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RFA *Argus* – the conversion of a ro-ro/ container vessel to an aviation training ship

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SYNOPSIS

The conversion of the ro-ro/container ship Contender Bezant to RFA Argus was a unique contract in many respects. It was the first 'whole ship' procurement contract to be placed following the Government's 'value for money' policy with respect to Defence Contracts. It was the largest conversion undertaken by MOD(N) and introduced the appointment of a Ship Weapon System Authority for system design, procurement and installation. In addition it represented the Builder's return to Naval work after an absence of almost 20 years.

This paper outlines the conditions of the Statement of Technical Requirements and the suitability of the chosen vessel to meet these. It describes the layout of the converted vessel and how the all important parameters governing roll characteristics and damage stability were achieved; the surgery carried out to the main hull, superstructure, tanks and machinery spaces; and the installation of additional items of machinery, with their associated pipework and electrical systems.

The conversion offered an exciting challenge to the Builders in the disciplines of design, construction and commissioning, which resulted in many innovative ideas and a unique and versatile vessel for the MOD(N).

INTRODUCTION

This paper describes the shipbuilder's view of the conversion of the ro-ro/container ship *Contender Bezant* to the RFA *Argus*, which has posed a number of interesting problems of Naval Architecture and Marine Engineering requiring innovative solution.

The Statement of Technical Requirements for the Aviation Training Ship (ATS) was issued in late December 1983. The invitation to tender indicated that a response was required by the end of January 1984 and that tenders could be submitted to either purchase and convert a suitable merchant ship or to design, build and fit out a new vessel. The peacetime role of the ATS was to provide a mobile base, with engineering and training support facilities, for helicopters embarked for air crew operational training in all helicopter warfare roles. In addition, in times of tension and war the vessel was to have a secondary role of deployment and ferrying helicopters and STOVL aircraft.

The ship was required to be capable of 18 kn in the deep load condition with an endurance of 8000 nautical miles at 15 kn and, in order to be flexible in operation, it was considered desirable that the vessel should be twin screw with each shaft driven by geared medium speed diesel engines. The ship's complement was to be 254 persons, divided between 79 Royal Fleet Auxiliary, 38 Royal Navy and 137 in the Squadron Training Detachment. The vessel was required to provide a stable platform for flying operations under sea conditions of mid-sea state 6 and was also required to withstand two compartment damage. The ATS was to rank as a Royal Fleet Auxiliary vessel with classification as Lloyd's +100A1, +LMC, UMS and a Department of Trade Class VII Cargo Ship. It was also to comply with the requirements of the Merchant Shipping (Load Line) Rules 1968, the Merchant Shipping (Passenger Ship Construction) Regulations 1980 and the International Convention for the Safety of Life at Sea (1974) with all amendments.

K M Walsh served an engineering student apprenticeship with Harland and Wolff after which he joined A Holt as a Marine Engineer Officer. In 1972, having gained Certificates of Competency and having served on many of the company's vessels, he lectured in Marine Engineering in the School of Maritime Studies at the Northern Ireland Polytechnic. In 1974 he returned to Harland and Wolff as Machinery Project Manager, and subsequently held numerous senior management roles within the Yard. In 1984 he was appointed Project Manager for the Aviation Training Ship and is presently employed in the aerospace industry. His outside interests include sailing and service with the RNLI.

N A J Wells was accepted for direct entry from school, in 1972, by the Royal Corps of Naval Constructors, after which he joined the Harland and Wolff Naval Architecture Design Office as an Assistant Naval Architect in 1977. Subsequently he moved to Harland and Wolff R&D with a brief to head a small team in developing an 'in-house' finite element structural and vibration analysis capability. In 1983 he was made Deputy Manager of Hull Design in the Naval Architect's Department and Secretary to the company's New Technology Committee, after which he became department Project Manager for the MOD/H&W Aviation Training Ship conversion project. In 1984 he was made manager of Pre-contract Hull Design and assumed responsibility for preliminary design work on the BP SWOPS project, including detailed design calculations on ship motions and dynamic positioning, after which he was promoted to assume responsibility for the Ship Sales Department. Appointed New Developments Manager at Short Brothers – MSD in 1988, he became Marketing Manager at Short Brothers – DSD in 1989.

The MOD had commissioned a study to identify the type and size of vessel suitable for conversion to give the necessary facilities and as many of the desirable features as possible. Three different basis vessels were examined, each of which was capable of satisfying the requirements. The findings of this study were made available to assist the company in making its selection for the conversion option. Of the three candidates examined in the report the *Contender Bezant* appeared to offer the most favourable qualities and was chosen by Harland and Wolff plc to be examined in greater detail against the Statement of Technical Requirements.

Harland and Wolff plc were awarded the contract to purchase and convert the *Contender Bezant* on 7 March 1984.

THE *CONTENDER BEZANT*

The *Contender Bezant* was one of two 18 500 dwt Italian-built vessels, designed by Hart Fenton for transport of both containers and rolling cargoes. The Contender class was essentially a development of the Tackler and Boxer classes, having been conceived as an economic means of transporting both container and rolling cargoes, but having the novelty of being able to sling a layer of containers under its hatch covers above any wheeled, unit-load, or container cargoes underneath. This configuration provided an ideal area of clear headroom for conversion to a series of hangar spaces. Another distinguishing feature of the Contender class was the complete absence of cargo space below the trailer deck, all this volume being devoted to tankage and providing an ideal basis for conversion of these areas also.

The *Contender Bezant* carried two cantilever mobile gantry cranes running on tracks along the entire length of the cargo area of the vessel behind the forward positioned superstructure. Wheeled traffic had the option of entering or leaving the ship through either a forward or aft watertight shell door/ramp designed by Navire. This feature was of interest for flexibility of operation of the converted vessel although ultimately the forward door was considered superfluous. The aft ramp is 9m wide and has a clear height of 4.5m. In the original specification this vessel had the capability to carry up to 30% of all cargo in ro-ro form, equivalent to 64x40 ft trailers plus 16x20 ft containers, corresponding to a net track length of 879m. This specification gives some guidance to the space available internally. The parallel mid-body was continued right aft to result in an enormous square transom stern at both shelter and trailer deck levels.

The torsional strength of the basic vessel, which had eight full width hatch openings along the cargo length, was ensured by three torsion box structures arranged port and starboard between the main deck and the shelter deck providing routes for pipe passages, walkways and cable ducts. A centre line bulkhead between the main deck and the shelter deck, included in the original vessel, had to be removed during conversion to open out the hangar spaces to the maximum width available between the two torsion box structures.

A feature of the vessel was that it also contained an auxiliary machinery room positioned in the forward tank spaces under the trailer deck. The forward machinery space was a sparsely used area and this consequently was beneficial for the conversion.

The *Contender Bezant* was an extremely broad ship at the after end and this was continued into the underwater form, with the twin propellers carried in skegs. Thus, the direct reversing main engines were positioned well apart with a low centre of gravity.

LAYOUT, ACCOMMODATION AND CLASSIFICATION

Several significant naval architectural problems were raised by the conversion. The first, and probably most significant one, was how to manage to produce loading conditions which resulted in sufficient draught to immerse the propellers correctly. This problem arose because of the total change in the nature of the cargo being transported. This cargo, which in the initial stages of the design study consisted of purely aircraft stores and limited bunkers, fresh water etc, was largely volume, rather than weight dominated and, as a result, a large quantity of ballast water was required to achieve the minimum draught. In itself this created further problems of excessive stability when the requirements of a slow roll period were examined for the successful operation of aircraft. The low centre of gravity of the ballast water exacerbated the vessel's already large metacentric height (GM). With the realisation that the vessel could only operate successfully with a significant amount of ballast water permanently on board, the MOD proposed that a more efficiently used vessel would result if the ballast water was substituted with dieso oil and top weight concrete ballast. In other words, the vessel should be considered for use also in a tanker capacity.

As a result of the deliberations a further set of loading conditions was examined to establish the maximum dieso capacity of the vessel, which eventually proved to be of the order of 3500t. A separate water ballast capacity was also maintained which included a large anti-roll tank normally kept filled.

This evolution of the design requirements resulted in considerable debate on classification issues and major 'knock-on' effects in vessel design. However, the RFA *Argus* will operate as a Class VII Cargo Ship and meet the requirements of Lloyd's Register Class 100A1. Figure 1 shows the profile of the converted vessel.

Originally designed as a container vessel with accommodation for 30 people, the converted ship will carry some 254 personnel divided between 79 RFA, 38 RN and 137 persons in the Squadron Training Detachment. This has been accomplished by the fitting of an additional superstructure block, which is totally integrated with the existing accommodation structure. This complete structure, together with other portions of the ship, is designed to NBCD standards making the complete citadel arrangement self-contained. The photograph in Fig 2 shows the installation of the lower module of the new accommodation block, with a total weight in excess of 800t and approximately 100t of pre-outfit material.

The accommodation block was built in two parts, the lower module consisting of deck numbers 1, 01, 02, and 03 weighing 530t at lift and the upper module consisting of deck numbers 04, 05, and 06 weighing just over 300t. The handling of modules of these proportions was made possible by the Yard's building dock cranes, which have a capacity of up to 800t.

All 146 cabins are fitted to the best commercial standards. Catering for the complement is supplied from a galley with a floor area of approximately 100m^2 and fitted out with Lef Bishop equipment. The junior ratings will use a self-service cafeteria with seating arrangements for 88 people, whilst the senior ratings and officers will all have table service dining rooms, each with their own recreation rooms and bars. There will be an aircrew refreshment bar, complete with its own mini-kitchen, seating 19 persons.

The hospital, for ease of access, is situated on the same level as the flight deck. Fitted out to commercial standards, it has

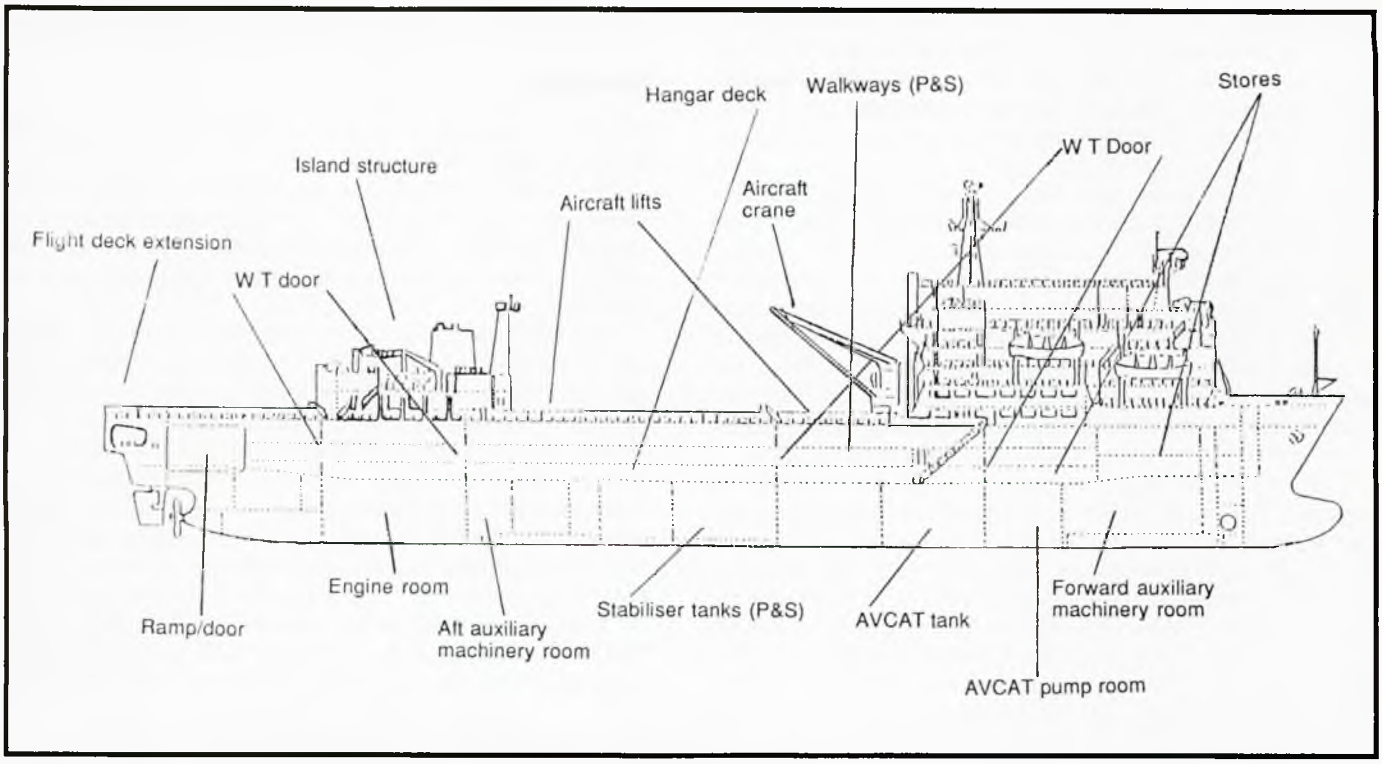

Fig 1: RFA *Argus* profile

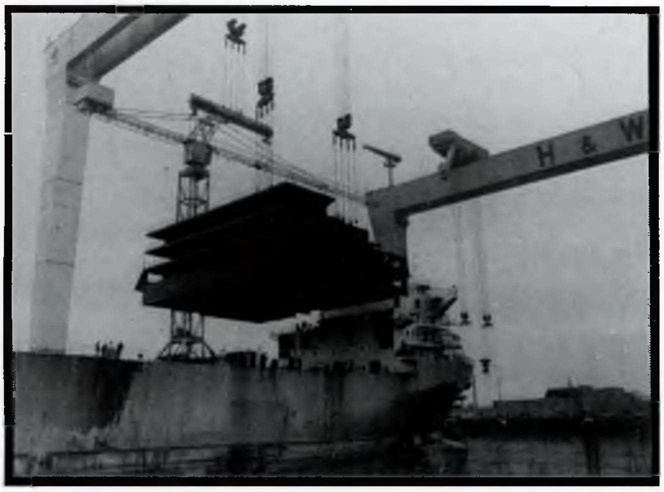

Fig 2: Placing of the lower new accommodation module

space for up to six people at a time and its own bathroom facilities. In close proximity to the hospital is the dispensary, equipped with dental facilities which include a dual purpose dentist's chair/operating table.

Under the main deck there are three junior ratings' dormitories, 2x15 persons and 1x27 persons. These are to RN standards, including bedding, lockers etc, complete with their own recreation areas and toilet facilities.

The entire accommodation down to and including the 13m flat forms the citadel. The area offers the crew protection should an NBC condition be encountered and can be maintained above atmospheric pressure, thus ensuring no direct ingress of air.

The citadel is subdivided into vertical zones and the atmospheric conditions within the zones are maintained by air filtration units which form part of the air conditioning system. Airlocks situated on 01 deck and No 1 deck provide personnel access to the open deck under 'closed down' conditions whilst a cleansing station provides the decontamination facility.

Lifesaving is catered for by the fitting of 4x132 man totally enclosed lifeboats manufactured by Lambie and hung on Schat davits. In addition to this, there are liferafts to cover the full ship's complement and a Pacific 22 rescue boat located on the casing at midships.

The primary function of the vessel is the operation of helicopters and to facilitate this a complete raised flight deck coated with Leigh non-slip flight deck coating to a total DFT of 750 μm was fitted. On both sides of the flight deck and 1.75m below its level there are walkways running the complete length of the ship. Along these walkways are fitted the services necessary to support flying operations, *viz* fire fighting, aircraft starting and AVCAT fuelling modules. In addition, the flight deck is covered by four foam monitors each with a throw of 51m in still air, thus affording full protection in the event of an accident. These are fitted fore and aft on the flight deck island (two off), and on the accommodation block aft (two off).

In the aft starboard corner of the hangar deck there is an hydraulically activated ramp, thus allowing vehicles and equipment to be loaded directly from the quayside/mexefloat to the ship or vice versa.

All of the supporting workshops are sited on the hangar deck, including an electronic maintenance room, an instrument maintenance room, an electrical maintenance room, mechanical workshops, an engine change unit and gearbox store and a large naval air store, thus allowing for ease of access and maintenance purposes.

This complete area is protected by a water spray lattice which is capable of deluging the largest of the four hangar areas with 12 200 litres of water per minute. Other specific areas are protected with AFFF foam or halon.

The tanks for carrying water ballast, dieso and AVCAT are housed below the hangar deck. The ship has been designed to issue fuel as well as receiving it, thus adding some flexibility to her operational role. There are four stations for replenishment at sea, one of which is served by a 25t Clarke Chapman crane fitted with rigging to handle the standard naval dieso RAS equipment. The 25t crane's main role is that of aircraft recovery.

As the *Argus* is intended as an Aviation Training Ship, it is imperative that the airflow conditions across the flight deck are relatively clear of excessive turbulence. In order to determine just what conditions could be expected, a series of wind tunnel tests on a water line model were conducted in the Aeronautical Department of Queen's University, Belfast. Initially, smoke emission tests were conducted to examine the dispersion of the main engine exhaust throughout the range of incident wind angles. These tests illustrated a good dispersion of the exhaust with very little reverse entrainment at any relative angle.

The second series of tests employed the use of a matrix of tufts to visualise the airflow across the entire flight deck at two particular heights above the deck. Photography of the tufts provided a permanent record of the flow regime with predominant flow direction and degree of turbulence registered for interpretation. The tests revealed a predominantly clear deck with some turbulence just behind the superstructure block in the headwind conditions. In fact, the vessel will be able to offer a range of conditions perfectly suitable for the graded training of helicopter pilots.

INTACT STABILITY AND ROLL STABILISATION

The basic design of *Contender Bezant* produced optimum stability when the ship was fully loaded to the design draught with minimal ballast. In the ballast condition, at a draft sufficient to submerge rudders, propellers and bow thruster, the vessel had a very large GM of 7m and consequently a short roll period of about 10s.

The RFA *Argus* in her air training role will not be carrying anywhere near the dead weight for which the vessel was originally designed and this, of course, would have lead to a highly stable vessel.

The removal of the two container gantry cranes, securing frames and fan casing was expected to reduce top weight by 400t, thus increasing the GM still further. Hence, without considerable modification, the vessel would have been much too stable to produce a natural roll period in excess of 12s, which was imperative for its successful use for flying operations and a contractual requirement.

Of all these criteria the prime area of concern was the excessive stability leading to a short natural roll period.

The addition of top weight, in combination with a roll damping tank, was finally selected as the best way of achieving the contractual requirements for a roll period in excess of 12s, while still maintaining all the other stability criteria. The addition of a substantial extension to the existing superstructure block therefore, was a major benefit and indeed it was possible to use heavier scantlings than usual for superstructures (8–10 mm plate) giving a dual benefit in top weight while making fabrication easier. In total, the additional superstructure, which comprises seven decks, had a weight in excess of 800t. Additionally, a substantial new main mast with a weight of 26t was fitted to carry the new radar and communication aerials. Another significant source of top weight was the addition of the new flight deck structure itself. This substantial structure, which is some 116 m long by 27m wide has a weight of 760t. However, in spite of all these major contributions to top weight the GM was still in excess of 5m and a further significant means of adding top weight had to be determined. This was achieved in the form of some 1800t of concrete ballast added just below flight deck level.

The flight deck had been designed at a height of 1.75m above the existing shelter deck leaving a volume ideally suited for ballast addition. A number of the existing hatch covers were then upturned to provide ready made trays to receive the concrete.

Five companies were originally approached to quote for the stabilising system for the ATS. These companies were initially given sufficient design information to make a provisional quotation. The design criteria included the maximum operational sea state, the required RMS ship motions in pitch and roll and the contractual requirement to achieve a 12s period of roll. Two companies submitted tenders for open flume systems which were not considered technically acceptable due to poor performance at low frequencies of encounter. The remaining three tenders were for U-tube systems, one of which did not offer any control system for frequencies of encounter lower than the natural resonance of the U-tube and this was also rejected as not being technically acceptable. The requirement for a 12s period of roll was discussed in detail with the remaining two companies, both of which were offering a controlled passive system meeting all the other technical requirements laid down by Harland & Wolff. One of these companies pointed out that the ship's response to roll excitation at various frequencies with a correctly tuned system is modified from the unstabilised single peak at resonance to a double peak response, with the low frequency peak predominating. Thus, if the period of roll was to be defined as the 'period of natural decline of roll', then a 12s period could be achieved at a higher level of statical stability than would have been suggested by the simplistic formulation involving just beam and GM. The consequence of this was that a reduced amount of permanent top weight ballast could be employed to achieve the required characteristic. In order to calculate the weight of ballast required to produce the required roll period, advice was taken regarding the probable values of added inertia acting on the hull due to the surrounding water. The roll moment of inertia for the hull alone was also calculated in some detail rather than having to trust some of the more empirical relationships.

Quite extensive simulations of the vessel/tank interactions in roll motion were performed in deciding the final tank geometry shown in Fig 3. In the basin trial of this stabilising system, with the vessel in the inclining experiment condition and a GM of just over 4m, the period of natural decline of roll was measured as 16.8s with the stabiliser air valves fully open, while in the controlled mode a period of 13.3s was recorded.

DAMAGE STABILITY

During the initial design study considerable effort was expended on satisfying the requirements of watertight subdivision. In order to meet the two compartment damage requirements it was necessary to introduce a number of additional watertight bulkheads. Fortunately the existing bulkhead arrangement of the *Contender Bezant* and the layout in the engine room permitted the insertion of two extra bulkheads below the hangar deck without much disruption. The first was required at

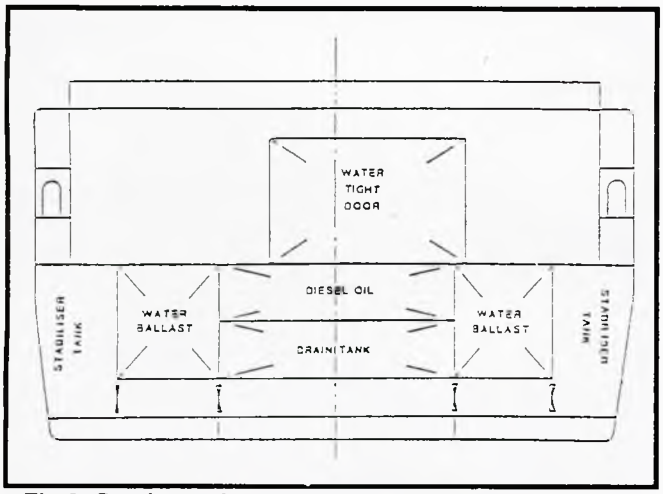

Fig 3: Section at frame 90 through the stabiliser tanks

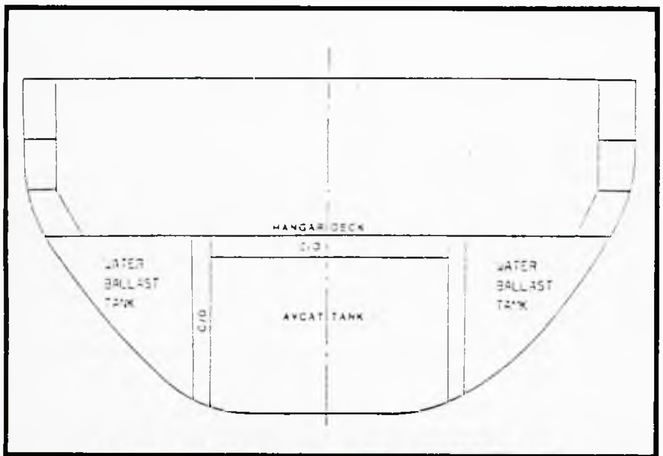

Fig 4: Section in way of the AVCAT tank

frame 63 to divide the engine room in two and a second bulkhead was required at frame 163 to subdivide the existing No 1 water ballast and fuel oil tanks. Additionally, four watertight bulkheads were required between the hangar deck and the new flight deck at frames 35, 63, 123 and 163. These bulkheads divided the hangar space into four sections and compensated for the loss of the continuous longitudinal bulkhead originally on the centre line. To maintain flexibility of operations and access to these hangar subsections they were interconnected by large horizontally sliding watertight doors. These doors are of MacGregor-Navire design and are single panel side rolling with a clear opening size of 9.75x6.1m. The doors are of open construction having a flat door plate stiffened by webs with welded face flats and angle bars. They are raised from the sealed position by means of a hydraulic pushing cylinder synchronised with an hydraulically operated winch unit and moved *via* a chain drive system to the open/closed position. These doors are fitted with double flanged wheels which run on guide rails on the deck and which lower into recesses when the doors are closed.

As the door reaches the closed position, wedge cleats at the top and side of the door and locating spigots at the base of the door automatically engage with similar fittings on the ship structure to bring the seals into contact. Hydraulic cleating mechanisms are also used to ensure that the door is pushed into the fully closed position with the seals compressed.

With all these measures taken into account it was possible to meet the MOD's rather exacting requirement for damage stability. The results of damage stability were evaluated using the SIKOB suite of naval architectural programs. The margin line for MOD damage calculations was taken as 76 mm below the hangar deck at side. In general, six stages of primary flooding were used for tanks which were adjacent to the damage. Cross connected compartments were flooded in one stage, after primary flooding was finalised, giving seven stages in all. Four loading conditions were investigated including:

1. diesel oil tanker condition;
2. deep load condition;
3. light load (gale);
4. light load.

The most onerous B/5 and B/2 damage cases at each bulkhead were then identified for detailed examination. In all cases the maximum angle of list or roll did not exceed 20° and the final angles of heel after cross flooding did not exceed 5°. With careful attention to avoid any premature down-flooding points all the examined damage conditions were found to comply with the MOD stability requirements and in this respect the vessel's high inherent transverse stability was a definite advantage.

MAIN HULL SURGERY

The main items removed from the *Contender Bezant* prior to its conversion to the ATS included the travelling gantry cranes and crane rails, the hatch covers, the centre line bulkhead in the 'tween deck space, the funnels and machinery casing, the hanging container guides and a host of smaller miscellaneous steelwork.

There were nine main structural conversion areas to be tackled. In addition to these main structural conversion areas, there were, of course, innumerable minor structural additions and alterations.

In order to gain access to a number of these alteration areas, it was necessary to cut out temporary openings in the hangar deck at several points as follows:

1. In the forward auxiliary machinery room on the starboard side of the centre line from frames 185 to 195 to give an opening of 7x2.74m. This opening was used for the removal of existing machinery, the shipping of new steelwork and finally for new machinery installation.
2. In the AVCAT pump room on either side of the centre line between frames 163 and 175. These two portions of deck were sent to the fabrication area to have a cofferdam fitted to the underside of the deck. While the tank was open, fabricated panels were fitted at longitudinal girder level to form the new floor. The fabricated motor flat, 6m above the base, was also fitted, together with the bulkhead at frame 174 extending from the 6m flat to the hangar deck. AVCAT pumps and tanks were then positioned on the new tank top and the pump motors on the 6m flat before the deck was finally repositioned over the pump room. In the area above the AVCAT tank itself, four further temporary openings were cut out on either side of the centre line to 8.5m port and starboard. These two portions of the deck were also sent to the fabrication area to have a cofferdam fitted to their underside and while the tank was open the following work was carried out:
   a. The bulkhead on frame 163 was fabricated in 10 parts because of the restricted access and erected across the ship.

b. The remaining longitudinal and transverse cofferdam panels were erected from eight piece parts to give the 1m clearance required (see Fig 4).
c. The existing longitudinal bulkheads were then shot-blasted to the required standard for AVCAT systems.
3. The stabiliser tank area extends between frames 89 and 123, both port and starboard of the centre line, out to the side shell. The extremely high work content of this complex tank necessitated substantial openings in the hangar deck in eight places.
4. The engine room bulkheads on frames 35 and 63 were accessed through the hangar deck after the existing engine room casing had been stripped and burned away. Again the erection of the new watertight bulkhead had to be made from many smaller piece panels because of restrictions in access.

In the stores and workshops area at the forward end of the hangar deck a watertight door was fitted on bulkhead 163 to provide access for fork lift trucks. The forward ship side door was removed and plated in and additional steelwork was required to facilitate the numerous specialised compartments.

In way of the new superstructure the existing hatch covers and coamings were removed and new plating erected flush to 01 deck. This work could not be carried out until the bulkheads for the areas beneath had been erected.

On the hangar deck it was necessary to erect three watertight bulkheads, which extended to the ship side, with watertight doors in the walkways, pipe and cable passages. Air locks are used for access from the side passages to the hangar areas.

At flight deck level, after the removal of the existing beams, the hatch covers were inverted, where appropriate, and welded to the coamings, ultimately to be filled with 1800t of concrete. The flight deck itself was erected 1.75m above the main deck and was extended aft by 2.1m to improve the landing spot arrangement. The mooring deck below was rearranged and extended to accommodate the additional winches.

The new superstructure was blocked in two sections and built in the block assembly area, prior to being installed between frames 150 and 183.

AIRCRAFT LIFTS

The aircraft lifts were specified as being required to service the hangar areas of the vessel. The minimum size of the lift platforms was considered to be 16.5mx9.75m, with a safe working load of the order of 18t. A number of different designs were considered for fulfilling this function, which included a travel distance between the two decks of approximately 10m with limitations to the space available beneath the lower lift well. The final selection was for a design by MacTaggart Scott of a chain driven cantilever lift.

The lift platform (see Fig 5), which had to be accessible from three sides at the hangar level, is of fabricated construction incorporating four main load carrying box beams for rigidity. The two athwartship box beams are tapered from the guided edge to give depth and stiffness in a cantilevered form. Self-aligning rollers are attached to the cantilevered deep beams which support the athwartship and longitudinal platform beams. The vertical guide columns are attached at top and bottom only and provide a rigid track for the cantilevered platform to run up and down.

The platform is secured at the flight deck on keeps which engage into the platform box beam. The keeps and latches are hydraulically operated and electrically interlocked.

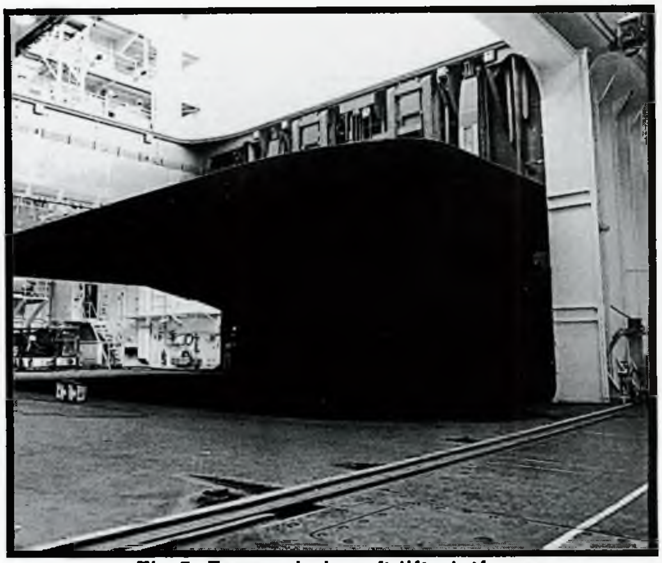

Fig 5: Forward aircraft lift platform

In the fully raised position the clearance between flight deck and platform skirt is sealed by a flexible lip seal and a pneumatic gas tight seal. The platform is raised and lowered by two hydraulically driven chain drive units each of which consists of an hydraulic motor driving two chain wheels *via* a gear box. The motors have integral fail safe breaks that are automatically spring applied if the electric or hydraulic power fails. The four triplex roller chains are attached *via* yokes to the guided edge of the platform between the guide beams.

The design of the hydraulic circuit and yoke attachment to the platform ensure that each chain carries the same load, although a mechanical cross connection exists between the two motors. The lifts can operate continuously, with a cycle time not exceeding 3 min, and recent trials have proven the success of this innovative but simple design.

MACHINERY INSTALLATION

Prior to conversion, *Contender Bezant* had a common main and auxiliary engine room. It was fitted with two four stroke, single acting main engines driving twin shafts through a reduction gearbox on each shaft. The main engines are Pielstick 18 PC2-5V airless injection, trunk piston and turbocharged. Each engine develops 11 700 bhp at 520 rev/min at its maximum continuous output. The gearboxes, supplied by Lohmann and Stolterfoht, are of the offset type and in association with the main engines provide power to the propellers at 120 rev/min.

A forward auxiliary machinery space housed a sewage plant, hydraulic power packs, bilge pumps and a spare propeller shaft.

Following conversion, the vessel now operates with the aft machinery space divided to form two compartments. This subdivision was a requirement of damaged stability calculations and to accommodate the new bulkhead some rearrangement of the existing auxiliaries was necessary, as well as the removal of the obsolete heavy oil fuel burning installation. In addition, new HP and LP air compressors, driers, receivers, a package boiler and two HP sea water pumps have been fitted.

As a result of the siting of the aft aircraft lift on the port side of the vessel and the need for a continuous flight deck, the


Fig 6: Aft aircraft lift recess hangar deck

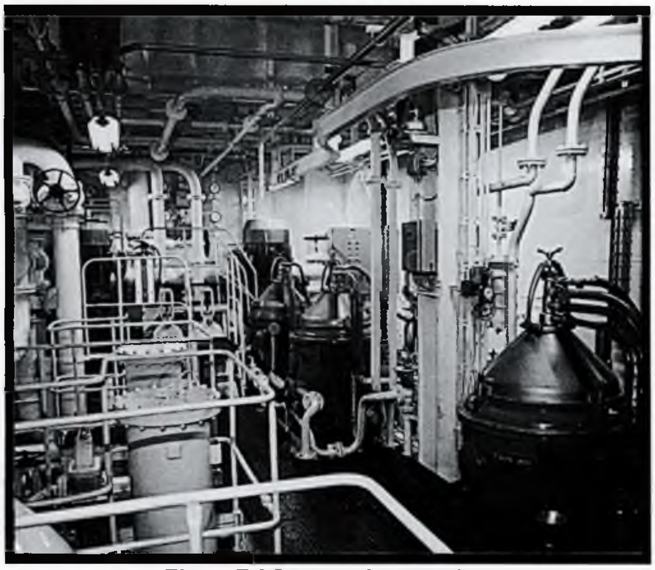
Fig 7: RAS pump installation

existing port funnel was removed and the main engine exhausts and vent trunks were rerouted to the new enlarged funnel on the starboard side. Prior to the conversion, the majority of electrical cables entered the main switchboard room *via* the portside. The installation of the aft aircraft lift recess (see Fig 6) necessitated the building of a dedicated trunking through which these cables were rerouted.

The watertight bulkhead aft frame 35 was extended below the 4m flat to seal the forward ends of the shaft tunnels.

The existing diesel generators remain in the new aft auxiliary machinery room (AAMR) which has been rearranged to accommodate many new items of equipment. These include a steam generator (Stone), oil fired with an evaporation capacity of 3103 kg/h to support the existing Sunrod cylindrical boiler. The additional steam capacity is to provide for hangar heating etc, an FW distiller (Nirex; 20 m^3/24h) air conditioning and air treatment units and the two replenishment at sea (RAS) pumps (see Fig 7). These pumps have a capacity of 490m^3/h (70m head) each and discharge through Boll and Kirsch filters.

Obviously considerable rearrangement of pipework was necessary to re-establish the systems, testing to the limit the ingenuity and skill of the Yard's pipemakers.

Lighting, ventilation and walkways also required many modifications.

As a consequence of the increased accommodation requirements and enlarged electrical load, the forward auxiliary engine room has had to be stripped of its original equipment and a considerable amount of new equipment installed. A new similar sized GMT diesel alternator to the existing ones has been installed in the forward space. Other equipment fitted into this space includes the following: the three AC chiller units, two out of a total of five HPSW fire pumps (Hamworthy; 325 m^3/h at 10 bar), two reverse osmosis plants (Caird and Rayner; 20 m^3/24h, two stage), two sewage treatment units (Hamworthy marine biological oxidation type), together with an Electrolux sewage collection unit. In addition to the main items of machinery were their supporting pumps, coolers, air compressors, a new switchboard and the domestic FW units. Thus, a space that was originally very sparsely occupied, has become packed with new items of machinery, pipework and cables.

In order to provide AVCAT to connections on the hangar and flight decks, a new pump room has been created immediately aft of the forward auxiliary machinery room in space previously dedicated to fuel tanks. Four AVCAT pumps and their associated equipment are now installed in this space.

A two tier ring main is provided for fuelling and defuelling of aircraft. The upper tier of the ring main system is fed with AVCAT, under pressure, through a single delivery pipe from the AVCAT pump room and supplies fuel direct to three 'on deck' fuelling stations as well as to three 'in hangar' fuelling stations. It is also used for the supply of AVCAT to a helicopter in flight refuelling (HIFR) point aft on the flight deck. Each fuelling station is provided with a filter/water absorber, flow meter, gas charged fuel shock alleviator, hose reel, hose end pressure controller/coupling, eductor pump and hand pump.

The AVCAT system has been installed to NES requirements.

The vessel's 3500t of cargo dieso is carried in seven tanks *viz* Nos 3 port and starboard, Nos 4 port and starboard, Nos 6 port and starboard, with No 5 centre being the issue tank, ie clean oil.

The designated bunker tanks are Nos 3 and 4 centre and, because of the difficulties in storing large quantities of dieso over lengthy periods, the transfer system has been arranged to provide circulation between all nine dieso tanks. Boll and Kirsch filters and water separators ensure the quality of fuel discharged during RAS (see Figs 8 and 9).

ELECTRICAL INSTALLATION

The three existing Grandi Motori Trieste, 1200 kw diesel alternators, have been supplemented by one further identical new set fitted into the forward auxiliary machinery space. Any three sets can be operated in parallel, the fourth being switched out by an interlocking key system.

The existing main switchboard required modification to delete circuits which were no longer required and to provide additional circuits for fire pumps, compressors, aircraft lifts etc, plus an interconnector to the new forward switchboard. The new switchboard for the forward alternator is shock proof to MOD(N) standard and is equipped with 440V and 220V sections. It is for the control and protection of the forward main

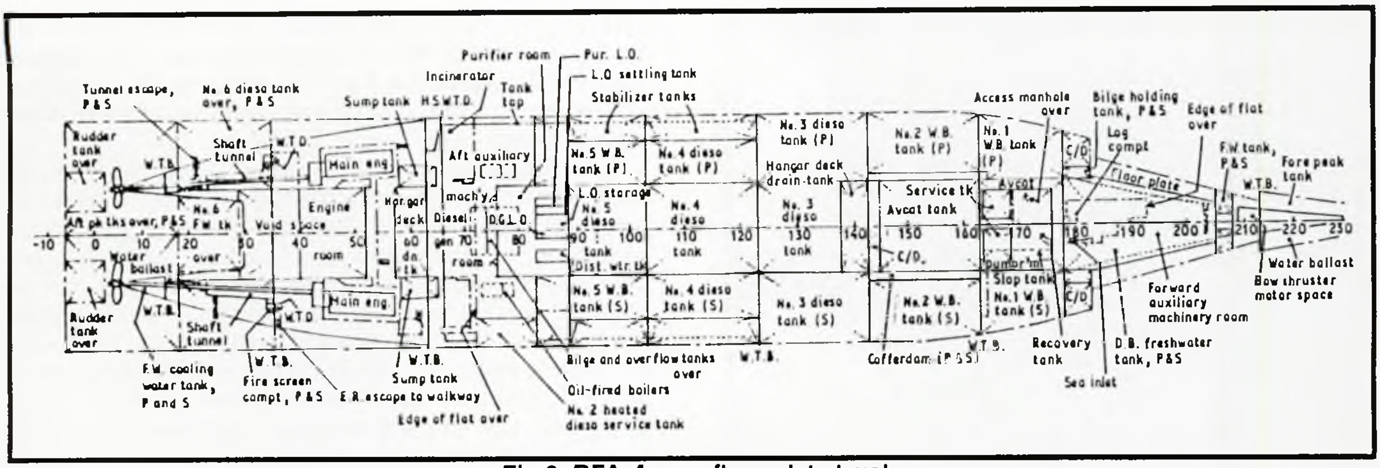

Fig 8: RFA *Argus*; floor plate level

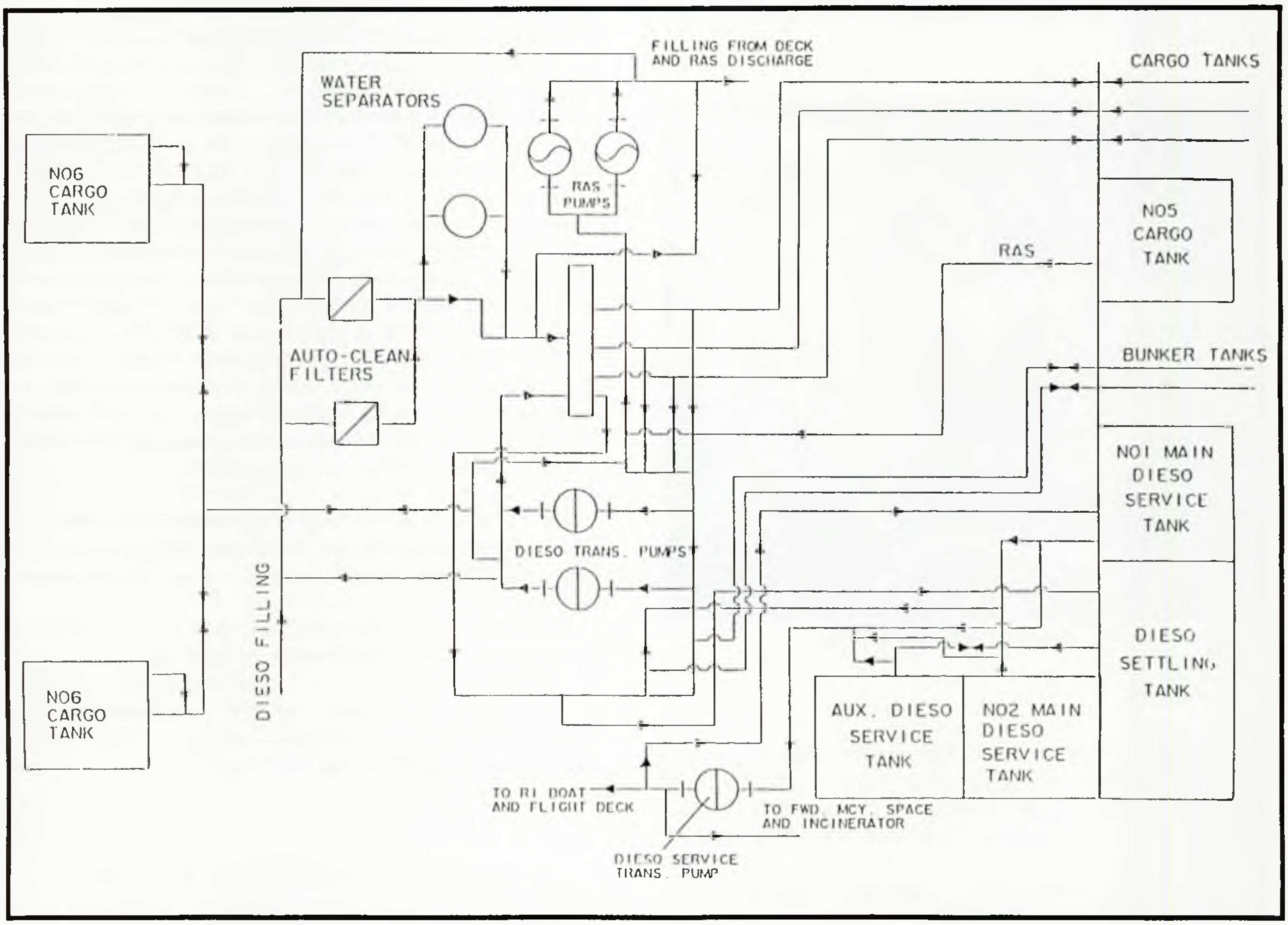

Fig 9: RFA *Argus*; dieso transfer system

alternator which is rated at 1200 kW, 1500 kVA, 0.8 pf, 440V, 60 Hz, 3 phase. The switchboard is a standard marine dead front drip proof cubicle type conforming to the latest requirements of Lloyd's Register for marine use under tropical conditions. The distribution capability covers the following: interconnector to aft main switchboard, shore power connection, 440/225V transformers (40 kVA single phase), 440/115V transformers (10 kVA and 15 kVA), forward machinery space, fire pumps, air compressors, aircraft lifts, aircraft starting and servicing, AVCAT pumps, hangar ventilation and essential engine auxiliaries.

On completion of the conversion, a growth factor of approximately 20% was available, balanced between forward and aft switchboards. Additional main transformers to NES standards have been fitted to facilitate the requirements of lighting, portable apparatus, weapons, flying aids, degaussing

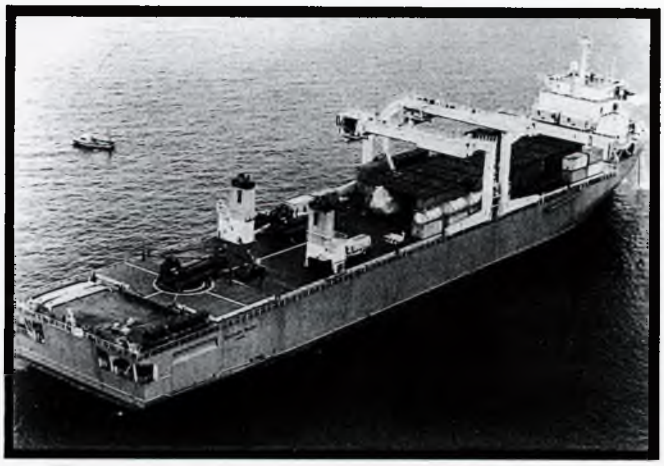

Fig 10: *Contender Bezant* in the Falklands – 1982

Fig 11: RFA *Argus* on sea trials; one view

Fig 12: RFA *Argus* on sea trials; another view

and various individual systems. Aircraft starting and servicing is catered for by frequency converter units (60 Hz/400 Hz). Additional motors fitted during the conversion are generally to the latest Lloyd's requirements and to BS 2949 or BS 4999/BS 5000, as appropriate for marine use, with squirrel cage rotors and rated for use under tropical ambient temperature conditions. Those motors below 130 kW are suitable for direct on-line starting and those above for star delta or auto transformer starting. Military standard motors meet the requirements of NES 632. The accommodation lighting has been fitted to commercial standards except in naval compartments, such as the operations room, communications room, air offices etc, where NES requirements have been applied.

The high levels of lighting in the hangar areas have been achieved using sodium floodlights to give 390 lux in the service areas and 250 lux in transit areas. Additional electrical power supplies have been fitted on the flight deck, within the hangar and workshop spaces for helicopter starting and maintenance.

All flying operations are controlled from the flyco, which has a mainly unobstructed view of the flight deck. The area aft of the machinery casing is covered by a surveillance camera with a monitor in the flyco. Within the office, full use is made of versatile consoles for enclosing controls and instruments used for communications, flight deck pattern lights and flood-lighting. The ship's pitch and roll recorders are fitted in the flyco and receive signals from the same sources as are used for the visual landing aids.

The fire detection systems, which originally only covered the machinery spaces, have been increased to cover the hangar deck, the accommodation alleyways and key installation compartments. A control panel for fire zone control and indication is fitted within the MCR/NBCD headquarters with repeater panels fitted in the wheelhouse and officers' alleyways.

In addition to the normal signal lights required by the Department of Transport and Suez Canal Regulations, a set of lights for naval operations has also been provided on the signal mast to be controlled from the wheelhouse. Visual signalling projectors mounted on pedestals have been provided on each bridge wing.

The existing commercial Marconi Marine radio equipment has been updated for normal ship operation. The radars have been replaced by Racal SMS 3 cm and 10 cm types to meet the Merchant Shipping Regulations and additional radio and radar equipment has been fitted for naval operations. Other navigational aids which have been fitted are a magnetic compass and two Admiralty pattern master gyrocompasses feeding the steering and bearing repeaters and radar displays etc, a Cherni Keef EM Log Mk II, an aquaprobe and a sonar 778A echo sounder. Meteorological facilities are provided within the meteorological office and include a wind speed and direction system, with repeat wind data indicators fitted at the flight deck and in the flyco.

Internal communications have been greatly enhanced to cater for the diverse operational requirements of the vessel. Additional systems fitted include a rationalised internal communications equipment (RICE II) network linking all operational stations, sound powered telephones for damage control, AVCAT operations, refuelling at sea (RAS) and cleansing station; briefing TV and telebrief systems are included, as are maintenance intercoms for military and commercial radars and other systems. An extended main broadcast system, with loudspeakers arranged throughout the vessel, provides facilities for group messages, entertainment and general/fire alarms.

The existing micro-computer based machinery supervisory system, supplied by Termokimik Corporation of Milan, consists of local units containing peripheral micro-computers transmitting to a centralised micro-computer. The local units are sited adjacent to groups of machinery equipment and receive electrical signals from the sensors on the equipment. The signals are converted to the appropriate variables and alarm and process measurement messages are prepared for transmittal to the supervisory micro-computer. The supervisory computer receives the alarm and measurement data from the peripheral micro-computers, processes them and displays and records them for operator information. The operator communicates with the supervisory micro-computer *via* a keyboard.

The large number of extra alarms and measurement data required to cover the new machinery equipment could not be accommodated in the existing supervisory system in total, due to unit space limitations. To overcome this problem it was decided to fit, local to each item of new machinery, an individual alarm panel from which a group 'fault' alarm is fed *via* the peripheral micro-computer unit to the supervisory micro-computer. Measurement data is also locally displayed at the machine.

The additional diesel generator is power monitored completely by the supervisory system, as are the existing generators. The generators are supervised also by a power management system which compares each machinery start load requirement, when a start is requested, with the running generator capacity and either allows the start or holds it until another generator is started to allow sufficient capacity. Also added to this system were the five additional fire pumps due to their large starting load requirement.

In the machinery control room, which is combined with the NBCD HQ, separate alarm systems are sited to monitor the space flooding of specialised naval compartments. A new console in this room now includes additional equipment necessitated by the increased fire fighting systems needed to cover air operations and the increase in the complement. The fire console also has a RICE communications panel and a main broadcast system. Sited adjacent is a dieso and LO tank quick closing valve operating panel.

The other sections of the console cover existing ballast and dieso tank gauging etc, and are modified to cater for the carriage of dieso (in tanks formerly used for SW ballast) for transfer to escort vessels etc. The ballast and dieso consoles have a pneumatic tank gauging system indicating various water ballast tanks, dieso tanks and fresh water tanks.

The ballast and dieso consoles have ballast, dieso transfer and RAS pumps, motor consoles, ship's draught gauges and an alarm panel for low and high alarms for various tanks. A mimic diagram is located on the console desk section and shows ballast, dieso and RAS systems, with in-line switches for remote control of ballast and dieso valves in machinery spaces. Valves located in the ballast tanks are operated by extended spindles.

CONCLUSIONS

A conversion of this magnitude presents many interesting technical challenges which generally can be successfully tackled with a little ingenuity, however, some of the most troublesome problems arise from the unexpected. For instance, in the *Argus* conversion, it was not expected that a fairly modern merchant vessel would have asbestos insulation installed, or that lead based paints should have been used so extensively. Similarly, one would have expected piping installation drawings to be available, but this was not the case.

The RFA *Argus* has yet to prove herself. However, we have no doubt that she will become a great asset with tremendous flexibility in service. It has been suggested that it is possible to convert rapidly merchant ships to configurations which make them the equal of warships (see Fig 10). In reality this just is not so. Ships taken up from trade (STUFT), with only minor alterations, have many severe shortcomings, not least of which is their susceptibility to underwater damage and problems in accommodating the needs of much enlarged complements. Conversely, the painstaking and detailed conversion of the RFA *Argus* shows that it is possible to take a mercantile hull and turn it into a quasi-warship without the inherent weaknesses of the rapid STUFT conversions (see Figs 11 and 12). The cost of such operations is not inconsiderable but, compared to the costs of new building, great value for money is achieved.

ACKNOWLEDGEMENTS

The authors would like to thank their colleagues at Harland and Wolff plc for their comments and assistance in the preparation of this paper. We also wish to acknowledge the contribution to the design process made by the MOD through scrutiny/comment on drawings and, at design liaison meetings, by the provision of many guidance drawings and by the use of Ministry Standards. The support given by the stabiliser tank subcontractors, Brown Bros & Co, in the calculation of roll motions and period was extensive and also needs to be acknowledged.

Discussion

M G Hart (MOD) The authors of this paper are to be congratulated for describing such a major conversion so succinctly. The 4 year conversion shows many lessons being learnt, not least that such a complex operation needs detailed planning and project management throughout the period.

Within the MOD I joined the *Argus* Project Group in February 1988 so that my contact with the ship started at the time of delivery. I intend to outline some of the ship activities since that time and combine that with some of my own comments on aspects of the design solution adopted by Harland & Wolff.

From delivery in March 1988 through to early 1989 *Argus* underwent a series of trials, intended to prove that the ship was fully capable of meeting her major role of providing shipborne training for helicopter pilots. From that time onwards the ship has been fully operational with a continuous programme of flying training.

In 1988 flying trials were conducted in a series of stages with the first being a comprehensive windspeed trial designed to gather data to correlate wind speed and direction at each helicopter spot on the flight deck with that recorded by the anemometers on the main mast. This trial demonstrated that the anemometers were sited in a region of turbulent air flow and were giving erratic readings. The authors mentioned that wind tunnel tests were conducted and with hindsight these should have been utilised to check airflow over the superstructure and around the mast. The problem was overcome by the Ministry designing and fitting new spurs at the top of the mast, so as to re-position the anemometers in undisturbed air flow.

Other stages of the flying trials involved different helicopter types being flown by experienced pilots and taking off and landing under all combinations of ship speed, wind speed, heading, etc. The extensive data gathered was then translated into the operating parameters to be used for pilot training. These trials also confirmed that the airflow across the flight deck in way of the helicopter spots nearest the superstructure could fluctuate significantly – so providing graded pilot training.

It is during flying operations that the Pacific 22 Rigid Inflatable is likely to be used as an emergency crash boat should a helicopter have to ditch. The Pacific is located on the starboard side of the aft island superstructure. The boat is some 13m above the waterline and lowered by a davit often with the ship still underway. Launching and recovery is made more complicated by the height above the water and the provision of a winch that has no inching facility. Initially the operator's winch control panel was placed inboard until H&W were persuaded to relocate it at the ship side so that the operator can see the boat at all times.

A ship motion trial was conducted which confirmed that the roll and pitch motions were close to predicted values so that the detailed work to design the ship stabilisation system and reduce excessive metacentric height was fully justified. However, the hull form remains that of a container ship with a bulbous bow and very flat stern sections combined with a twin skeg arrangement at the after end. For the original ship there is little doubt that this arrangement was selected to maximise internal cargo space. However in certain sea states, with a following sea, there is a tendency for stern slamming to occur and this type of motion is perhaps less satisfactory for pilots under training than could be provided in a newbuild vessel.

Though the ship has twin screws and a bow thruster, ship handling in high winds is difficult and this is a minus factor in respect of converting an existing ship. Increased accommodation was necessary and this could only be provided with an enlarged superstructure. However, the windage increased accordingly and in confined waters the Captain's task became more onerous. In opting to convert a ship and introduce a major role change then these aspects of ship motion and handling are ones which the 'owners/operators' have to recognise as not generally amenable to change.

Other trials proved the systems associated with replenishment at sea of fuel oil, water and solid stores. Trials of ventilation and air conditioning equipment were carried out in tropical conditions off West Africa and a sub-Arctic trial in the Baltic was abandoned due to unseasonal temperatures of above 0°C. Operation in the UK, as well as during the tropical trial, showed that operational compartments in the superstructure generate considerable heat, but that the air conditioning system arrangements lack sufficient flexibility to cool these compartments without feeding very cool air to other spaces. The system design is being examined to identify changes that could be introduced to overcome this problem.

The purchase of a foreign built vessel and then extensive conversion may give rise to the impression that all the machinery will have been replaced. With *Argus* this is not the case and much of the original main and auxiliary machinery has been retained and was overhauled. To date there have been a few incidents when spare parts have had to be obtained direct from Italy and this has resulted in delay to the ship's programme. It is a problem that may increase the longer the ship is in service.

Despite drawing attention to some of the problem areas I must make it clear that the Navy has a very large and capable training ship which is being operated efficiently by a relatively small crew. In a conversion, compromises are inevitable if a practical solution is to be achieved and for RFA *Argus* the conversion has proved to be a success because the ship is well equipped for her role.

K M Walsh and N A J Wells (Harland & Wolff plc) I would like to thank Mr Hart for his account of the vessel's Part IV trials and for highlighting in such detail the findings and shortcomings which have resulted from such a trials programme.

His comments with respect to the vessel's handling in confined waters and high winds are appreciated and must be accepted as a minus factor. The size, shape and position of the enlarged superstructure on *Argus* must influence both the airflow across the flight deck and the handling of the vessel. It is another area of compromise.

On the *Contender Bezant's* delivery voyage to Belfast from Bremerhaven, North through the North Sea, we experienced following gale conditions of F8/F9. The vessel was light with a GM of close to 8m and considerable stern slamming was evident at that time together with a vicious 'cork-screwing' motion.

The Italian origin of much of the vessel's original mechanical and electrical equipment was identified at an early stage in the project as an area of concern. The builders, as part of the contract, were required to survey totally all aspects of the hull and machinery so that the converted vessel was handed over with the Lloyd's Register survey clock at zero, so to speak.

The availability of pump and electrical spares is not good, particularly with respect to delivery. Delays were also experienced due to some complicated financial transactions with Italian banks.

There is no doubt that this problem will increase in the fullness of time and an obvious solution would be a phased replacement of the smaller pumps. It was in this area that the main difficulties lay.

P M Low (Shell Seatex) This project was imaginative in concept and demanded great imagination and innovation in its execution. It has been quite unique and I hope that we shall see further similar projects in future. The resulting vessel provides a most valuable training facility at a fraction of the cost of a purpose-built craft. As tax payers we are all very interested in seeing value for money in defence expenditure and I wonder if the authors could give some indication of the overall costs of this conversion relative to the costs of a newbuilding.

K M Walsh and N A J Wells (Harland & Wolff plc) The overall cost of the conversion is something which we are not in a position to discuss. Suffice it to say that todays (1990) cost for a repeat vessel would be in excess of £100M.

Compared to a 'near' equivalent naval vessel, eg a through-deck cruiser, this represents probably 25% of the newbuilding cost.

C G Loughran (Mobil Oil Company Ltd) May I thank the authors for a most interesting paper. One of my questions has already been answered, namely that the overall cost was only 25% of an equivalent naval vessel.

I have one observation and one question. My observation is that I find it incredible that original ship drawings were not available to Harland & Wolff during the conversion.

My question concerns the operation of the drain tanks that are brought into use when the hangar deck water deluge system is operational. I notice there are no freeing ports in the hull structure.

K M Walsh and N A J Wells (Harland & Wolff plc) A set of the original drawings came with the vessel at purchase. These included line plans, general arrangement and structural details etc, but unfortunately did not include 'as fitted' pipework and electrical details. The company approached the Italian yard with a view to obtaining these. The costs and timescales quoted for reproducing the necessary drawings were prohibitive. This was surprising as we were told that the systems drawings had been produced originally on CAD.

Hangar deck drain tanks are provided at four locations, ie at frames 35, 63, 94 and 142. These are sized to allow the deluge system to run for 10 min, in each of the areas, before a build up of water level is experienced on the hangar deck. The free surface effect from such a large area would be considerable.

The drain tanks are piped to the bilge system, and the 10 min period is sufficient to allow the pumps to be set up for discharging the spray water overboard.

R K Stevens (Royal Fleet Auxiliary Service) I sailed on RFA *Argus* from November 1988 to July 1989 as the Senior Engineer Officer (2nd Engineer Officer) and I would like to point out the position of the machinery control room (MCR) in relation to the three machinery spaces.

The combined MCR and NBCD HQ1 is situated on 04 deck for'd under the wheelhouse and some considerable distance from the machinery spaces, both for'd and aft.

During standby conditions, and working UMS, it was our policy to employ the Duty Engineer Officer in the aft main machinery space and myself (Senior Engineer Officer) in the MCR. The Marine Engineer Officer (Chief Engineer Officer) would be on the bridge.

This system enabled us to establish good communications with the aft machinery spaces and the switchboard room from the MCR. It also allowed the Duty Engineer Officer to be in position if an emergency situation arose, and time loss was eliminated in getting aft via the starboard walkway and the watertight doors.

K M Walsh and N A J Wells (Harland & Wolff plc) Mr Stevens has highlighted a problem recognised prior to the conversion. During the vessel's delivery voyage to Belfast I timed the journey from the MCR to the aft machinery space at something in the region of 3 min, using the side passages.

The WT bulkheads installed during the conversion extend to the ship's side of course and in the walkways WT doors had been fitted in these, thus making the journey slower. It is of great interest to hear details of the working arrangement you have developed to cope with this.

P M Low (Shell Seatex) It has been most valuable to have contributions to the discussion from the users of the vessel. Such feedback, quite naturally, focuses on any shortcomings and things which could be improved. It is nevertheless extremely valuable and yet is often the most difficult information for a shipbuilder to obtain.

I would like to offer my congratulations to Harland & Wolff for the success of this project and my thanks to the authors for giving us the opportunity of seeing the details of this conversion from the inside.