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REPORT ON THE PROCEEDINGS OF A SYMPOSIUM ON NUCLEAR SHIPS

HAMBURG, 10-15 MAY 1971

by

D. J. HIGSON

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SYMPOSIUM
ON
NUCLEAR SHIPS

Jointly sponsored by
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and the Gesellschaft für Kernenergieverwertung
in Schiffbau und Schiffahrt mbH (GKSS)

HAMBURG

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REPORT ON THE PROCEEDINGS

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SUMMARY AND CONCLUSIONS

To some extent the Hamburg Symposium on Nuclear Ships was disappointing in that no major technical advances were reported and no new projects or plans for the application of nuclear propulsion to commercial shipping were announced. In fact, a number of papers tended to be a rehash of ideas which have been current for the past ten years, without throwing any new light on the problems. This was particularly notable in the regulatory area. Since the formulation in 1962 of the Brussels Convention on the Liability of Operators of Nuclear Ships, there has been very little real progress towards the acceptance of unrestricted operation by commercial nuclear-powered vessels.

However, technical development has been proceeding steadily and an advance towards commercial exploitation has become evident. Some important trends, such as an increasing interest amongst shipowners, were also apparent at the Symposium.

In terms of actual industrial activity West Germany is now the leader in this field and dominated the proceedings. The research vessel "Otto Hahn" has been in service since 1968 and has carried commercial cargoes. This ship is operated by the Gesellschaft für Kernenergieverwertung in Shiffbau und Schiffahrt mbH (GKSS) which is a government controlled corporation through which industry collaborates in government backed design, research and development work.

Japan and Italy are also active and the first Japanese nuclear powered ship, the "Mutsu", is being fitted out at present for commissioning in 1973. The USA confined its contributions to the Symposium mainly to reporting experience with the NS "Savannah", which is now laid up. Only one paper (presented by Vickers Shipbuilding) originated from the UK. However, the US and UK Governments, though not currently optimistic about the commercial prospects for nuclear propulsion, have the technical and industrial backing to enter this field at short notice if the business becomes attractive.

Economically the position is fairly clear although strongly dependent upon the cost of bunkering oil fuel for conventional shipping. Oil costs are very high at present and, assuming the continuation of this situation, it appears that large nuclear powered container ships of 120,000 shp and 30 knot service speed would be competitive in operation between Australia and Europe and probably also on shorter runs (e.g., the Pacific trade). Once established, it should then be possible for nuclear propulsion to be applied economically to other types of shipping and to smaller power units. A return to the low prices for fuel oil which prevailed in 1969 would probably make nuclear propulsion totally uneconomic however. In any case, significant governmental support would be an essential investment in t   rly stages.

Generally there can be no doubt concerning the ability of nuclear marine propulsion to provide a reliable service with the characteristic of sustained high power which could not be obtained in any other way but questions of legal liability, indemnification and international acceptance remain to be resolved. In some related respects the technical status of nuclear propulsion is not entirely satisfactory. A number of safety problems have not yet been convincingly solved and these matters will require careful evaluation by regulatory authorities. There could well be a need for the feedback of views to the designers. This will become an urgent problem if commercial exploitation proceeds at the rate which some authorities predict, and pressure is already growing for a reduction of restrictions upon the operation of nuclear ships.

1. INTRODUCTION

The Hamburg Symposium on Nuclear Ships (1971) was sponsored jointly by the International Atomic Energy Agency (IAEA), the Inter-Governmental Maritime Consultative Organisation (IMCO) and the Government of the Federal Republic of Germany (FRG), in co-operation with the Kernenergie-Studiengesellschaft (KEST) and the Gesellschaft für Kernenergieverwertung in Schiffbau and Schiffahrt mbH (GKSS). Papers were presented at nine formal sessions and there were ample opportunities for discussion. Arrangements were also made for participants to visit and inspect the Geesthacht Reactor Center and the nuclear research ship "Otto Hahn".

The Symposium was attended by more than 450 participants from 33 countries. Australia was represented by Capt. G. A. Bennett and Mr. K. T. Hope of the RAN and Dr. D. J. Higson of the AAEC. Representatives of many industrial and shipping concerns were present and a number of official national bodies (such as the US Maritime Administration and Coast Guard, the UK Department of Trade and Industry and the British Chamber of Shipping) were also represented. The UKAEA was not strongly represented, however, and no member of the USAEC staff was listed as attending the Symposium. The USSR sent one observer.

English, French, German and Italian languages were used. Abstracts of the papers were available in English, and normal translation services were provided.

Papers were classified under six subject headings as listed in the Appendix. These classifications proved a little artificial, therefore the material in this report has been rearranged, though the presentation is broadly on the original lines. Full Proceedings together with discussion will be published later by the Symposium organisers.

2. EXPERIENCE WITH NUCLEAR SHIPS

Three nuclear powered ships were discussed: "Savannah" (USA), "Otto Hahn" (Germany) and "Mutsu" (Japan). Italy also has plans for a research vessel "Enrico Fermi" which is to be operated by the Italian Navy.

The "Savannah" operated for eight years and sailed 454,675 miles with a reactor availability of 99%. However, the ship is now laid up indefinitely. The future of the ship, its shore-based facilities and the support barge "Atomic Servant" is uncertain.

In 1968, the reactor was refuelled at the Todd Shipyard's nuclear facilities in Galveston, Texas. Refuelling took fourteen days; maintenance, inspection, testing, etc., extended the stay in dock to about two months on this occasion. Refuelling consisted of replacement of only four fuel elements and rearrangement of the remaining 28 elements. This resulted in a calculated 50% increase in core life. Estimates and details relating to further proposed fuel changes were presented also.

The "Otto Hahn", although uneconomic in commercial terms, has been in service since 1968 as a research vessel and ore carrier, and operation is planned to continue into the foreseeable future. Unusual features of its reactor design (particularly self-pressurisation and once-through steam generators producing superheated steam) give rise to some novel control problems, and it is therefore important to note that satisfactory operating characteristics and manoeuvrability of the plant were reported even in heavy seas.

The first refuelling of the "Otto Hahn" is planned for 1972. Details of docking requirements have not yet been determined but these may not need to be elaborate or expensive because the ship has fuel handling machinery on board.

Experience with the "Savannah" and the "Otto Hahn" so far has demonstrated that nuclear merchant ships can operate safely and reliably in scheduled service. However, a number of important repairs, modifications and maintenance operations have been necessary. Failures of the canned-rotor pumps have occurred on both ships, caused apparently in all cases by leakages of water or air into the electrical windings. Leakages of seals in valves, feed pumps and control rod drives has occurred on a number of occasions. Replacement of the main feed pump, replacement of the radiation monitoring system and complete overhaul of the control rod drive systems has been undertaken on the "Savannah". Replacement of gears for the primary feed pumps has been necessary on the "Otto Hahn". Deterioration of containment leak tightness was observed on the "Savannah" and necessitated preventative maintenance.

The "Mutsu" is still under construction. It was launched it 1970 and is now being fitted out. Nuclear plant will be delivered during 1972 and sea trials are expected early in 1973. The ship is intended primarily as a research and development project, and will be used also for transportation of nuclear fuel. Discussion centred mainly on design principles and associated experimental work. Nuclear plant for the "Mutsu", like the "Savannah", will be "dispersed", i.e. with pressuriser and heat exchangers separate from the reactor pressure vessel. This contrasts with the "Otto Hahn" which has a self-pressurised reactor with integral heat exchangers inside the reactor vessel.

Details of the three ships may be summarised as follows:

Nuclear Ship	"Savannah"*	"Otto Hahn"	"Mutsu"
Length, metres	196	172	116
Breadth, metres	25.6	23.4	19
Draft, metres	9.7	9.2	6.9
Displacement, tons	21,850	25,182	10,400
Service speed, knots	21	16	16.5
Crew complement	110	60	57
Reactor thermal power, MW	74	38	36
Core life, full-power-days	760	500	375
Shaft horse power	22,000	10,000	10,000
Current status	Laid-up	Operating	Fitting-out

* Previously published figures for comparison.

Considerable attention was given to questions of crew selection, organisation and training. Training programmes in Japan and the USA in particular were discussed in some detail. The most intensive training is naturally given to senior engineering officers and includes courses in basic nuclear theory, health physics and all aspects of reactor engineering and operation. The total training period generally exceeds two years, in addition to normal training and experience in conventional shipping. Deck officers also receive some general training in nuclear technology.

A total of more than 300 officers of all types so far has been trained in the USA to serve on nuclear merchant ships, and about 70 in Germany.

3. SAFETY

When industrial nuclear power generation is under consideration, questions of safety are usually regarded as being of the utmost importance. This reflects the degree of public concern and the close official scrutiny which forms a normal part of regulatory controls. In this context, the discussions of nuclear safety at the Nuclear Ship Symposium showed a disappointing lack of critical maturity, possibly because only one nuclear ship at present is receiving attention from the various national regulatory authorities throughout the world.

Emergency cooling, for example, is regarded as a vital safety feature on land-based nuclear plant and is currently the subject of some concern and controversy. However, very little attention was paid to the specification of emergency cooling systems for nuclear ships on this occasion, and almost none to the performance and effectiveness of the systems which have been proposed.

It was pointed out that the 1960 Convention on the Safety of Life at Sea did not specifically require emergency cooling provisions on nuclear ships, but that the USAEC would now require this feature. The reactor plant installed initially in the "Savannah" did not include an emergency cooling system. At the time operation was suspended, however, modification was in hand to provide emergency cooling. For the "Otto Hahn", safety arguments in this respect rest upon the claim that failure of the primary coolant circuit is not credible.

The absence of effective provision for emergency cooling greatly increases the importance which must be attached to emergency procedures, containment and assurances of primary coolant circuit integrity. In the last of these respects, the "integral" design of the reactor used for the "Otto Hahn" offers considerable advantages by enclosing the primary circuit mainly within the reactor pressure vessel.

Frequent reference was made to the importance of in-service inspection and component monitoring in ensuring the integrity of nuclear plant. New and more rigorous standards of inspection have been proposed for land-based reactors in recent years (even since construction of the "Otto Hahn" and the "Mutsu" commenced) and many current inspection requirements and techniques would be difficult to apply to the existing nuclear ships. It was also pointed that conventional techniques and schedules of inspection ıt not be suitable for maritime reactors. For example, ɜ major operations could only be conducted during a pro- ȝed stay in port and might be practicable only in assoc- ion with refuelling (say, once in four years). The ortance of developing classification rules for the inspect- of nuclear ships and of allowing, at the design stage in ure, for the inspection of reactor plant was therefore ar. Any such developments would have to be linked closely commercial considerations, since the economics of nuclear p operation could be significantly affected.

The importance of containment as an engineered safe- rd was stressed. The form of containment system which far has been adopted for nuclear merchant ships consists a primary containment vessel, designed for high pressure, uated within a sealed compartment which forms a low ssure secondary containment. The primary containment is ipped with some form of cooling device to control post- ident pressure. The secondary containment is normally ntained at reduced pressure and its atmosphere can be tered. Any escape of airborne radioactivity which leaks m the primary containment under accident conditions can refore be controlled.

Plant radiation levels, shielding and routine eases of low-level radioactive effluents were discussed. should be noted that radiation levels around the "Otto n's" reactor are very low because of the integral design. s access to the primary containment is possible for limited iods of time, under health physics control, even at full er. This is not the case with "Savannah" for two reasons: iation levels would be much higher, and the atmosphere is rted during operation to prevent the risk of explosion of rogen which might be formed by metal-water reactions in the e in a loss-of-coolant accident.

Two types of reactor primary containment were dis- sed: "conventional" full pressure containment based on othetical instantaneous release of all reactor coolant lowing a major failure of the primary circuit, and pond- e pressure suppression containment. Several highly hnical papers were presented on pressure suppression, ering both theoretical and experimental work. It must recognised, however, that the performance of suppression tems is dependent upon the rate of primary coolant blow- n, and they offer little advantage over conventional tainment unless it is assumed that break sizes are limited the cross-sectional area of small pipes. Pressure suppress- cannot be regarded as the alternative to an emergency ling system which has been designed for large breaks, since ther the containment nor the emergency cooling would be ective under these circumstances.

For the marine nuclear power system to remain safe er sinking of the ship, one requirement is that the con- nment should remain intact. It is necessary therefore to automatic flooding valves to equalise the pressure inside outside the containment boundary as the vessel sinks. s requires an estimate of the maximum sinking velocity. eriments aimed at determining this velocity for "Otto n" were reported.

Useful consideration was given to protection against ship collisions from the point of view both of avoiding collisions, and of structural protection to limit damage to the reactor installation in the event of such a collision. Computer assisted navigational systems were described for use either as aids to manual steering or as part of a fully automated manoeuvring and navigating system. Taken to its limit this approach might become similar to the existing ground control of aircraft movements.

Collision protection structures so far have been of the energy absorbing type, although resisting types are under consideration and test. It has never been a practical proposition to provide full structural protection for nuclear plant against high speed collision with the largest ships afloat. Safety arguments must therefore be based upon a low probability of such collisions, backed by improved methods for controlling movements of shipping to avoid collision. However, the collision barrier of the "Mutsu", like the "Savannah", has been designed on the basis of collision with a T2 tanker. This might be thought inadequate in view of the relatively large size and high speed of many modern ships and the frequent use of bulbous bow forms.

Although the importance of emergency measures (such as towing a stricken ship to a safe remote berth or anchorage) was recognised, there was no detailed discussion of such measures. Several papers presented general reviews of safety problems and port entry considerations, and special mention was made several times of the need to simplify port entry requirements, to eliminate the need for intergovernmental agreements and detailed technical evaluation of each ship, and to make visits of nuclear ships a routine matter. Although the authors generally intended to imply this as a desirable goal for the future, several participants in the conference clearly considered that immediate relaxation is called for and stated that safety requirements were placing an unnecessary restriction on the development of nuclear shipping.

These statements were made despite the fact that only two nuclear powered merchant ships have yet been operated by non-communist nations and no nuclear ship or power plant has so far been built of commercial design, size and characteristics. A relaxation of regulations, although undoubtedly necessary before nuclear ships can enter fully commercial operation, presupposes a technical basis and a degree of standardisation which does not therefore exist as yet.

4. ENGINEERING

The papers presented on nuclear ship propulsion plant engineering can be classified broadly into three categories: description of overall design and development programmes for nuclear power plant, development of specific plant items, and rationalisation of propulsion systems with ship design.

Overall design and development programmes formed the largest of these categories, including a number of papers from the GKSS-Interatom and the Fiat-Ansaldo-Euratom associations. GKSS and Interatom are engaged in the development of a more advanced version of the reactor used in the "Otto Hahn". This advanced design is designated EFDR and will also be an integral, self-pressurised PWR. As far as possible the new features of the design will be tested in the second core of the "Otto Hahn".

Attention has been given to reoptimisation in the EFDR design. It appears that the optimum is not sensitive to fuel rod diameter and lattice pitch and the original BWR-type parameters will therefore be retained. However, Zircaloy cladding for the fuel, and finger-type control rods will be used in future. Improved prediction techniques as well as engineering devices (e.g. swirl promotors) will permit higher power density without loss of estimated dry-out margins.

The use of fixed burnable poison pins for burn-up compensation will continue, but limited use of chemical shim will also be adopted. A maximum of about 5% reactivity will be held down by soluble poison; the coolant density coefficient will always be positive and the coolant temperature coefficient will always be negative.

The joint Fiat-Ansaldo-Euratom programme commenced in 1961 and reached an important stage in 1965 with the completion of an 80MW(th) reference design for an integral self-pressurised PWR with forced circulation of coolant. During this period an associated research and development programme was formulated, including comprehensive investigation and testing of collision barriers, and this had been almost completed by the end of 1970.

One major item of development in the Italian programme was the reactor control system and in-core instrumentation. The design departs from that normally adopted for a land-based PWR in that the overall system consists of two sub-systems:

(i) a power control sub-system providing prompt reactivity variation, and

(ii) a temperature control sub-system providing long term reactivity compensation to restore the reference value of coolant average temperature after any change of power.

A complicating factor in the design and control of this type of reactor plant is the influence of the steam generators on the behaviour of the nuclear system. The two-phase natural circulation of boiler water and stability of water levels in particular are affected by the motion of the ship. A detailed steam generator evaluation programme has been carried out, including both theoretical and experimental activities, with the main objectives of developing computer programmes, optimising stability and steam quality, and defining a suitable feedwater control system.

The development and testing of an hydraulic drive system for positioning and scram of control rods was described as a part of the German programme, and design criteria for other auxiliary systems were also discussed. A particular problem in the design of integral self-pressurised PWRs is the limited net positive suction head (NPSH) which is available. With pumps situated near the core inlet, as in the "Otto Hahn", adequate NPSH can be arranged for normal operation. For other possible design arrangements or for some conditions of part-load operation this is more difficult and the use of a cover gas pressure may have to be considered.

In practice the use of a cover gas is neither convenient nor economic. The gas partly dissolves in the water, with undesirable side effects, and its partial pressure raises the design pressure of the reactor vessel. The use of reduced pump speed for part-load operation is therefore being investigated for the EFDR.

Most of the remaining papers in this section of the conference consisted mainly of descriptions of nuclear propulsion applied to container shipping - ship designs, plant layout, operating characteristics, etc. These studies naturally tended to lead on to questions of economics, which will be dealt with later in this report. There was some tendency to base discussion upon rather misleading comparisons between nuclear and conventional power applied to identical ships and operating schedules, rather than attempt to identify and exploit the special characteristics of nuclear propulsion. To some extent, however, the latter course is illustrated by the selection of container ships for study. A few years ago all such studies were related to oil tankers whereas it is now recognised that container shipping is an application more likely to favour the exploitation of nuclear power.

Only one paper explored the possibility of totally new forms of merchant shipping. Containerisation of cargoes being basically a means of increasing the load factor on expensive equipment, this paper went a step further and evaluated the use of a detachable nuclear powered driving unit to push or tow a freight unit or barge. The possibility of assembling a number of freight units with a single driving unit was also considered. These proposals are interesting in principle but pose considerable engineering problems for ocean going vessels.

A final paper considered the possibility of applying the direct cycle, high temperature gas-cooled reactor (HTGR) to marine propulsion. Reactor systems adopted for maritime purposes have been almost exclusively of the pressurised water type, but attention has been intermittently directed for many years to other types, including gas-cooled. Superficially the HTGR is attractive but the important safety problems of operating this reactor system at sea were not discussed.

5. ECONOMICS

A number of economic studies were reported and all showed at least a qualified optimism regarding the near term application of nuclear propulsion to commercial shipping. However, this session was overshadowed by a paper which had been published a few weeks earlier and was not actually presented at the Symposium: the "Report of the Nuclear Ship Study" by the UK Department of Trade and Industry, which concluded that there would be an "evident and high disparity in cost between nuclear and conventional propulsion for the foreseeable future". In later paragraphs of the present report this conclusion is re-examined in the light of changing economic circumstances.

The UK Government's report gives what is probably the most detailed available analysis of the technical and economic status of nuclear power for ships. The cost estimates which have been made by various interested parties have not always made full allowance for development costs and for the variable factors which can be described by the term "learning curve". The infrastructure necessary to the operation of a nuclear ship (indemnification against risk, port entry restrictions and regulation, crew training, shore based facilities and associated industry, etc.) is also frequently ignored. The UK report takes account of many of these factors and compares the various cost estimates which are available. While minor discrepancies remain, the major apparent differences are reconciled.

The UK Government's report particularly contrasts with a much-publicised recent Japanese study ("Long Range Outlook for Nuclear Ships", Report by the Nuclear Ship Committee, Japan Atomic Industrial Forum) which predicted the construction of 280 nuclear merchant ships by the year 2000. However, the Japanese report frankly admitted this to be a "bold projection".

A vitally important factor in all the reported investigations is the cost of bunkering fuel oil for conventional propulsion plant. This varies with time and also between different types of ship use and ports of call. Details of price are usually confidential to the fuel supplier and ship operator, but at the time of the UK Government's study (1969), it was thought that bunkering costs were generally below $10 per ton of fuel. Since then prices have risen sharply and now vary up to about $30 per ton. Future variations are the subject of much speculation. The UK Department of Trade and Industry is still convinced that in the 1980s and 1990s bunkering charges will, in real terms, be lower than the 1969 figures but other authorities expect further rises. It was even predicted by some participants during the discussion that the continued availability of fuel oil will be in doubt before the end of this century.

Other important factors affecting the competitive position of nuclear power are the size and speed of the ship and the type of trade for which it is intended. These factors determine the power level and load factor of the propulsion plant. For oil tankers nuclear power has the additional advantage that space otherwise occupied by fuel for conventional propulsion is available for cargo. However, the optimum speed of tankers being low, even the largest oil tanker which is now being planned does not require a sufficiently large power unit to make nuclear propulsion an immediately attractive proposition. Container vessels, on the other hand, have higher optimum speeds and large power requirements, together with the potential for long voyages and fast turn-around which results in very high utilisation.

Despite the problems which operators have experienced in establishing container services, the use of nuclear power in this type of ship cannot be ruled out for the immediate future.

Most of the detailed economic studies reported at this Symposium showed the break-even point for nuclear propulsion to be at speeds well above the optimum for minimum transportation cost, even for large container ships. It may be that some factors associated with the type of cargoes or the details of the operator's schedules might place a premium upon speed, or in effect shift this optimum as a result of a thorough overall assessment. Only the ship owners are really in a position to know this and they have been notably and understandably reluctant in the past to release such information. Further unknown factors are the return which an owner expects on capital investment and the incentive which he would require to move into a largely new and untried area of technology. It was therefore interesting to note that ship owners were much more strongly represented at this Symposium than has usually been the case at similar events in the past, and that several of them gave indications of intending to participate with ship builders and nuclear plant designers in future economic studies.

In view of the large capital investment and the long lead time on supply of a nuclear ship (perhaps five years or more), it will no doubt be necessary for ship-owners to obtain a clear idea of the type of vessel most likely to invite the early application of nuclear propulsion and therefore to warrant detailed consideration. Assuming that:

(i) there is a world demand for several hundred such vessels in the next ten to twenty years, and

(ii) bunkering charges remain approximately constant at their present levels,

nuclear power appears to be attractive for a ship of the following general specification:

Type - container vessel carrying about 3,000 standard 20 ft containers.

Speed - 30 knots.

Power - 120,000 shp, single reactor.

Drive - steam turbine, twin shaft.

Route - long haul, e.g. between Australia and Europe.

The capital cost of the reactor for this ship, without fuel, could be expected to be in the region of $10 million assuming it to be one of a series in production. The nuclear fuel cost would be of the order of 0.2¢/shp/hr.

Container ships of this size and performance have already been ordered with conventional oil burning machinery, and an expanding demand for ships of at least this power level has been predicted confidently by a number of authorities.

Thus there may be a good chance here for nuclear power to break into the market. Undoubtedly there will be competition for this business and, therefore, it is quite possible that the number of orders for any one reactor supplier would be numbered in tens rather than hundreds even up to the end of this century. However, a general acceptance of nuclear propulsion and the resulting availability of large power units at relatively low cost would be likely to promote developments favourable to the use of nuclear power in the shipping industry; e.g., the development of advanced types of vessel, revised schedules and new types of trade, and the application of nuclear propulsion to smaller ships.

Two major economic obstacles remain to be overcome before the true commercial position of nuclear shipping can be established by free industrial exploitation:

(i) the large non-recurring costs associated with the first nuclear merchant ships of commercial size and performance, and

(ii) indemnification of owner-operators against the large though highly improbable risk of a major nuclear accident.

There is no immediate prospect that these problems can be dealt with except by intervention at government level. It is becoming normal practice for national governments to underwrite nuclear risks, but no obvious incentive appears to exist for them to give any other major support to the industry.

6. LEGAL ASPECTS AND INDEMNIFICATION

This Symposium served to illustrate quite clearly that the present status of the law regarding nuclear powered ships is not suited to free commercial operation. A prime interest of national governments is to safeguard the welfare of their people, and they have set out to do this in two ways: by satisfying themselves technically that the risk of accidental release of radioactivity in their ports and territorial waters is acceptably low, and by ensuring that adequate indemnity is available in case of such an accident. A review of laws relating to conventional shipping shows that the normally accepted rights, such as peaceful passage and access to ports in case of emergency, can be withdrawn from nuclear ships on the grounds of exceptional risk.

The two relevant international treaties which set out to establish a basis for acceptance of nuclear shipping are, firstly, the International Convention for the Safety of Life at Sea of 1960 (the SOLAS Convention) and, secondly, the Brussels Convention on the Liability of Operators of Nuclear Ships of 1962. The SOLAS Convention has been generally ratified by governments and contains rules and recommendations aimed at preventing the incidence of nuclear damage. The Brussels Convention, which is not yet in force, deals with problems regarding the settlement of damage claims. So far it has been signed only by the governments of a small number of nations which might act as hosts to visiting nuclear ships but which do not as yet have plans for operating such vessels.

Before the Brussels Convention can come into force, it must be signed also by the government of at least one of the nations which operate nuclear ships. Other nations will then have to decide their attitude to this treaty.

A major factor preventing ratification of the Brussels Convention by the major maritime nations appears to be the inclusion of warships in the treaty as it stands. There is naturally a disincentive for governments whose navies operate nuclear warships to accept any international restriction on their use.

Several other governments (including the Government of the Federal Republic of Germany) are delaying ratification for a variety of domestic reasons, such as problems regarding procedural difficulties, loopholes and the harmonisation of national laws with international treaties. Some participants expressed concern at the concept of liability without any need to prove negligence, and also at the suggestion that a host nation might demand absolute control over a nuclear ship in the event of an emergency. Norway apparently rejects any limitation upon the liability of a nuclear ship operator. Liability for accidents during maintenance and refuelling was debated also.

This is clearly a rapidly evolving situation and notice was given of further developments at the Geneva Conference later in the year.

The main object of the operation of nuclear merchant ships to date has been to establish international agreements and acceptance, and to clarify the insurance position. This has actually transpired only to a limited extent because these operations for the most part have been seen as untypical. In the USA, for example, the Price-Anderson Act was extended on a once-off basis to the "Savannah", and this could not be expected to occur again for other nuclear ships. Nevertheless, limited conventional insurance was purchased for the "Savannah", and the Hull and Protection and Indemnity claims experience (nuclear and conventional) during the entire period of operation was reported to have been outstanding. Not one claim based on nuclear liability has been filed. The excellent claims record of the past five years of commercial operating experience with the "Savannah" and the premiums charged for coverage during this period present a favourable picture for prospective underwriters of insurance on nuclear merchant ships in the future.

Insurance of the "Otto Hahn" for nuclear liability has been effected with private insurers, but the amount of this cover is limited to a total payment of DM5.7 million (approximately A$1.5 million) on claims occurring in any one year of insurance and a total maximum indemnity of DM14.7 million (approximately A$3.8 million) payable for all claims arising during the validity of the insurance. Under German Nuclear Law the German Federal Republic is under obligation to assume liability for any amount exceeding the cover specified above up to a limit of DM500 million (approx. A$130 million). The insurance covers claims arising under legal liability provisions and special agreements relating to the entering of foreign ports and waters. It also covers not only the liability of the owner as reactor operator, but also that of persons authorised to effect services connected with the planning, installation, putting-into-operation, operation, maintenance and repair of the "Otto Hahn", and persons for whom the shipowner is obliged to effect insurance cover by reason of special agreements on the entering of foreign ports and waters.

As the Brussels Convention is not yet in force, it has been necessary for the "Otto Hahn" to operate on the basis of bilateral agreements negotiated between the German government and the governments of other nations, e.g. the agreement already reached with Holland. Draft agreements of a similar type have also been proposed to a number of other nations, including Australia. A liability limit of DM400 million (approximately A$104 million) was mentioned in connection with these agreements.

German delegates at the Symposium suggested that the German Federal Republic is likely to sign the Brussels Convention soon (despite some misgivings) with a view to bringing it into force, to encourage wider ratification and thereby to reduce the need for these separate bilateral agreements. They expected Japan to take similar action to facilitate operation of the "Mutsu". Belgium and Holland also appear to be working vigorously to promote ratification of the treaty.

Amongst other nations, Spain has had specific laws relating to nuclear ships in force since 1964 and a hint was given that Spain may be planning to operate nuclear ships itself.

There was a clear desire amongst the shipping interests of the major maritime nations to reduce, as far as possible, the restrictions on the operation of nuclear ships, to establish the routine acceptability of visits from nuclear powered ships and to eliminate the requirement for detailed evaluation. Indications of this attitude were the public relations exercise of mooring the "Otto Hahn" in the heart of Hamburg docks and providing facilities for a Symposium reception on board, and an attempt to put pressure on the Italian Government to accept at short notice a visit from the "Otto Hahn" to Genoa during the 1971 Geneva Conference. However, it is likely that responsible regulatory authorities will continue, for the immediate future, to consider all visits from nuclear merchant ships on an individual basis.

APPENDIX - THE SYMPOSIUM PAPERS

Operating Experience, Commissioning and Maintenance

SM 141-6 - Operating Experiences with the "Otto Hahn". D. Ulken, H. Fock, H. Kühl, H. Lehmann-Willenbrock, W. Schumacher (GKSS, FRG).

SM 141-46 - Maintenance and Repair Experience of the N.S. "Savannah". R. Allen (TODD, USA).

SM 141-36 - Preparation for the Operation of the "Mutsu". J. Kitagawa (Japan Nuclear Ship Development Agency, Japan).

SM 141-47 - Analysis of Core Performance and the First Refuelling of the N.S. "Savannah". W. J. Gallagher, G. H. Kaiz, J. N. Sorensen (NUS, FRG); C.W.Hathaway (TODD, USA).

SM 141-48 - Classification Requirements for Nuclear Ship In-Service Inspection. T. W. Parker (American Bureau of Shipping, USA).

SM 141-49 - N.S. "Savannah" Officer Training Programs Licensing Experience and In-Service Results. L. S. McCready (US Merchant Marine Academy, USA), C. W. Parker (US Maritime Administration, USA).

Propulsion Plant and Ship Safety

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SM 141-50 - Safety Audit of N.S. "Savannah's" Commercial Operations. A. P. Honeywell, E. A. Saltarelli (NUS, USA).

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SM 141-9 - The Safety Review of the N.S. "Otto Hahn" on Behalf of the Licensing Authorities. L. F. Franzen, A. Merton (Instut fur Reaktorsicherheit, FRG). (Not Presented).

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Nuclear Ship Propulsion Plant Engineering

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SM 141-34 - PWR Development for Nuclear Ship Propulsion. L. Chinaglia, G. Cesoni, L. Criscuolo, G. Previti (Fiat, Italy).

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SM 141-40 - Some Differences between Conventional and Nuclear Container Ships with Equal Cargocapacity and Speed. P. B. van Berkel (Sea Transport Engineering N.V., Netherlands), W. Vinke (Technical University Delft, Netherlands).

Nuclear Ship General and Miscellaneous Papers

SM 141-37 - The Design and Construction of the "Mutsu". M. Inouye (Japan Nuclear Ship Development Agency, Japan).

SM 141-17 - Reactor Dynamic Experiments with the "Otto Hahn". M. Kolb, R. Fiebig, E. Robinson, E. Schwieger (GKSS, FRG).

SM 141-18 - Nuclear, Thermohydraulic and Fuel Element Design by Interatom, AEG and GKSS. E. Müller, W. Rossbach, A. Schinner, W. Will (Interatom, FRG), W. Fricke, H. Friedrichs, K. Guse (AEG-Telefunken, FRG), D. Bünemann, H. J. Manthey, A. Müller (GKSS, FRG).

SM 141-27 - Nuclear Ship Propulsion System with Gas Turbine. K. Bammert, G. Krey (Technische Universität Hannover, FRG), E. Boehm (Gutehoffnungschütte, FRG).

Economic Aspects

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SM 141-35 - Possibilities of Employing Nuclear-Propelled Container-Ships in the Italian Merchant Fleet. M. Cavaggioni, V. Crisá, G. Maturo, L. Rubbi, I. Salvati (Comitato Nazionale Energia Nucleare, Italy).

Legal Aspects

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SM 141-4 - French Legislation Relating to Nuclear Ships. M. de Nercy, M. Lagorce (Commissariat á l'Energie Atomique, France).

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SM 141-26 - Statutory Provisions of Nuclear Propelled Ships - A Comparative Review of National Legislation at Present in Force. W. Bischof (Institut für Völkerrecht der Universität Göttingen, FRG).

SM 141-53 - N.S. "Savannah" - The Insurance Story. W. H. Lane, C. R. Fullenkamp, C. R. Hart, C. W. Parker (US Maritime Administration, USA).

SM 141-55 - The Insurance of Nuclear Vessels, with Specific Reference to the N.S. "Otto Hahn". K. F. von Schlayer (ALLIANZ Versicherungs-AG, FRG).