U 92
INTERNATIONAL CONFERENCE ON SUBMARINE SYSTEMS

BY

P. H. BRISCOE, CENG, FRINA, RCNC
(Sea Systems Controllerate, Bath)

Following the success of a similar conference in 1990, 'U 92—International Conference on Submarine Systems' took place at the Royal Institute of Technology, Stockholm from 3 to 5 November 1992. The conference was sponsored by the National Defence Research Establishment and Swedish naval industries, with the active support of the Royal Swedish Navy who provided the session chairmen.

The conference lived up to its 'international' billing with over 150 delegates attending from 14 countries. A total of 35 papers originating from 8 countries were presented, many by representatives of major suppliers of conventional submarines and their equipments. A wide range of interests was covered including overall design, propulsion systems, weapon systems, acoustics and human factors. As with other conferences of this type, some of the contributions were more of a marketing exercise than a technical dissertation. The following review is not a comprehensive resumé of every paper but picks out some of the major themes.

Setting the Scene

The opening addresses by the Commander in Chief of the Royal Swedish Navy, the Head of Naval Materiel Department and the Director General of the National Defence Research Establishment set out the Swedish view of future submarine development into the 21st century. The U 92 initiative clearly had support from the highest level of the Swedish military establishment.

Sweden has a long history of non-alignment and neutrality and in line with this independent political stance the defence procurement strategy has been for Swedish industry to provide the majority of its military equipment. This has led to the development of large and internationally successful defence contractors such as Kockums, Saab, Bofors and Nobel. However such companies are prey to the same political and commercial pressures as other Western defence industries following the end of the Cold War.

The threat to Sweden has always been perceived to be from the East and submarines to operate in the Baltic have been built since the turn of the century. The Swedish Navy maintains a flotilla of 12 submarines by ordering a new class of 3 or 4 submarines every 7 to 10 years. Not only does this fulfil the military requirement but it ensures continuity of design, development and building expertise at Kockums and equipment suppliers; 3 Gotland (A19) submarines were ordered in 1990. The drawback of this procurement process is that development costs are spread over only a few submarines.

The Baltic Sea is relatively shallow and is a small operating area and so deep diving depth, long range and high transit speeds are not the highest priorities. The most important features for future designs are seen to be stealth, increased passive sonar performance, long-range torpedoes to enable a rapid undetected strike, and the ability to remain at sea submerged for long periods to avoid detection.

In common with other Western nations, the Swedish armed forces are being trimmed and equipment budgets are expected to follow suit as defence expenditure becomes politically and socially less attractive in these changing times. Sweden is faced with problems that are all too familiar to the MOD(PE)—changing roles, affordability, value for money, containing R & D costs, maintaining the industrial base, etc. The message that came across loud and clear was that in future Sweden is very keen to foster cooperation with other nations in research, development and procurement. U 92 was therefore a forum whereby Swedish industry could promote its submarine technology base. However, successful cooperation requires a two-way traffic of research, development and procurement. An example of Sweden importing foreign know-how is the future Bofors heavyweight torpedo Type 2000, the tail of which has been designed in the UK by Marconi Underwater Systems.

Future Submarine Designs

RAN 'Collins' Class

The COLLINS Class has been designed by Kockums for the RAN and represents something of a commercial coup for the company against strong international competition. The order was placed in 1987 and the first of class will be launched in 1993. A lesson to be learnt from the COLLINS Class contract is that it is not necessarily the lowest risk or even the cheapest solution that wins an international competition and that the overall procurement package offered by the shipbuilder is just as important.

It was of prime importance to the Australian government that the submarines should be constructed in Australia together with manufacture of a large percentage ($>$ 50%) of the equipment. To meet this requirement Kockums formed the Australian Submarine Corporation in conjunction with Australian industrial interests; the design and build contract is between this company and the Australian Government. Many of the subcontractors have set up production facilities in Australia, e.g. Strachan and Henshaw who have designed the weapon discharge system.

From the outset the COLLINS Class has been a high risk and very expensive programme involving not only the design of the submarines but also the building of a construction facility on a 'green field' site, unproven 'home' equipment suppliers, a new submarine base, simulation facilities and new underwater ranges. The submarine is built on a modular system pioneered by Kockums and this has enabled some large sections of the first of class to be fabricated in Sweden and assembled in Adelaide. The COLLINS Class is a large submarine by SSK standards and has a submerged displacement in excess of 3000 tonnes; it is three times larger than the VÄSTERGÖTLAND Class on which the design is based. The RAN Project Office appeared satisfied with progress to date and is looking forward to the day when Australia is well positioned to supply the SE Asia submarine market!

Submarine 2000

In 1990, the Swedish Defence Materiel Administration commissioned Kockums to carry out concept design studies for the next generation submarine for the Swedish Navy, designated Submarine 2000 (in-service date rather than displacement). Much use has been made of computer modelling and simulation in order to achieve the best technical/tactical/cost balance. The aim is to produce a submarine which is a step change in technological development; the artist's impression looked very futuristic with only a vestigial bridge fin. The emphasis is on stealth—new hull form, anechoic coating, ducted propulsor and comprehensive sonar fit with towed array. The submarine will be fitted with air independent propulsion for several weeks' endurance, and might not have main diesel engines. It was not clear how affordability would be achieved with this ambitious remit, although a strategy for cost reduction had been developed; faith was placed on technological breakthrough, increased system integration and subcontractors reducing costs. The presentation was high on hype but low on fact.

The Moray Submarine

The Moray submarine is a Dutch design being marketed by the Rotterdam Dockyard Company (RDM). In 1989 the Moray design was proposed to the RNlN as a possible replacement for the ZWAARDVIS Class. Following a Navy assessment, a Project Definition contract was placed in 1990 with RDM as prime contractor and a Contract Design Specification was duly delivered in Spring 1992. By that time, the requirement for a ZWAARDVIS replacement had been dropped by the naval planners, and the design was handed to RDM to promote as a commercial venture.

Minimizing development and unit costs has been a driving force in all aspects of the Moray design and the overall aim was to produce a submarine smaller than the 2800 tonne WALRUS Class but still capable of ocean-going missions. The Moray 1800 design has a submerged displacement of around 1900 tonnes indicating some growth between concept and project definition—a familiar story. The following measures have been taken to reduce size and cost—a reduction in diving depth, a monohull as opposed to double hull arrangement, reduced reserve of buoyancy i.e. smaller main ballast tanks, a complement reduction to 32, 'off the shelf' equipment and modular construction.

A novel feature of the Moray submarine is that it has been designed from the outset so that a Closed Cycle Diesel (CCD) propulsion system can be fitted either on build or at refit. The system design and tankage has been optimized for the CCD version of the design. The Moray 2200 design has a 9·4 m long pressure hull section inserted immediately forward of the main propulsion motor; this houses the self-contained CCD system and LOX supply. Operational studies had shown that the CCD system should be capable of propelling the submarine at around 10 knots and that for an ocean-going submarine it was not feasible to dispense with the main diesels. At very low speeds the CCD system gives a submerged endurance of 450 hours.

Air Independent Propulsion

The submarine stands alone as a stealth vehicle capable of operating undetected in surveillance roles and covert operations. However all conventional submarines have limited submerged endurance and are vulnerable whilst snorting and recharging their batteries. It has been a long standing ambition of submarine designers worldwide to produce SSKs which can remain submerged for days or even weeks by utilizing air independent propulsion—AIP. The concept of an AIP system for submarines dates back to before World War II but until recently no system was sufficiently developed for submarine fit. But all has now changed; the 1990s are the decade of submarine AIP, i.e. stirling engines, closed cycle diesels, fuel cells and advanced batteries. Most of these propulsion systems have been described in technical detail in earlier issues of this *Journal*.

Stirling Engines

The stirling engine system has been developed by Kockums as a technically mature concept based on an existing V-4 diesel engine. A prototype system has been at sea in the *Nacken* since 1988; the submarine was taken out of service, split in two, and a hull section inserted containing two stirling engine generators and internal LOX tanks. The submarine has run for 4000 hours on the stirling engine and has achieved a maximum submerged endurance of 10 days at low speed. It is reputedly very quiet as a result of its continuous combustion cycle.

The Swedish stirling system is a low power system developed for low speed surveillance operations. The maximum power of the engine is 75 kW and higher power requirements are met by multiple engine fits; there are no plans to develop a larger stirling engine. In view of the success of AIP in the *Nacken*, the GOTLAND (A19) submarines are being fitted on build with the Nacken stirling engine system. Kockums are currently promoting the stirling engine system as an 'off the shelf' propulsion module which can be back fitted into most current SSKs in a similar manner to the Nacken 'stretch'.

Closed Cycle Diesels

CCD propulsion is not a new idea and was considered for the UPHOLDER Class at the concept stage, but was not sufficiently developed. CCD systems are being developed in a coordinated programme by RDM in the Netherlands and Thyssens in Germany; both companies gave presentations at U 92. Development of a CCD system utilizes proven commercial diesel engine technology and is therefore a relatively low risk route to AIP.

The CCD runs on diesel fuel and oxygen stored onboard in internal LOX tanks. The exhaust gas is mainly carbon dioxide which is dissolved in sea water before discharge overboard; undissolved oxygen in the exhaust is recycled and mixed with argon and oxygen before being fed to the air inlet of the diesel engine. An ingenious part of the CCD system is the water management system which supplies sea water to the CO_2 absorber and then discharges it overboard. This equipment functions independent of depth and uses a negligible amount of energy; the water management system has been developed in collaboration with Carlton Deep Sea Systems (formerly Cosworth Engineering) in the UK.

A 150 kW CCD has been tested ashore at RDM and is currently being fitted in the German submarine U1 at Thyssens for full-scale trials. A 400 kW CCD is about to be tested at RDM and this will be fitted in the decommissioned Dutch submarine *Zeehond* in the near future. It is this latter system referred to as the 'Spectre' system which is incorporated in the Moray 2200 design; it is the only 'available' AIP system which produces sufficient power for medium speed operations.

Detractors of the CCD concept draw attention to the inherent noise disadvantage of the diesel combustion cycle. A considerable amount of development effort has gone into reducing the noise signature of the CCD system, e.g. triple mounting, acoustic hoods and control of the water management system. It is claimed that at low speed the CCD is as quiet as electric propulsion at 6 knots.

Fuel Cells

A prototype German fuel cell propulsion system has been successfully operated at sea in the U1 submarine; this has been presented at other symposia. A paper was presented at U 92 by the Canadian Defence Department on their research programme to develop a fuel cell propulsion system for an SSK design to replace their ageing OBERON Class submarines. Development effort is being concentrated on a solid polymer fuel cell supplied by Ballard Power Systems and on an aluminium-based semi fuel cell. A net energy and power requirement of 100 MWh and 300 kW has been specified and studies to date indicate that both systems are feasible and would add around 10 metres to the length of an SSK.

The solid polymer fuel cell requires a supply of methanol (the source of hydrogen) stored in the keel and LOX carried in inboard tanks. The Canadians have a long-term aim to achieve a 70 day submerged endurance on AIP, and so they are looking to improve upon the efficiency of current fuel cell systems. Even so, a submarine to achieve that level of endurance is dominated by the size of the LOX tank, with major penalties on other aspects of the design. Over the next three years the Canadians plan to develop and test tenth-scale 40 kW energy conversion systems using both the above technologies before deciding on the way ahead for a full scale AIP system.

Submarine Environment

Life support systems and atmosphere monitoring and control have long been a prime design requirement for nuclear submarines. SSKs fitted with AIP systems are now achieving submerged endurances of 10 days or possibly more, and so there is a more severe atmosphere control problem than in the past. However a pre-requisite for any SSK systems is that they should consume very little power, otherwise the endurance advantages of AIP are prejudiced. An Australian perspective of future developments was presented. Of particular note are the small 4·5 kW regenerative CO_2 scrubber and the ambient temperature CO/H_2 eliminator developed for the COLLINS Class.

With their firm commitment to AIP in future classes of SSK, the Swedish Navy have embarked on a wide ranging research programme in the areas of submarine medicine and human factors, making use of the strong environmental sciences base in Sweden.

Submarine Systems

There is insufficient space in this article to review every paper presented at U 92. The following topics were also featured at the conference: heavyweight torpedo development, torpedo launch systems, integrated C^3 systems, sonar systems, acoustic materials for signature reduction, Hedemora turbocharged diesels, advanced batteries, system management and automation, escape and rescue. The conference papers are available (price 1000 SEK) from Captain (res) Olle Harlin, RSwN, Skarmarang 2, S-139 00 Varmdo, Sweden.

Footnote—a Stockholm Visit

No trip to Stockholm is complete without a visit to the Vasamuseet. The *Vasa* is Sweden's biggest naval architectural disaster which nowadays is one of their major tourist attractions; she is Sweden's answer to the *Mary Rose* or rather *vice versa*. The *Vasa* was the King of Sweden's flagship which capsized and sank in Stockholm harbour on her maiden voyage in about 1630. She was rediscovered in the 1950s and raised in 1961 and within the last few years has been placed in a permanent museum. The *Vasa* is in a remarkable state of preservation having lain in the low salinity Baltic water for over 300 years; the ornate carvings on the sterncastle are particularly noteworthy.

The *Vasa* was the largest ship built in Sweden at that time and she blew over in protected waters with only four out of ten sails set. Why did it happen? The King of Sweden wanted a larger ship to enforce a blockade of Danzig and so the solution was to add an extra deck to a hull half built! Why wasn't the loss of stability known about? It was; the *Vasa* failed its stability check. A dynamic rolling test was abandoned because roll amplitudes were excessive but no-one dared to tell the King. Luckily for the designer he died before the event.