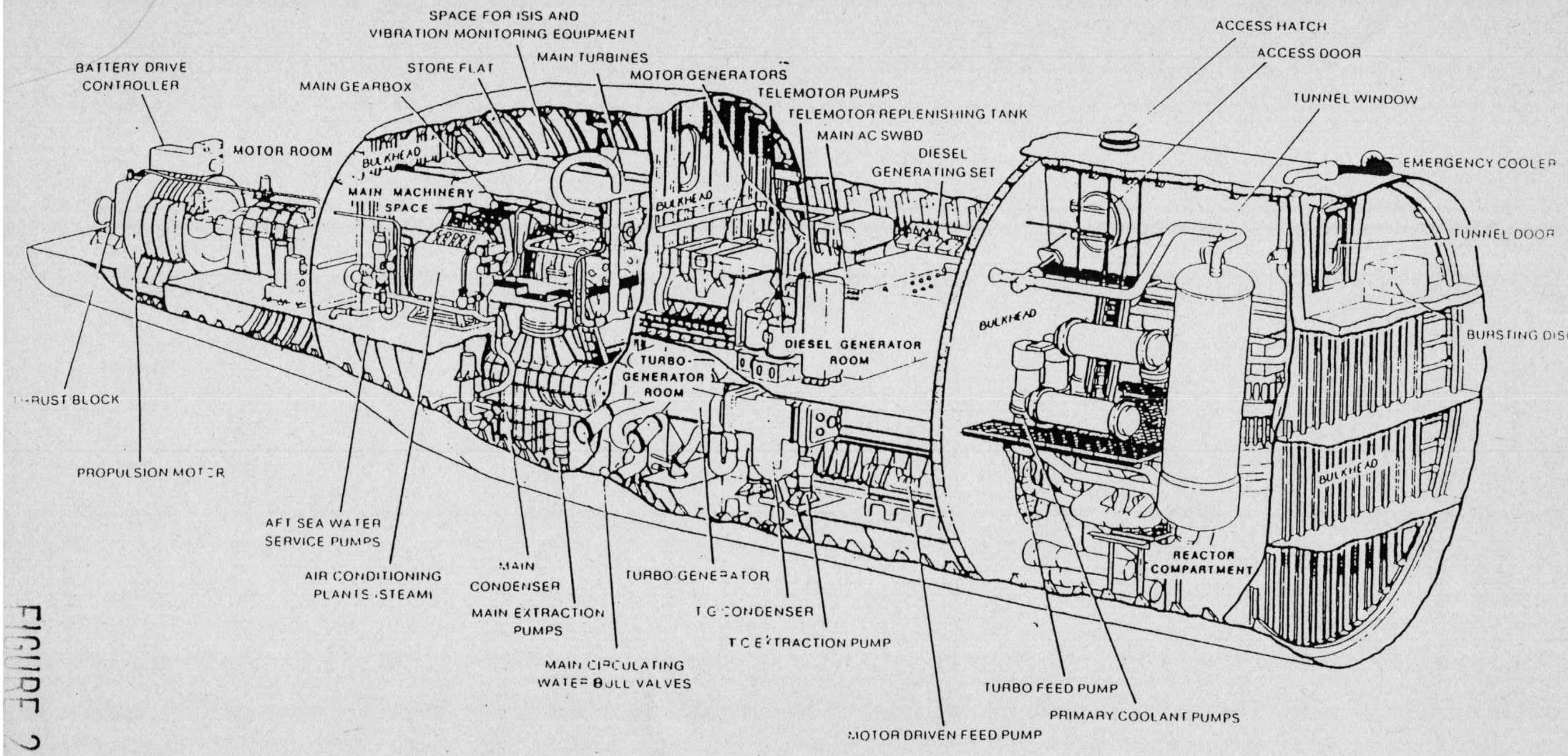


FIGURE 1


BATTERY DRIVE CONTROLLER
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STORE FLAT
SPACE FOR ISIS AND VIBRATION MONITORING EQUIPMENT
MAIN TURBINES
MOTOR GENERATORS
TELEMOTOR PUMPS
TELEMOTOR REPLENISHING TANK
MAIN AC SWBD
DIESEL GENERATING SET
ACCESS HATCH
ACCESS DOOR
TUNNEL WINDOW
EMERGENCY COOLER
TUNNEL DOOR
BURSTING DISCS
BULKHEAD
MAIN MACHINERY SPACE
BULKHEAD
BULKHEAD
DIESEL GENERATOR ROOM
TURBO-GENERATOR ROOM
BULKHEAD
BULKHEAD
REACTOR COMPARTMENT
THRUST BLOCK
PROPULSION MOTOR
AFT SEA WATER SERVICE PUMPS
AIR CONDITIONING PLANTS (STEAM)
MAIN CONDENSER
MAIN EXTRACTION PUMPS
MAIN CIRCULATING WATER HULL VALVES
TURBO GENERATOR
T G CONDENSER
T G EXTRACTION PUMP
MOTOR DRIVEN FEED PUMP
TURBO FEED PUMP
PRIMARY COOLANT PUMPS

FIGURE 2

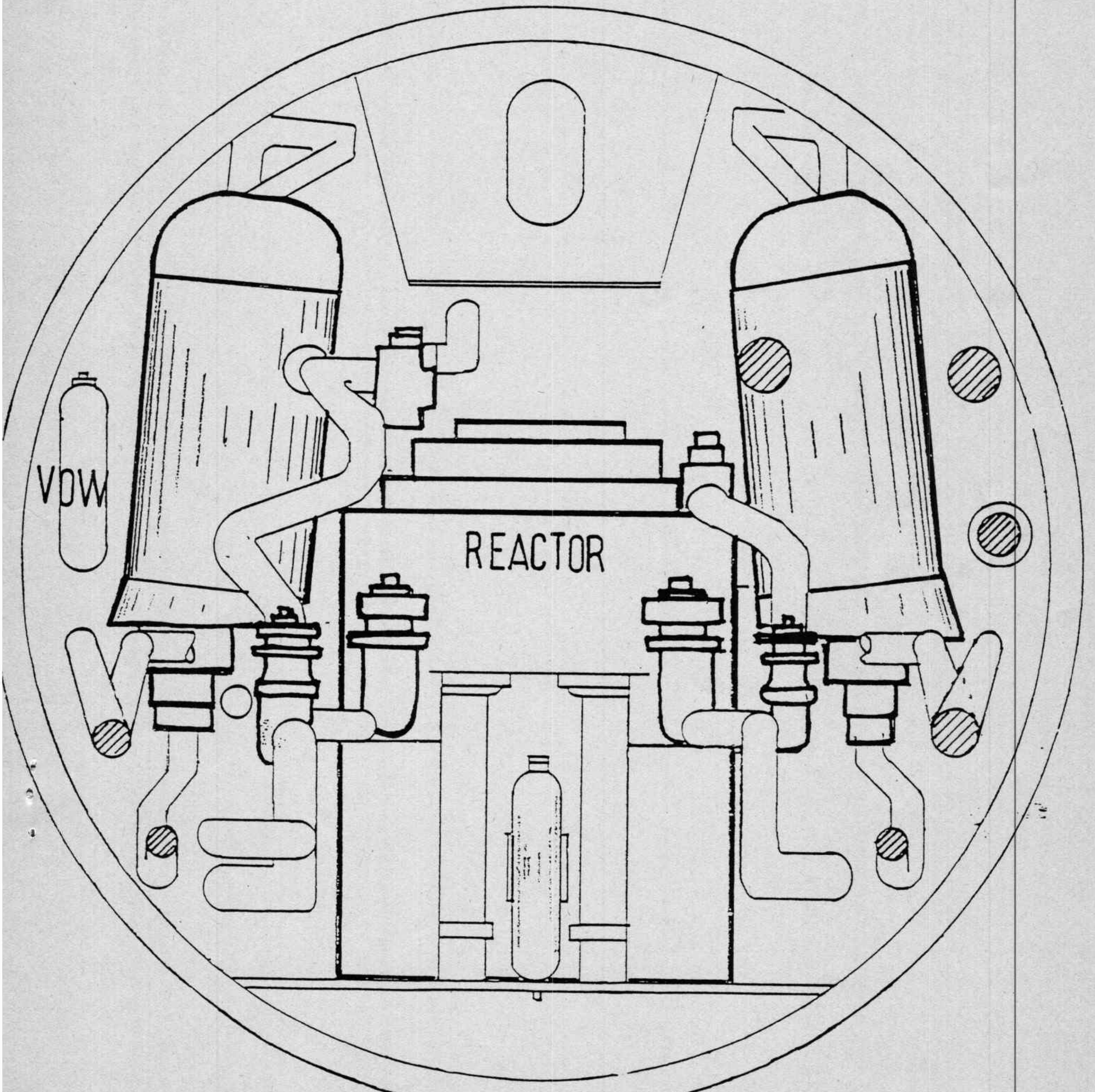


FIGURE 3

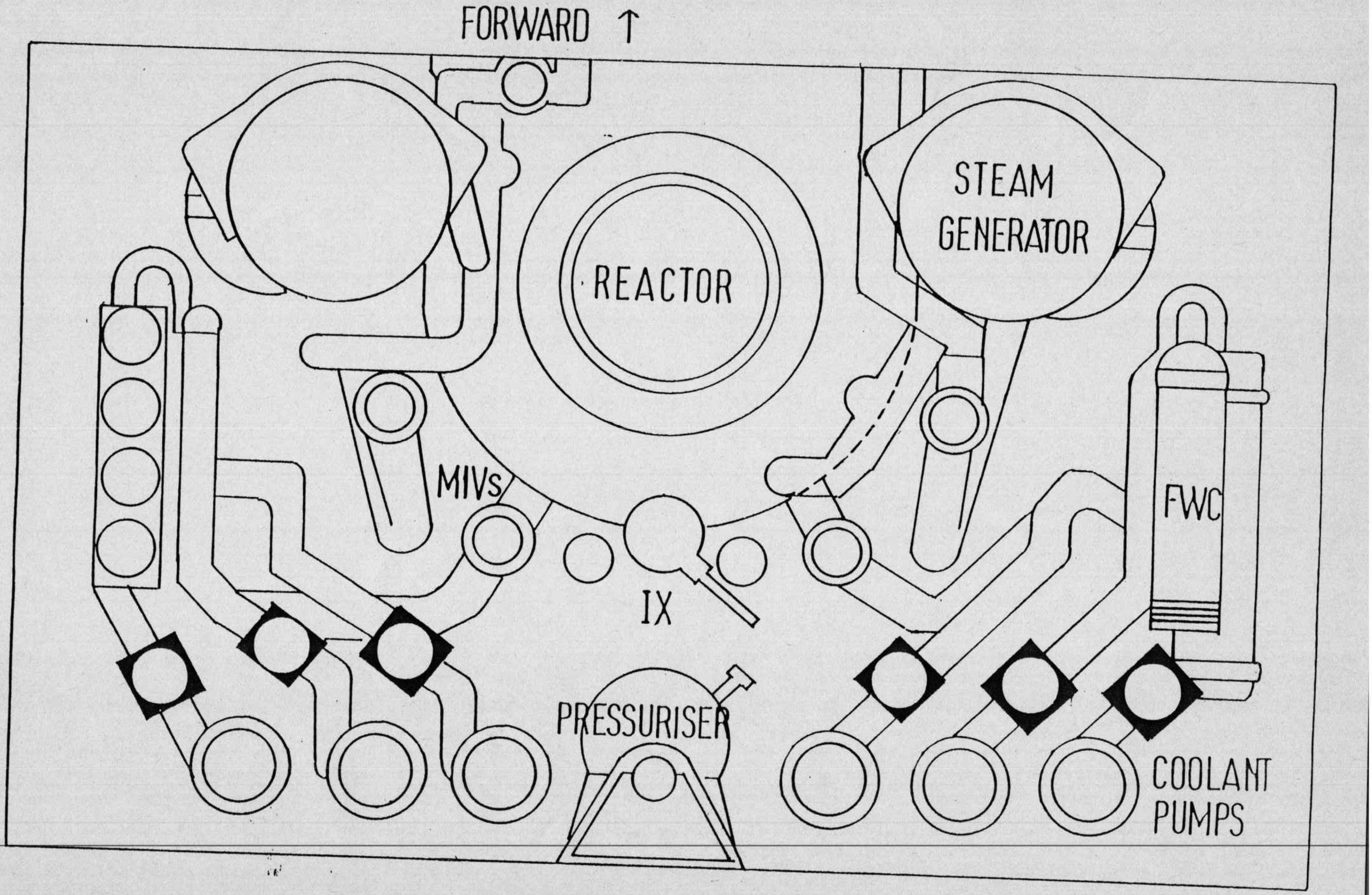
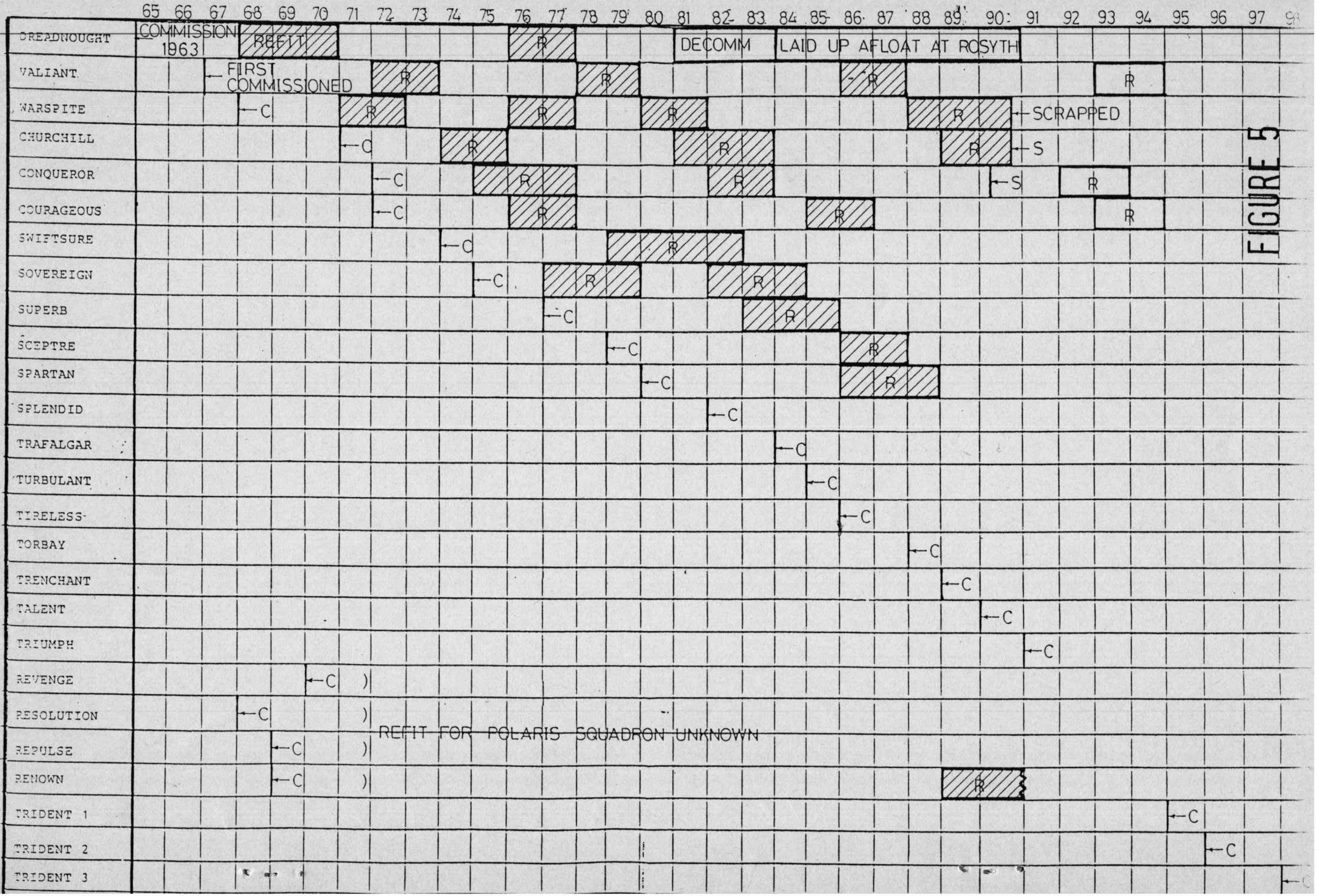

FORWARD ↑
STEAM
GENERATOR
REACTOR
MIVs
IX
FWC
PRESSURISER
COOLANT
PUMPS

FIGURE 4



65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
DREADNOUGHT
VALIANT
WARSPITE
CHURCHILL
CONQUEROR
COURAGEOUS
SWIFTSURE
SOVEREIGN
SUPERB
SCEPTRE
SPARTAN
SPLENDID
TRAFALGAR
TURBULANT
TIRELESS
TORBAY
TRENCHANT
TALENT
TRIUMPH
REVENGE
RESOLUTION
REPULSE
RENOWN
TRIDENT 1
TRIDENT 2
TRIDENT 3
COMMISSION 1963
REFIT
DECOMM
LAID UP AFLOAT AT ROSYTH
FIRST COMMISSIONED
SCRAPPED
REFIT FOR POLARIS SQUADRON UNKNOWN

FIGURE 5