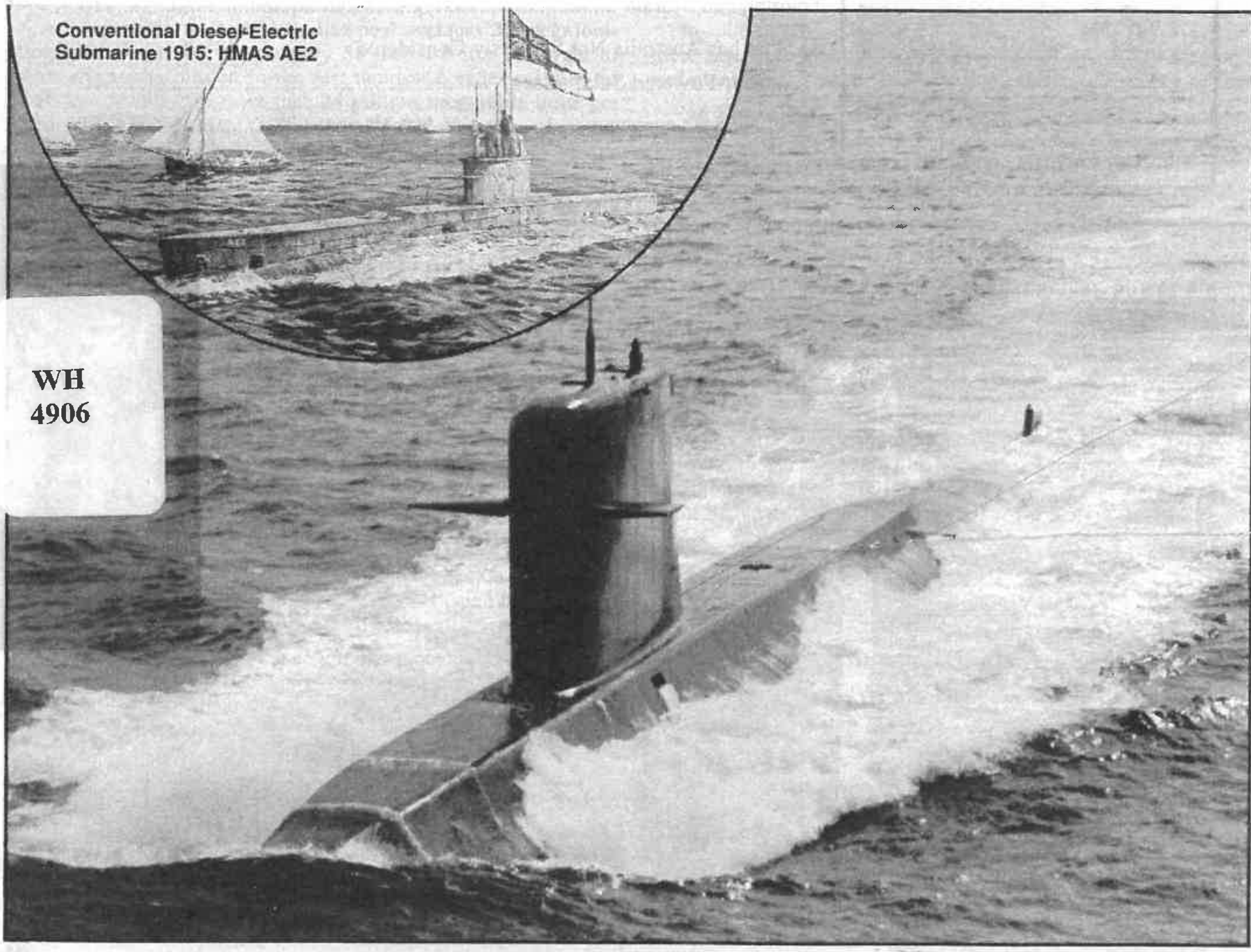
The Navy League of Australia

Nuclear-Powered Submarines for the Royal Australian Navy?



A paper written for

The Navy League of Australia

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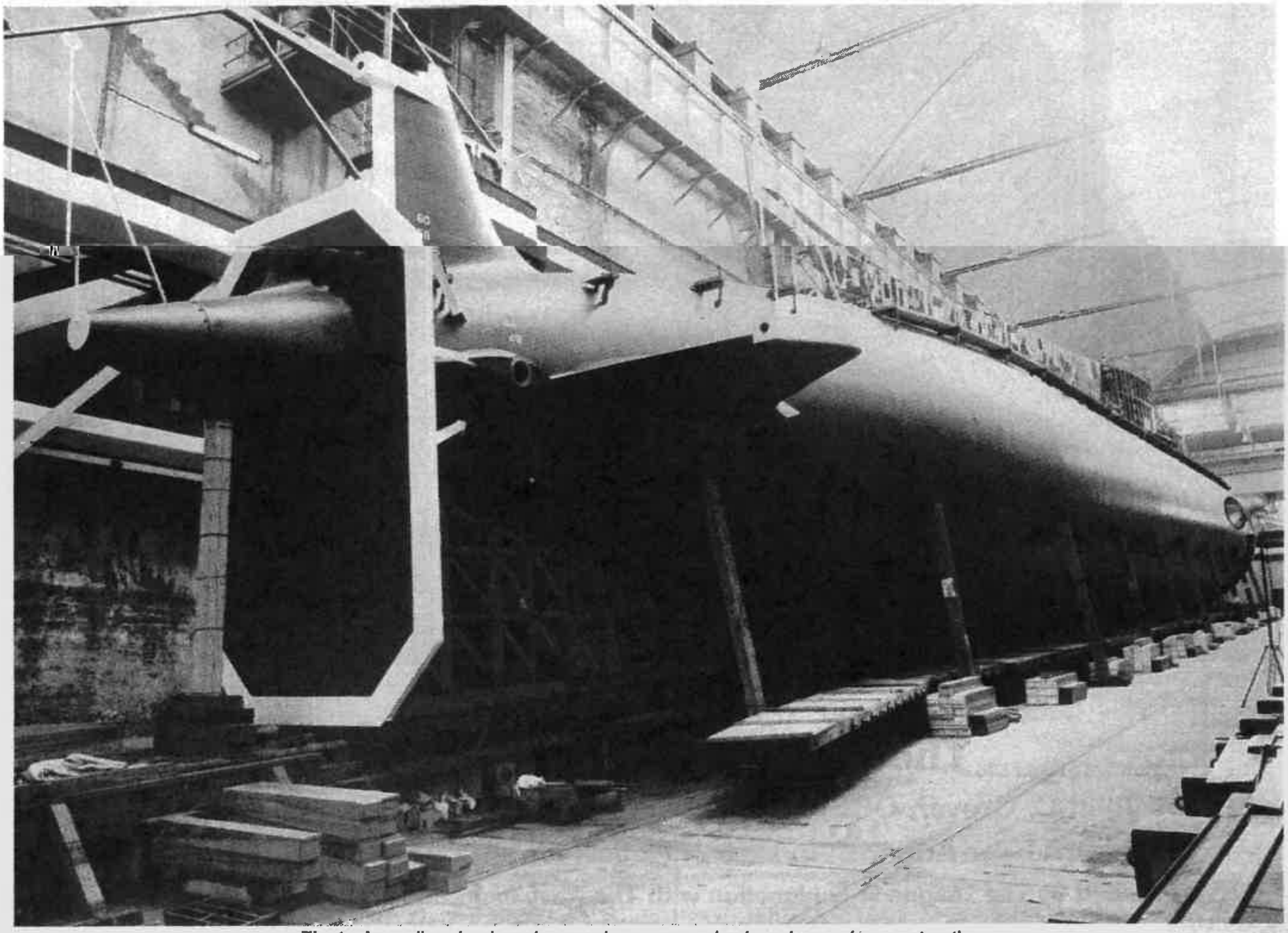


Fig 1: *A smaller-sized modern nuclear-powered submarine under construction.*

INTRODUCTION

What are the facts about **Nuclear Energy?**

While the nuclear-powering of ships is an issue which can be discussed on its own merits, it is often discussed in the context of nuclear power stations as a whole. It therefore seems appropriate to consider briefly the nuclear power question before moving onto the subject of power for warships.

A kilogram of washed Australian coal averages **35 megajoule units** of energy. Oil has roughly **38 units.** But a kilogram of natural uranium burned in the fast neutron breeder reactors of tomorrow would give more than **24 million megajoule units** per kilogram! *The difference is 35 versus 24,000,000 units of energy per kilogram.*

Thus very small small quantities of uranium, easy to transport and store, can replace huge quantities of coal or oil for the production of electricity in power stations or for powering ships.

While acknowledging the vital need for very high standards of design, quality control, construction, training, operation and safety in nuclear power stations or nuclear-powered ships, this technology has considerable advantages over coal-fired installations, not only with respect to the bulk of the feedstock used, but also with respect to pollution.

The results of failure to observe high safety standards are obvious, particularly as shown by the Soviet disasters of Chernobyl and lately Ust-Komenogorsk, and in Soviet submarines.

It must be remembered, however, that nuclear facilities are not alone in posing latent hazards. There have been major disasters in other areas of production where appropriate standards have not been observed, for example in chemical works (such as at Bhopal in India), and in coal mine explosion disasters all over the world.

While much effort is being devoted to reducing pollution from coal, the problem is formidable as most 1000 megawatt coal-fired power stations use about 400 tonnes of coal *per hour,* producing the following pollution burned in 4500 tonnes of air:

- carbon dioxide: about 1200 tonnes per hour;
- nitrogen oxides: as from 200,000 motor cars running continuously;
- organic compounds: about 50, some known to be carcinogens;
- radioactive isotopes: about 50, including highly toxic Protactinium 231 and Radium.

Nuclear power stations produce no such pollution and the radioactivity therefrom is much less than from coal-fired stations. (The design allows for the radioactivity in the event of mishaps to be confined to the containment building. Only the Russians have been building stations generally without such reinforced concrete buildings, until recent years).

While oil, being a liquid, is more flexible as an energy source than either coal or uranium because it can be readily piped, it is also polluting, but not quite as seriously as coal.

However, our oil production is set to decline substantially during the 1990s while our consumption increases about 2% annually (APEA 1990).

In spite of recent finds on the NW Shelf of Western Australia, more discoveries are needed if Australia is to be even 50% self-sufficient in the year 2000. We could be in serious trouble by then.

On the other hand Australia has an abundant supply of uranium (as it has of coal), a good reason for discussing nuclear energy and its applicability to us, for part of our future power production, particularly in remote areas, and for ship propulsion.

Australia's uranium has more energy potential than all the oil of Saudi Arabia, yet most of it lies undeveloped.

Despite Chernobyl the world's nuclear power-station development continues apace. World-wide, 19 large nuclear reactors went onto electricity grids in 1989[2]. Some are being decommissioned after 30 years or so. The world total is now 422 with 68 more under construction and another 83 under firm plan (March 1991).

France now has 55 reactors which produce between 75 and 80 per cent of her electricity, and supply other European countries including Britain. This is a remarkable achievement, without major incidents. (Eight more reactors are under construction.)

In our general region Japan has 40 operating, 12 more under construction, 15 more under firm plan, for a total of 67.

China has three reactors building and four more on firm plan.

Taiwan has six reactors operating and two more planned, totalling eight.

South Korea has nine operating, two building and another three planned, totalling 14.

India has seven operating, seven more building and 12 more under firm plan, for a total of 26.

Indonesia's first nuclear power station is scheduled for construction in 1995.

While Sweden had ideas of phasing out nuclear power stations, the great increase in the price of oil following the invasion of Kuwait has caused a rethink of this policy.

But Australia has so far not embraced nuclear energy. We are therefore to a large extent cut off from this very important technology of the 20th century and run the risk of technological decline in comparison with our trading partners.

While this is of significance to national development, of importance also is the use of nuclear power for the propulsion of warships.

By nuclear propulsion is meant the use of nuclear fuel to heat water to produce steam which drives a turbine in the same way as a coal-fired or oil-fired ship. The nuclear argument is thus about heating water for steam and not about nuclear weapons.

The Naval use of Nuclear Power for Ship Propulsion

The historic message from US Submarine *Nautilus,* **"Under way on nuclear power"** came in 1955, more than 35 years ago. Voyages under the North Polar ice-cap signalled a world moving into the nuclear age.

The nuclear-powered submarine's submerged speed of 25+ knots could be sustained almost indefinitely with almost total discretion.

Air-independence made snorkel masts obsolete, for *Nautilus* did not have to stop and raise such a mast to recharge her batteries.

Better living conditions included virtually limitless fresh water from distillation, as well as air conditioning.

For the first time since the days of sail, nuclear power gave navies vessels whose range was limited only by the endurance of machinery, supplies and crew – and not by fuel.

Nuclear power for submarines has now been accepted by the USA, Britain, France, the USSR, China, India and probably Pakistan.

Launched in 1960, Britain's first nuclear-powered submarine, *HMS Dreadnought*, displaced 4000 tons dived.

Her largest nuclear-powered submarines are the four *Resolution* Class carrying long-range ballistic missiles and displacing 7500 tons dived.

The Russian double titanium hulled *Alpha* Class SSN has a reported world record speed of about 40 knots submerged, and can operate at a depth of 700 metres. Built in the 1960s, it has several times the power of the US nuclear-powered submarines (SSNs).

The largest submarines in the world are the Soviet nuclear-powered *Typhoon* Class of 26,500 tons dived, each about half the size of the Battleship *USS Missouri*, a recent visitor to Sydney Harbour.

Lately one *nuclear-powered* submarine was being launched every few weeks by the Soviets, whose nuclear fleet totalled about 229 compared with 133 in the USA, according to the 1990 *Jane's Fighting Ships*. However, numbers were being cut back in 1990 – in older boats – as superpower tension eased.

France launched in 1967 the first of her nuclear-powered submarines: *Le Redoutable* displacing 9000 tons submerged. She now has eleven nuclear-powered submarines, five of which are the very interesting small *Rubis* class.

Initially built around large reactors, nuclear-powered submarines were too large and too expensive for smaller nations to consider.

So in 1955, the year of the *Nautilus*, France began thinking about nuclear power for the propulsion of smaller vessels comparable in size and cost with the newest designs of diesel-electric submarines.

A new nuclear boiler concept with its steam generator placed *above and within* the reactor achieved a silent primary water circulation by convection.

For speeds up to 18 knots this eliminated the need for primary booster pumps, the major radiated noise factor in nuclear-powered submarines until then. It also occupied less space.

This concept has been proven in the *Rubis*, first tested in 1975, and in the *Amethyste*, the latest version fitted with updated technology and weapon and sensor systems.

In the natural convection mode the submarine runs silently[2]. The noise of reduction gearing has been eliminated by electrical transmission: the steam turbine drives alternators which power an electric motor on the propellor shaft.

The *Rubis'* reported top speed of about 25 knots submerged is, of course, less than that of the more powerful and larger British *Trafalgar* (5200 tonnes) and the US *Los Angeles* (7000 tonnes) class submarines. But 25 knots continuously is an enormous improvement over the limited endurance at speed of the latest diesel-electric submarines.

The 48 megawatts nuclear reactor of the *Rubis* Class requires only about one tonne of fabricated uranium fuel.

Depending on operational speeds, *refuelling would not be needed for years – perhaps once in the submarine's lifetime of about 30 years*[3].

In 1985 the *Rubis* steamed submerged from Toulon via the Cape of Good Hope to Noumea in New Caledonia, where her maintenance tender joined her *a few weeks later.* But no maintenance was needed on the nuclear plant side, and only minor attention to the non-nuclear steam turbine circuit, which was not beyond the resources of the crew.

The *Rubis* then steamed submerged to Tahiti, and thence submerged for 35 days back to Toulon.

In her underwater circumnavigation she covered 32,500 nautical miles at a mean transit speed of 15 knots[4].

A diesel-electric submarine could not have undertaken this venture without support from shore-bases or surface ships for refuelling and probably diesel maintenance. It would have taken perhaps three times as long.

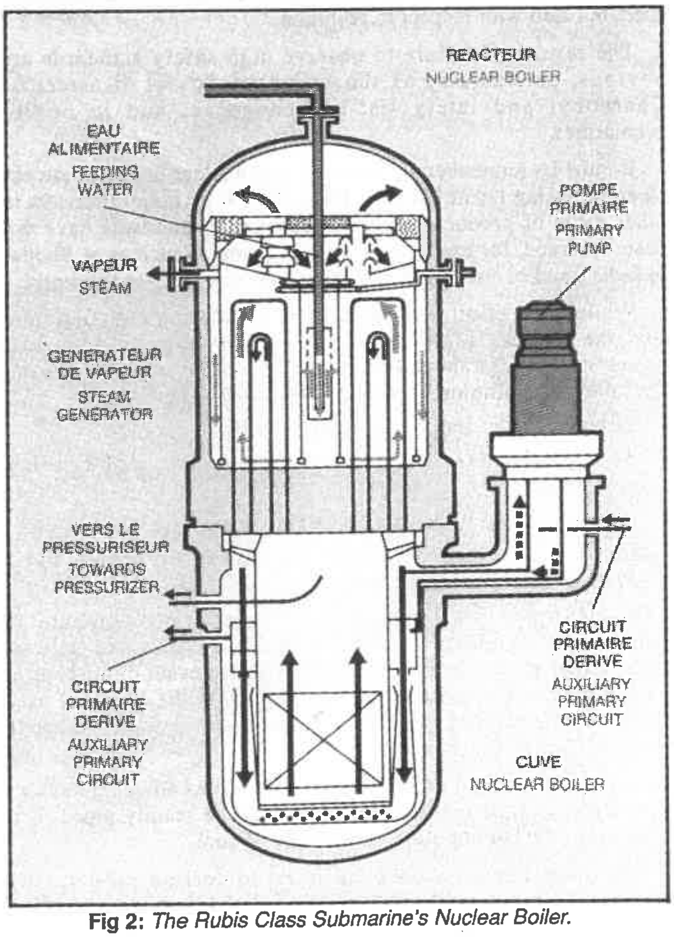


Fig 2: *The Rubis Class Submarine's Nuclear Boiler.*

India to get 6 Soviet N-subs

From PETER SAMUEL in Washington "AUSTRALIAN" 5/6 MARCH 1988

INDIA is acquiring a force of six cruise missile-carrying, nuclear-powered Soviet submarines, says a naval authority, Mr Norman Friedman.

He says the recent acceptance of one nuclear submarine by the Indian Navy is the first of six, and that it may involve a secret Soviet-Indian security treaty.

An Indian crew was flown to Vladivostok in the Soviet Far East earlier this year to take charge of the submarine, which has been given the Indian name Chakra.

Nuclear submarines can operate without the need to surface, have an enormous range and superior speed compared with conventional submarines.

Mr Friedman, writing in the latest issue of the United States Naval Institute's Proceedings Journal, says that the Soviet-supplied submarines, together with new German and Soviet conventionally powered underwater boats, would help make India a major power in the Indian Ocean.

Previously, only the US, the Soviet Union, Britain, France and China have deployed nuclear submarines, although Canada has announced its intention of buying 10 to 12 from either France or Britain.

A Washington naval authority, Mr Norman Polmar, says the Indian submarine is not a Victor III, as had been previously reported, but a Charlie I Class boat.

The Charlie Class submarines began being produced in the late 1960s and the Victor IIIs in the late 1970s.

Charlie I Class vessels have a 5000-tonne displacement submerged and a cruising speed of 23 knots. They are armed with eight SS-N-7 anti-ship cruise missiles and SS-N-15 anti-submarine rockets, as well as conventional torpedoes. The missiles are housed in the bow in tubes angled diagonally upward.

Victor III Class boats have a 6300-tonne displacement submerged, a speed of 29 knots and are armed with two classes of anti-submarine missiles – SS-N-15s and 16s – plus torpedoes.

The Charlie Class SS-N-7 cruise missiles have a range of 65km and can carry either a nuclear or conventional explosive warhead of 500kg.

The Victor III missiles are submarine rockets fired from torpedo tubes and can also carry nuclear or conventional warheads.

Mr Polmar says he doubts whether the Soviets would provide the Indian Navy with nuclear warheads, although India may be capable of building them itself.

The director of security studies at Johns Hopkins University, Mr Michael Vlahos, says that India is becoming a major naval power.

"India must be thinking ahead to potential conflicts with other regional powers, such as Indonesia," he says.

The Charlie I submarine . . . armed with missiles, rockets and torpedoes

Fig 3: *Editorial*

In 1988 India took delivery of her first Soviet-built nuclear-powered submarine – of six reportedly planned. A second is believed to have been handed over in 1989 although there are contrary reports of the return of the original submarine to the USSR. India's navy, based on two aircraft carriers and a force including submarines, escorts and marines, is now the most balanced and powerful in our general region.

China has four 8000 ton nuclear-powered submarines, with others planned.

Pakistan is reported[5] to be acquiring at least one nuclear-powered submarine from China.

While commercial uses of marine nuclear power are limited to Arctic icebreakers and barges and one Japanese cargo ship under test, there are now more than 370 nuclear-powered warships operating in the navies of six nations.

While these are mostly submarines, the Americans have entire Carrier Task Forces – carriers, cruisers and escorts – all nuclear-powered, thus giving immense flexibility and freedom from the need for bases or costly and vulnerable tanker support. France also is now building a nuclear-powered aircraft carrier.

Maritime nuclear power shares with supersonic aircraft the distinction of having been a most remarkable success.

How do Diesel-Electric Submarines Compare with Nuclear-Powered?

Diesel-electric submarines similar to our present *Oberon* class are silent when running on their batteries. At four knots they can cruise for about a day and a half submerged – say 150 nautical miles in still water. However, normally they need to "snort" – to raise the snorkel-mast – after about 12 hours to get air to the noisy fast-revving diesel engines in order to recharge batteries. Ventilation and replenishment of the atmosphere is a by-product of that action.

At a top speed of about 22 knots, modern diesel-electric submarine batteries would last about one hour – from Garden Island they would be able to reach Palm.Beach with a flat battery.

They would then require to snort to recharge batteries for several hours.

While charging, the submarine listening capability is degraded and it moves very slowly. It is vulnerable to detection of its snort mast by radar, by the recognition of its gases exhausted into the atmosphere and by the noise from the diesel generators.

Most *modern* diesel-electric submarines operating at five knots would have to "snort" for about 7% of the time, and at 10 knots for about 20% of the time. This is known as the "indiscretion ratio", a measure of the risk of detection.

In practice they would "snort" in bursts to minimise the possibility of being detected.

Equipment for detecting submarines was already well advanced 50 years ago and recent improvements have been such that *many doubt whether diesel-electric submarines using snorkel masts could survive for long in modern war against a well-equipped and trained enemy. The exposure of any mast above the surface considerably increases the risk.*

Towards the end of World War II, faced by experienced radar-equipped corvettes, destroyers, escort aircraft carriers and shore-based aircraft, only two out of every 10 German U-boats which set out could be expected to return. New Captains, even with veteran crews, stood little chance of returning from their first patrols. This was mainly because they had to surface to charge batteries. The snorkel system in the newer U-Boats reduced the detection rate.

But the overall figures are revealing: *of the 842 conventional diesel-electric U-Boats which saw action, 781 were lost – 93%. Their crews suffered 85% losses.*

The modern diesel-electric submarine, while of better endurance and armament, and much quieter, still has serious limitations: slow continuous submerged speed and a significant "indiscretion ratio".

The Swedish Kockums diesel-electric submarines now being partly built in South Australia will be among the best equipped and most modern diesel-electric submarines in the world. Additionally, air-independence is a possible development, using a Stirling Heat Engine and liquid oxygen supply – some of which is used for air purification in conjunction with carbon dioxide removal.

Invented by a Scottish Presbyterian Minister more than a century ago, the Stirling Engine runs on a mixture of oils and oxygen, exhausting into the sea. The first Stirling unit was installed in the diesel-electric Swedish submarine *Nachen* for maintaining batteries at full charge while operating at very slow speeds, preferably four knots.

Continued on Page 6

Nuclear fuel **1** contained in reactor vessel **2** boils the primary water **3**. This water circulates by natural convection into the steam generator **4** and causes the evaporation of the secondary water **5** to feed the turbines **6**. The secondary water is cooled in the condenser **7** before being returned to the steam generator. Each turbine drives two alternators **8** and **9**. The propulsion alternator **9** produces the necessary electricity for the main electric motor **10** that drives the propeller **11**. Power alternator **8** provides the necessary electricity for the ship's services.

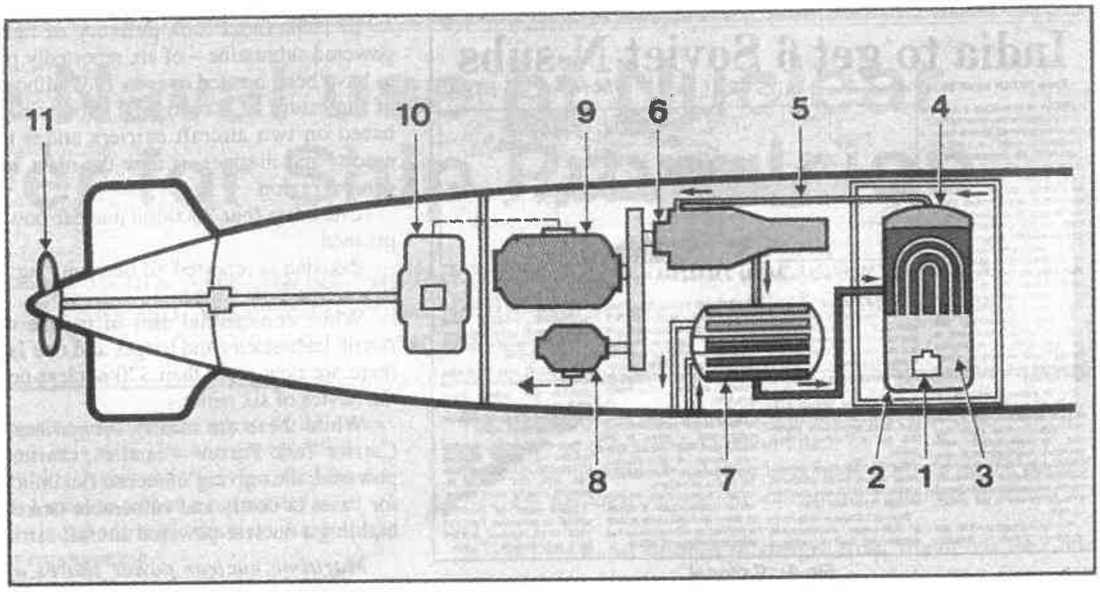


Fig 4: *Rubis Class Nuclear Submarine's Electric Motor Propulsion System.*

While it would greatly increase underwater endurance at low speeds, *it offers no solution to covering Australia's vast distances quickly.*

Nor does it overcome the other disabilities inherent in lack of sustainable high speed and low endurance at high speed. It is not at present planned to fit this system in Australian submarines.

The Captain of even a modern diesel-electric-powered submarine is forever concerned at the state of his batteries.

Although, if fitted with modern long-range missiles, these disadvantages are reduced, he will often still be unable to intercept fast targets or chase at high speed, or to escape by using maximum speed for more than an hour or so – which is not very satisfactory.

The limitations caused by his battery capacity prevent him from keeping up with surface warships or merchant vessels and thus he cannot act as an escort. He cannot be deployed at high speed submerged in an emergency, and he uses diesel fuel, which could be in short supply, for charging his batteries.

In contrast, small nuclear-powered submarines can steam submerged and sustain high speed for thousands of miles without stopping – with *very little indiscretion.* Their mobility and small size inhibits detection.

With their modern nuclear steam generators, convection cooling up to a speed of about 18 knots, and very powerful electric motor drive, they are silent in operation and they do not require refuelling for years.

Thus they are very flexible in operation and there is no need for the Captain to worry about conserving energy in a wartime situation.

While they have a slightly larger crew than a diesel-electric submarine of comparable size, and a slightly higher running cost, *operational advantages far outweigh these considerations.*

Independent of air, they are faster for virtually unlimited distances, they could never run short of fuel in operations; they make no call on possibly short diesel fuel supplies; and they can escort shipping (but not protect against air attack).

They can go places submerged in about one-third the time of a diesel-electric submarine and thus can be deployed quickly from ocean to ocean if necessary.

Given our two-coast defence policy, the great distances between our bases and our northern areas, and the ever-present possibility of last-minute decisions in a democratic society, this rapid reaction capability could be of great importance to Australia.

In addition, because of the speed of deployment, more time can be spent on patrol. Sustained silent speed means that larger areas can be patrolled in the same time as a slower diesel-electric submarine.

As a rough rule, to deploy two submarines continuously on patrol needs a total force of five nuclear-powered or eight diesel-electric with similar detection equipment[6].

Under some circumstances nuclear-powered submarines have a higher chance of survival than do diesel-electric submarines. For example the higher speed of nuclear-powered submarines could sometimes enable them to outrun torpedoes fired at them. Similarly, provided conditions enable them to use their high speed, they can evade or escape more easily.

Objections to nuclear-powered submarines, highlighted in the press, state that they are "noisy" and "too large to operate in shallow waters". *This is no longer true.*

The *Rubis* Class nuclear-powered submarine can go anywhere a similar-sized diesel-electric submarine can go. It is neither noisy nor too large.

Nuclear-powered submarines are considered so superior to diesel-electric submarines that the US Navy has refused to build any more of the latter for itself or for its Allies. (Other countries, however, continue to build them.)

The only war experience with nuclear-powered submarines was in the Falklands War. Britain's nuclear-powered submarine *HMS Conqueror* steamed from the North Atlantic at high speed submerged for 6500 miles, then shadowed and sank a cruiser when ordered to do so. With others, she bottled up Argentina's Navy for the rest of the war – a convincing demonstration of the speed of deployment, flexibility and deterrent power of nuclear-powered submarines.

What about the **Nuclear Waste?**

The technology for handling and storing waste from nuclear reactors is now a reality.

Before the fuel is sent for reprocessing it is stored in water until about 85% of the radioactivity has been dissipated. It is then separated and the waste stored in tanks until about 99% of the radioactivity has decayed. Dried out, it emerges as a black sand which is mixed with glass "frit" and heated until molten.

Since July 1978 the "high active" nuclear waste has been commercially treated in this way at Marcoule in France. It is then poured into stainless steel containers where it cools to resemble glassy lava. In 1981 one of the authors observed how it was done in the "hot cell" – watching through a window of glass one metre thick.

The sealed containers were lifted from the "hot cell" and lowered into wells in the floor of the outside hall. Red lids indicated waste connisters below, one atop the other. There were enough wells for thirty years of waste from the French nuclear industry, for the quantities per year from each reactor were very small.

Australia's own nuclear waste disposal method SYNROC has also been well-studied and researched.

It should be remembered that the waste from a nuclear-powered submarine after many years is only about the size of a car battery. This could be easily dealt with overseas if facilities were not developed in Australia.

Disposal into the sea of solid low-level radioactive wastes (contaminated bags, cloths, clothes, resins, etc) has been prohibited in the US since 1970. This material is packed and shipped to Nuclear Regulatory Commission burial sites.

Thus high and low radioactive nuclear waste disposal seems no longer to be a major technological problem.

Fig 5: *Marcoule, France: storage wells for nuclear waste glass after melting with "frit" and pouring (as a molten rock) into stainless steel containers.*

What if a Nuclear-Powered Submarine is Sunk?

The only information on this comes from US sources.

The USS *"Thresher"* (1963) went down 160km from land in waters 2590 metres deep, and the USS *"Scorpion"* (1968) 64km SW of the Azores at a depth of more than 3050 metres.

Water and sediment samples were taken close to the sunken submarines (the only ones lost by the US Navy), and analysed soon afterwards. New samples were taken much later. *No radioactivity was found in excess of that which occurs naturally.*

Built-in safety features are designed to ensure that the reactor core cannot explode like a bomb. Fuel rods are solid metal alloy rounds which cannot leak and are corrosion-resistant, even in sea water. Submerged for decades, scientific opinion is that they would not release fission products.

The corrosion rate with salt water exposed to the air might be a few millionths of an inch per year, but completely submerged it would remain intact indefinitely.

The Western countries' design criteria are superior to those for their land-based reactors. It is hard to see how fission products could escape from the very thick special-steel reactor pressure vessel. (Soviet design standards in their earlier submarines seem to have been to some extent inferior to those of the US, Britain and France.)

What about
Radioactivity Effects on the Crew?

Ambient radiation is continuously monitored in the USN. The total radiation exposure in 1983 for all US submariners was only 1/4 of that in 1966, as shown in Figure 6.

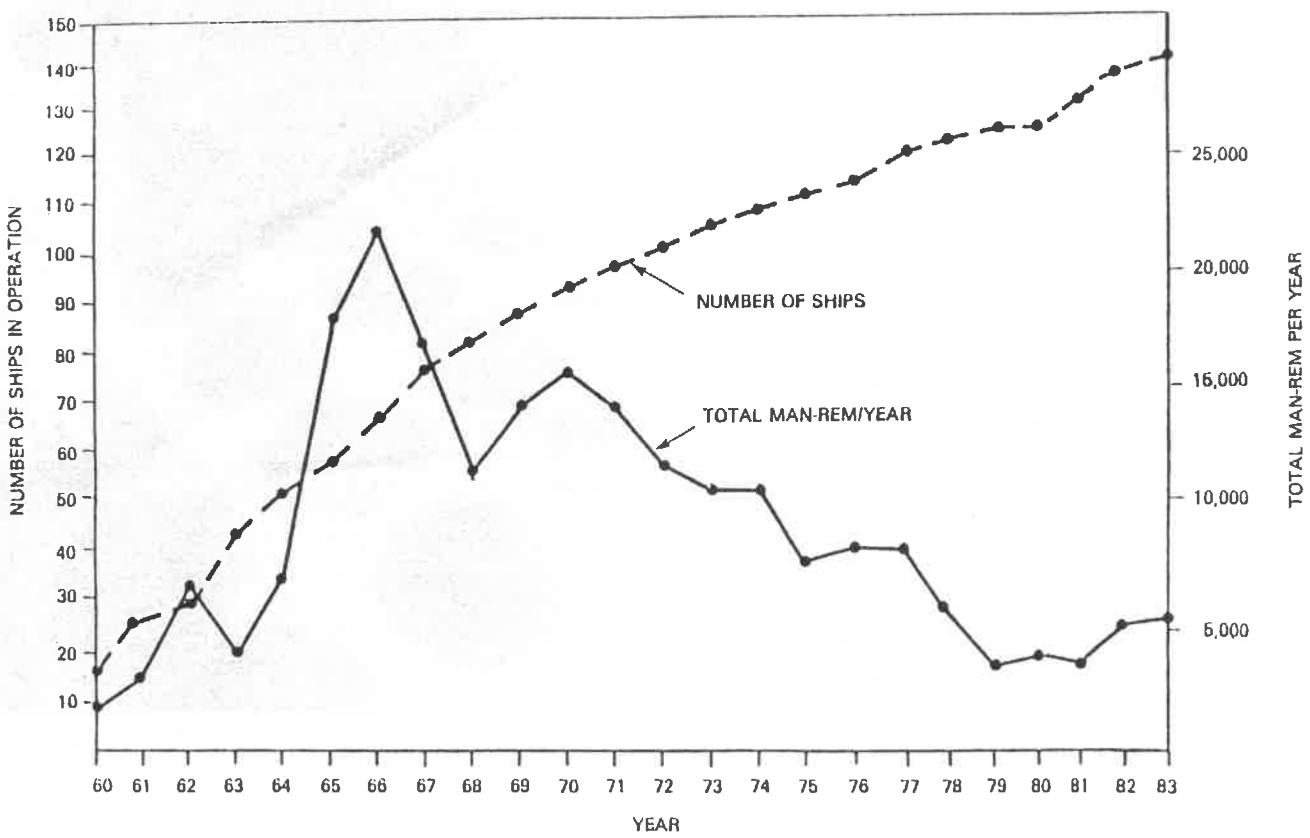


Fig 6

This graph shows the total radiation exposure of both military and civil personnel in the US Naval Nuclear Propulsion Program from 1960 to 1983.

In spite of the increase in nuclear-powered vessels from 10 to 142, after 1966 the total radiation exposure of thousands of men was reduced from 20,000 man-rems to 5000 man-rems per year: a 75% reduction.

Each successive program had successfully reduced the radiation effects further.

(Radiation comes in three kinds. Alpha particles cannot penetrate a sheet of paper or your skin; beta particles will pass through your hand; gamma rays will penetrate deeply into concrete.)

Sailors at sea in nuclear-powered submarines get less radiation than people ashore because the natural radiation exposure at sea is less. *Radiation increases considerably with altitude above sea level because of cosmic rays – which do not penetrate beneath the sea surface.*

Additionally, tenders or barges which service nuclear-powered vessels in port are shielded as are all nuclear support facilities.

In shore bases, radioactive materials are limited to a minimum number of places, and specific traffic routes have to be followed. An accountability system covers transport of nuclear materials outside the established facilities – to ensure that none is lost or misplaced.

From the foregoing *the US naval nuclear experience seems reassuring with respect to radiation effects on crews.*

What about the Environmental Impact of Nuclear-powered Submarines?

The environmental impact of US nuclear wastes in all ports and harbours from 142 nuclear powered vessels[7], was less than 0.002 curies in 1983 – a remarkable achievement. (A curie is the radiation given off by a gram of radium[8].)

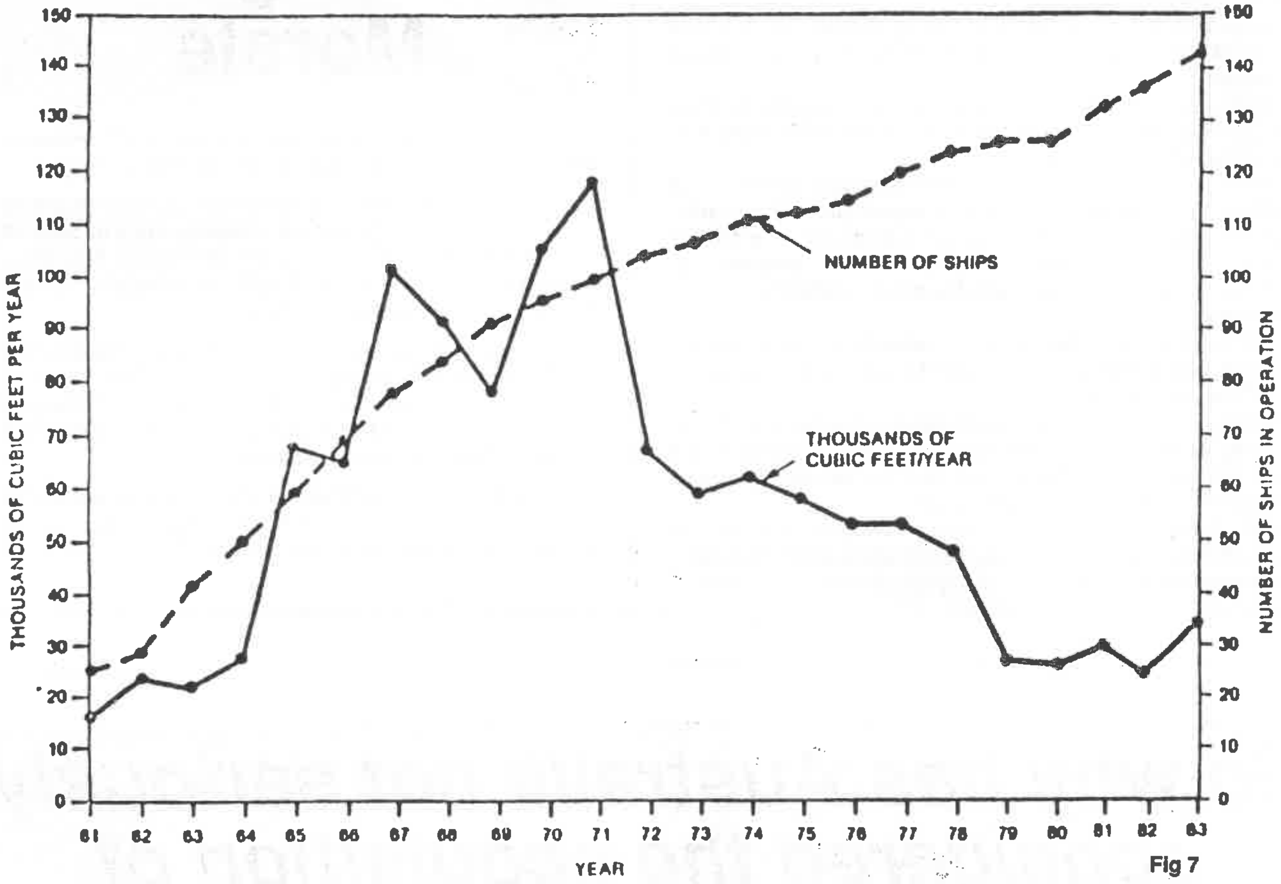


Fig 7

Two-thousandths of a curie is so small that if it were possible to drink all this annual discharge of waters at once, one would not exceed the annual radiation exposure allowed to an individual nuclear worker.

Great improvements were made between 1961 (with 25 ships) and 1983 (with 142 ships) – the upper dotted line in Figure 7 gives numbers. The thousands of cubic feet per year of all kinds of waste are shown by the lower full line. It also represents a major achievement in mastering what was a new technology in the 1960s.

Monitoring is checked by the US Dept of Energy Laboratories, and the US Environmental Protection Agency (EPA), sampling independently.

Water with radio-nucleides is filtered through an ion-exchange resin bed to containers which are then carried ashore and again processed prior to re-use instead of being discharged. High quality water is produced.

In the 1960s millions of gallons of radioactive waters were discharged into the sea within 12 miles of harbours, but by 1973 this had been reduced to less than 25,000 gallons.

Releases at sea are now close to zero – very much less than recommended by the authorities (the Council for Environmental Quality[9], Marine Protection Law [10] and the National Research Council[11].)

Of course, the sea is radioactive naturally, to the extent of about 390 picocurie units of radioactivity per litre, about the same as beer. (A picocurie = 10^{-9} curies.)

Whisky is even more radioactive, 1200 picocurie units per litre, milk about 1400 and salad oil about 4900 picocuries per litre. Brazil nuts may have between 200 and 7000 picocuries per kilogram.

Everything we eat and drink is radioactive to some extent but in such small quantities that it is not harmful to us!

Thus evidence so far indicates that nuclear-powered ships have no discernible effect on the quality of the environment.

But what if, despite all the evidence of careful over-design, quality control and experience, the unthinkable should happen: an accident in port with a nuclear submarine's reactor?

All such marine reactors have supplementary alternate cooling arrangements.

Common sense arrangements limit the danger to the public. Nuclear-powered warships could be based away from centres of population – there is already one such suitable base in Western Australia.

The provision of tugs with trained crews to tow away damaged vessels to remote anchorages is clearly another sensible precaution.

Comprehensive and competent organisations in naval dockyards and bases with equipment, facilities, and trained staff to deal with nuclear matters would be a normal part of planning for operation and maintenance.

But What About Cost?

Definitive information on costs is always difficult to obtain, and there are different ways of measuring such costs. However, according to some sources the Swedish-designed diesel-electric submarines being assembled in South Australia were originally to have cost about 30% less than a small nuclear-powered submarine of the *Rubis* class built overseas[12].

While the cost of a new *Rubis/Amethyste* Class submarine is not known accurately, given that the cost escalation of our own submarine building programme is likely, it seems a reasonable assumption that it would be comparable to that of a modern diesel-electric submarine fitted with a Stirling Engine built here.

There is also the possibility of acquiring surplus US or British submarines at a fraction of the cost of new vessels, in view of impending cut-backs overseas.

Australia would need an Atomic Energy Authority responsible for advice on safety measures for the population and for the control and licensing of the nuclear energy activities by the RAN.

Appropriate infrastructure would also be needed, but this is not prohibitively expensive. After all, US Navy nuclear-powered submarines have been maintained from time to time at Cockburn Sound in Western Australia. To reduce infrastructure costs, submarines requiring refuelling could be returned to the country of origin, noting that this might be only once in their lifetime.

But how will any additional cost be met, given the economic condition of the nation, falling defence allocations, and the announced re-organisation of our defence arrangements?

Basically this comes down to the resolution of two priorities. Firstly, what priority the nation itself is prepared to give to long-term defence; and secondly, what priority should be given to the future provision of nuclear-powered submarines in the defence budget itself.

Clearly if the Government of the day gave either of these priorities sufficient emphasis, the money could be provided noting that it would not be required for some years, by which time the nation should have emerged from its current economic malaise.

Training and Morale

Finally it must be remembered that one of the important tasks of submarines is to train our anti-submarine forces.

Since there are now so many fast nuclear-powered submarines in the world's navies, including those of some of our neighbours, it is essential that our forces (warships, submarines, naval helicopters, RAAF anti-submarine aircraft) be trained to detect and combat them.

Such training can only be done effectively for the total force if we possess nuclear-powered submarines ourselves, for their sustained high speeds offer a much more challenging problem for both RAAF and RAN anti-submarine forces than do diesel-electric powered submarines.

Such a decision would give a huge boost to morale, an incentive to service in our submarine forces, improve the retention rate of sailors, and provide the RAN with some real teeth.

So why has Australia not seriously considered the acquisition of Nuclear-Powered Submarines?

The failure to inform the public on nuclear power issues has been compounded by consistent media promotion of the emotional arguments, by confusion with nuclear weapons, and by official measures which have militated against a balanced perspective.

For example, the Cain Government of Victoria, soon after its first election to office, was reported as having instructed the Department of Industry, Technology and Resources to cease distributing to enquirers printed information on the peaceful uses of nuclear energy and return it all to the Uranium Information Centre[13].

Public enquiries were thereafter to be referred to the Movement Against Uranium Mining, The Australian Conservation Foundation and the Centre.

The *"Victorian Government Nuclear Prohibitions Act"* is still law, as is a similarly restrictive law in NSW initiated by the Wran Government, the *"Uranium Mining and Nuclear Facilities (Prohibitions) Act 1986"* – which seems to outlaw uranium.

Books on nuclear power are not readily available in libraries.

The lack of public debate and *censorship of information by omission* has led to disinformation and confusion on all nuclear matters, and to ill-informed reactions and breaches of normal civilised behaviour with international ramifications[14].

This has earned us a shameful reputation with those Western Allies who had been our protectors, friends and brothers-in-arms in former times.

It seems clear that the main opposition to the acquisition of nuclear-powered submarines centres on a low level of public understanding of the issues involved, and on perceived political attitudes[15].

CONCLUSION

There has been far too little informed debate on the advantages and disadvantages of nuclear power for submarines and ships of the Royal Australian Navy – in spite of 35 years of highly successful world experience with hundreds of nuclear-powered submarines and surface warships.

The considerations of cost, disposal of nuclear waste, infrastructure needed, environmental issues and safety seem solvable and certainly not beyond Australia's means.

All warships including submarines have inherent dangers from the weapons, ammunition, and the fuel they carry. However, with very exacting standards of design, quality control, construction and operation, western warships have achieved high levels of safety. Similar considerations apply to nuclear power.

Given our immense oceanic distances, our almost complete dependance on shipping for imports and exports, our developing shortage of local oil supplies, and the clear military advantages of maritime nuclear power, there is a convincing argument that Australia should acquire at least two small nuclear-powered submarines, and in due course consider the application of nuclear propulsion for surface warships.

Such submarines would augment our future force of six modern diesel-electric submarines for the tougher and more rapid deployment tasks in war, for which only nuclear-powered submarines have the needed capability. They would also ensure that our anti-submarine forces could be trained effectively.

Together with the new diesel-electric submarines, if effectively armed[16], they would provide a modest deterrent to possible foes – arguably the most cost-effective type of deterrent in manpower, capability and flexibility for an island maritime nation.

They would also augment our small escort forces for the defence of our surface warships and vital merchant shipping.

Like our Army and Air Force, our Navy must be equipped with the most modern technology, including nuclear-powered submarines, if it is to attract high calibre personnel and carry out effectively its vital role in the defence of the nation.

While the May announcement of major defence changes must put in doubt the immediate possibility of new programmes, the building of an effective navy for the 21st century is a matter of major national security importance to an increasingly exposed and isolated island nation. This requires not only vision but a bipartisan continuity of decision-making and allocation of resources in future years.

In this rapidly-changing world, when self-reliance in defence becomes more important, one must seriously question whether, given the facts, Australia would really accept that its Navy should be denied the most potent and rapidly deployable submarines while at least two nations in our general region already possess such vessels.

ENDNOTES

(1) ANSTO: *Quarterly Review of Overseas Events* for September 1989, June 1990 and October 1990. *Only for reactors >30 MWe.*

(2) Commander N.S. Stewart, RN (retd), FRINA, MIMechE: *Technical Aspects of Nuclear Submarines for the Royal Australian Navy* a lecture to the Australian Nuclear Association, 12 March 1985.

(3) Perhaps at the half-life 15-year refit. The new core would not be dangerous. The used one would be kept in a pool of water, later trans-shipped in a water-cooled container, a well-organised procedure in ships regularly plying between Japan and Europe.

(4) Betzinger: "The *RUBIS*-Class SSN" **in** *Defence 2000,* 13.12.85 p6.

(5) In NAVINT of 28 September 1990, page 8.

(6) It is misleading to compare a 2400 T diesel electric submarine with a large American nuclear-powered submarine. Valid comparison is only possible between diesel-electric and the nuclear submarine having the same sized and shaped body. French calculations indicate that over 30 years the nuclear *Rubis* operation costs about 37% more than the diesel-electric equivalent. But the cost per day at sea over the same area at much greater speed is only about 3% more. The cost per square km patrolled is much less.

(7) See *Environmental Monitoring and Disposal of Radioactive Wastes from US Naval Powered Ships and their Support Facilities,* Naval Nuclear Propulsion Program, Dept of the Navy, Washington, DC.

(8) The number of disintegrations per second being officially defined as 3.7×10^{10}.

(9) Council for Environmental Quality (CEQ) Report to the US President, Oct 1970: *Ocean Dumping: a National Policy.*

(10) US Public Law 92-532: *Marine Protection, Research and Sanctuaries Act of 1972.*

(11) Report 658, Nat Acad of Sci, Nat Rsch Ccl: *Radioactive Waste Disposal from Nuclear Powered Ships, 1959.*

(12) See (6) on left.

(13) The Uranium Information Centre, GPO Box 1649N, Melbourne, Vic 3001.

(14) (a) The refusal of refuelling facilities to a US Navy observer aircraft during the MX Missile tests in the Pacific.

(b) The refusal of dockyard facilities in NSW to some British warships.

(c) The tug bans after anti-nuclear demonstrations, when thousands of British sailors who had been invited to Melbourne's Bicentennial Celebrations were unable to land.

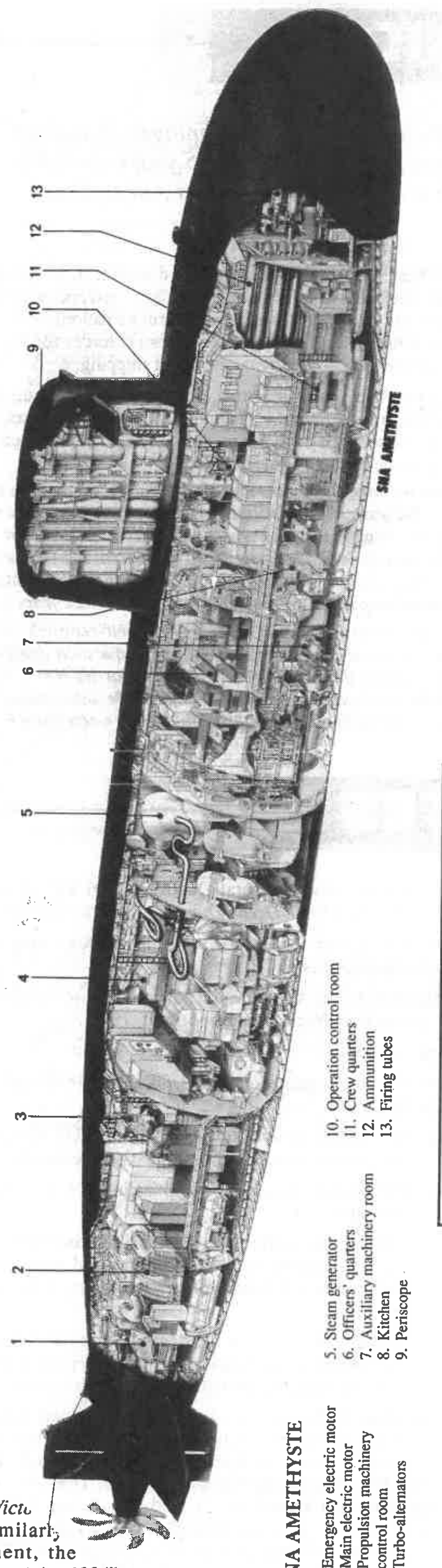
While some of these incidents have been related to the possible carriage of nuclear weapons, there have been cases of allied nuclear-powered vessels being harassed.

(15) The Chief of the Defence Force had suggested that nuclear-powered submarines should be considered for the RAN according to a report in the *Sydney Morning Herald* of 16.5.88 ("Beazley sidesteps nuclear sub debate"). The Chief of [illegible] Staff had also argued for "a study of the nucle[illegible] option" according to *The Australian* of the sam[illegible] swamped by water hazards").

1991

(16) Possibly with *Tomahawk* weapons.

Institution of



SNA AMETHYSTE

1. Emergency electric motor
2. Main electric motor
3. Propulsion machinery control room
4. Turbo-alternators
5. Steam generator
6. Officers' quarters
7. Auxiliary machinery room
8. Kitchen
9. Periscope
10. Operation control room
11. Crew quarters
12. Ammunition
13. Firing tubes

and the

The "Victo
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Government, the
(Prohibitions) Act 1986" –

Fig 9: *Detail of one of RUBIS's hull hatches being opened. The presence of these hatches allows maintenance and conversions to be performed without openings being cut in the pressure-resistant hull.*

	'Rubis'/'Amethyste'	'Trafalgar'	'Oberon'
Tonnage (submerged)	2,600	5,200	2,400
Length (m)	72	85	90
Torpedo-tubes	4	5	6
Weapons – (torpedoes, missiles)	18	20	20
Speed (kts) – max. (subm.)	25 +	32 +	17 *(burst)*
Transit	15-20	15-20	7
Diving depth (m)	300 +	300 +	200 +
Crew	66	97	64

Size comparisons of two nuclear-powered submarines with Oberon Class.

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