REPLENISHMENT AT SEA

BY

F. R. JONES, M.SC., C.ENG., M.I.MECH.E., R.C.N.C.
(Ship Department)

This article is based on a paper read by the author at the Commonwealth Engineer Officers' Conference held at Bath on 3rd/4th May 1979.

Changing Requirement

No doubt replenishment at sea (RAS) was practised by ancient mariners between their ships but the modern literature credits Captain Scott with the first public pronouncement on the subject: '. . . I think, moreover, that if you have groups of squadrons somewhat equal in load carrying power you require a means of coaling at sea which we have not hit upon.'

It is part of history however than in 1870 the Channel Squadron was delayed for a day to tranship to H.M.S. *Captain* 50 tons of coal from the bunkers of two other ships in open boats. From this point, we were set on an evolutionary pattern of development with methods of astern fuelling initially for coal and then oil becoming established practice and later the abeam methods commonly in use today.

This evolution has been heavily dependent on seamanship and, with the basic techniques established, development became a finely balanced amalgam of seamanship and technology. Today, this evolutionary tree has formed rather more branches with the changing scenes of operation and with Fleets becoming more dependent on replenishment. A step change in capability occurred at the start of World War II with the introduction of the automatic tensioning winch (ATW) with its Ward Leonard drive, and this has remained up to now the heart of replenishment capability.

It must be recognized that the ATW has some severe limitations for modern requirements. Operationally, the North Atlantic is the area of most interest and there nine days in twenty have sea states of 4 or less and nineteen days in twenty have sea states of 6 or less. Automatic tensioning winches only have the capability to RAS solids up to sea state 5 with any certainty of them arriving on deck in one piece, and then only provided a favourable course is adopted usually into seas perhaps 20° off the bow. For the future, such restrictions are regarded as unduly constraining and new equipments are being introduced with considerably improved capability. Predominantly this refers to the GEC Mk II RAS system although other contractors are improving winch designs.

New R.N. System

The GEC Mk II system has been designed against five primary objectives. These are:

(*a*) a minimum need for expertise or judgement from operators;
(*b*) to accommodate ship motions in sea state 6 without risk to equipment or operators;
(*c*) to have no requirement for special equipment onboard the receiving ship;
(*d*) to be powered and controlled by the supply ship;
(*e*) for fast transfer.

If any of these objectives are relaxed then a considerably simpler system would be possible.

The adopted system has been fully described in other literature and an article in Vol. 19, No. 1 of the *Journal of Naval Engineering* described the principles, but for completeness and in brief it consists of three hydraulically-driven winches two of which control a modified Housefall Rig and known as the A and B wires and the third winch carries the M wire which is tensioned between the ships and provides the necessary control signals of velocity, acceleration, and distance for the system. FIG. 1 shows a schematic arrangement of the system.

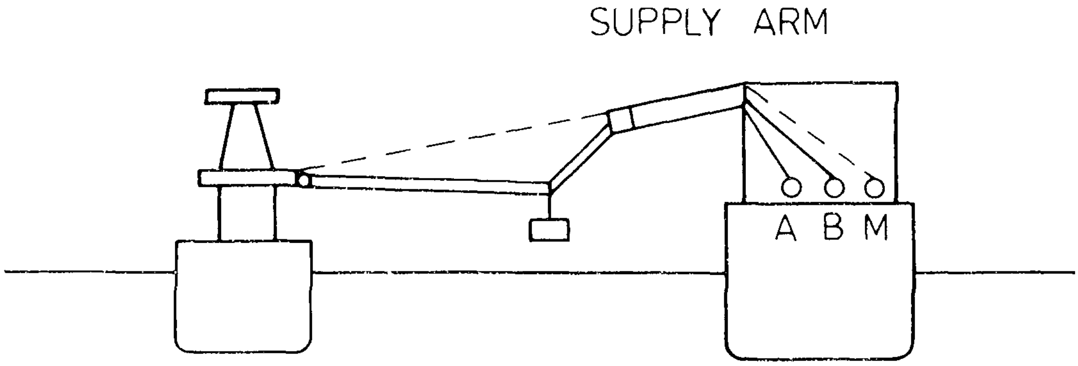

FIG. 1—SCHEMATIC DIAGRAM OF SYSTEM

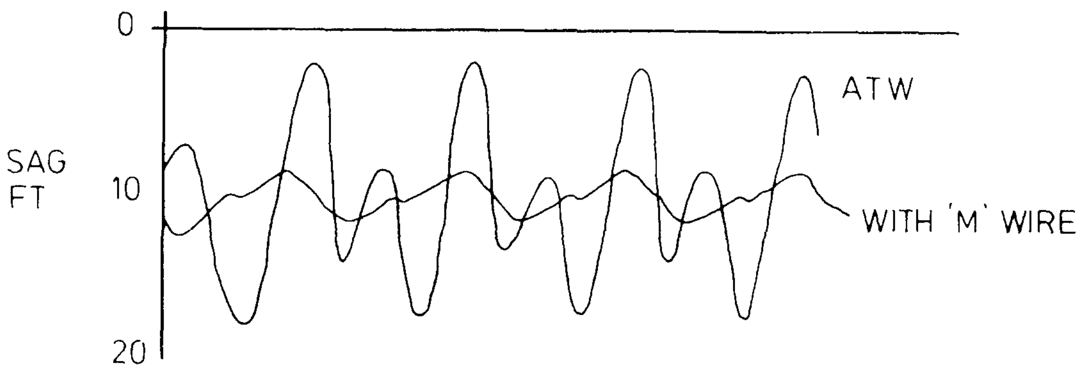

FIG. 2—ANALOGUE TRACE COMPARING ATW WITH MK II RAS SYSTEM—SAG

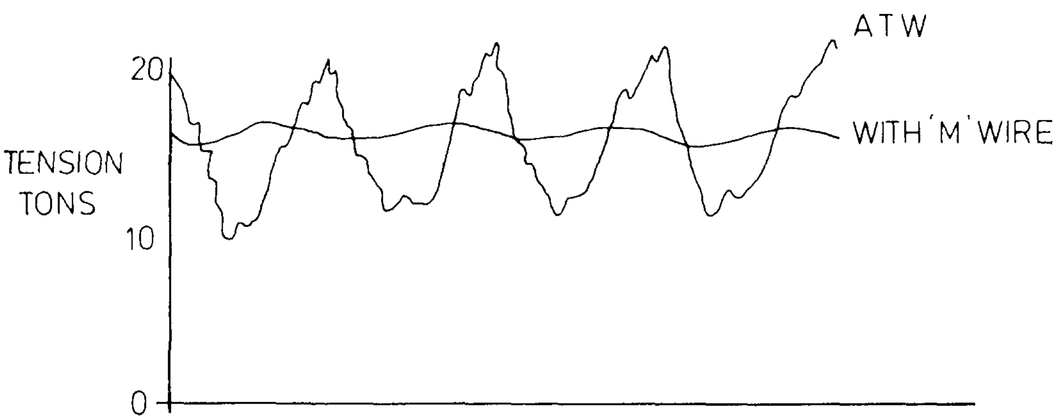

FIG. 3—ANALOGUE TRACE COMPARING ATW WITH MK II RAS SYSTEM—TENSION

Limitations of the Automatic Tensioning Winch

The analogue traces of an automatic tensioning winch and for a winch using the Mk II method of control with an M wire are shown in FIG. 2 and FIG. 3. These traces indicate the movement and fluctuating tensions in the two systems and show the marked improvement of the Mk II over the ATW. For missiles where delicate handling is important the advantages of such a system are obvious. These motions are from the movement of a single ship—the receiving ship— as given in TABLE I. The system has been designed to cope with sea state 6 using the induced motions for a frigate as the design criteria. Comparison with the main parameters of the conventional ATW is made in TABLE II; features to note are the low inertia of the system coupled into the winch drums, the similar steady-state horsepowers, and the very different peak value of horsepowers. The basic arrangement of the system is a power-pack-driven gearbox with hydraulic drive from the gearbox to the winch drums. This large storage of energy in the gearbox with the responsiveness of low inertia winches makes the system ideal for dealing with the problem of damping out the oscillating behaviour of a load in transit.

TABLE I—*Ship motions expressed as simple harmonic motions*

	Supply Ship		*Receiving Ship*	
Component	*Amplitude*	*Period (Secs)*	*Amplitude*	*Period (Secs)*
Roll	± 8°	15	± 10°	9
Pitch	± 2°	8	± 2°	6
Heave	± 10 ft	9	± 10 ft	7
Sheer	± 5 ft	14	± 5 ft	10
Yaw	± 1½°	16	± 1½°	8

TABLE II—*System parameters*

Parameter	*ATW*	*RAS Mk II*
Max. normal payload	2 tons	2 tons
Nominal rope tension		3 tons
Nominal ship separation		200 ft
Max. horiz. high point accln.	2.5 ft/s^2	12 ft/s^2
Max. vert. high point accln.		10 ft/s^2
Max. high point velocity	5 ft/s	20 ft/s
Inertia coupled to drum	55 000 lb.ft^2	4250 lb.ft^2
Steady-state horsepower	195	150
Peak horsepower	195	1200

Commissioning Problems

As can be expected from any system of this complexity, the commissioning problems have revealed inadequacies in the detail design which on a short time schedule have proven difficult to resolve. The major problem has been the interface equipment between the hydraulic system and the electronic controls. Specifically the position transducers were originally inadequate: they failed due to mechanical damage to the internal electrical components because of poor detail design and excess shock loads from the system. Once this problem had been dealt with, the rigs could be fully exercised (but only on an opportunity basis) and the usual crop of early problems occurred, such as leaking hydraulic joints and a number of minor failures that can best be described collectively as 'infant mortalities'. Although a prototype had been built, its design was changed as a result of a value analysis. The complexity of this new system warranted a further shore-based prototype and dynamic testing of the system before being committed in operational ships. That this was not done is an object lesson to all who contemplate short cuts when introducing new equipments into ships, and it largely accounts for the long period which elapsed before acceptance of the system. However, these problems have been resolved and the rigs have successfully performed over a six-week period in the Atlantic off the Continental Shelf in sea states up to and including 7 with ship motions equal to and in excess of the design criteria.

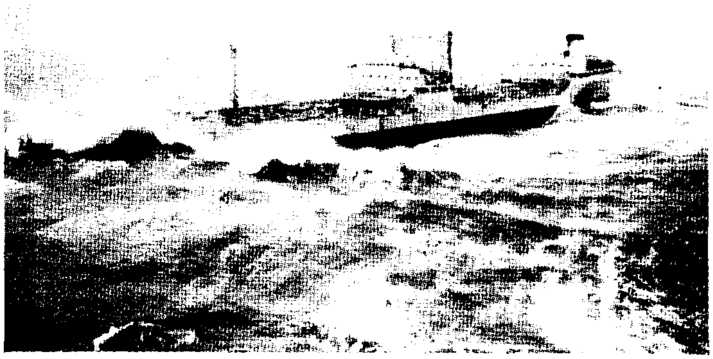

FIG. 4—R.F.A. 'PLUMLEAF' MAKING STERN APPROACH

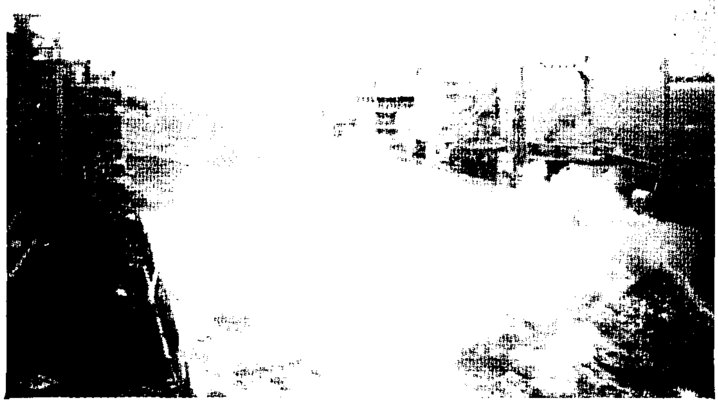

FIG. 5—R.F.A. 'REGENT'—TYPICAL SEA CONDITIONS

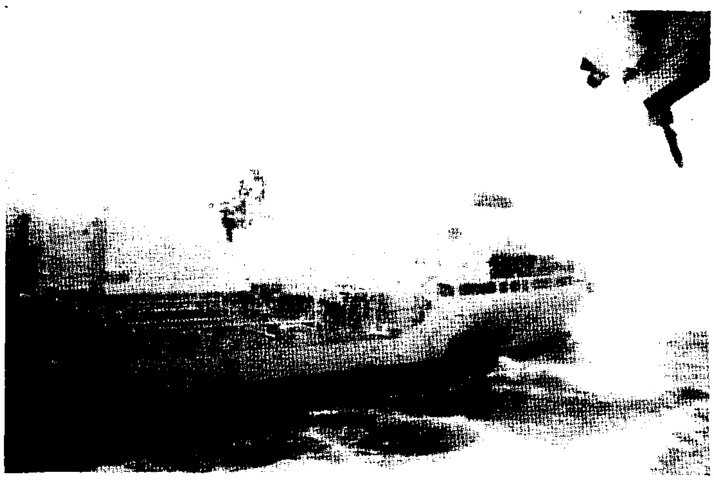

FIG. 6—'M' WIRE HAULING OVER THE FLOUNDER PLATE

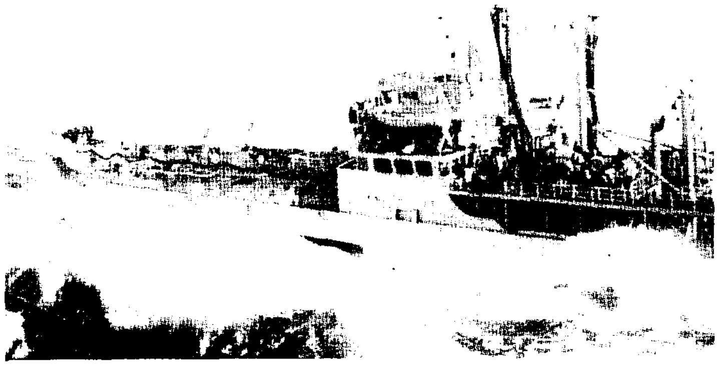

FIG. 7—R.F.A. 'PLUMLEAF'—ILLUSTRATION OF SHIP MOTION

Dedicated Trials Period with RAS Mk II

The dedicated trials period began in the new year of 1979 with a time operating the rig against a shore high point at Glen Douglas to resolve any outstanding problems and generally to tune the rig. After completion, this was followed by two roughly equal periods using R.F.A. *Plumleaf* with a fixed high point and R.F.A. *Regent* with a receiving arm. *Plumleaf* is shown in FIG. 4 making a stern approach in the roughest weather experienced—sea state 7 with supply and receiving ships both heading across the wave front. The ship motions induced on that day were in excess of the design criteria. FIG. 5 shows *Regent* in typical sea conditions which rarely dropped below state 5–6 throughout the whole period. During the final period, *Regent* with all problems identified and the rig and crews worked up, the rig transferred 36 loads per hour of two tons each. FIG. 6 shows the rigging operation with the 'M' wire hauling over the flounder plate and A/B wires. This is done completely by the supply ship once the 'M' wire messenger is snatched into the special block in the receiving ship. When the flounder plate arrives at the receiving ship, she has to make the necessary connection if a high point is used but, if a receiving arm is installed, this is achieved automatically. The rigging operation requires a maximum of three men on the receiving ship. FIG. 7 illustrates *Plumleaf*'s motion during the period.

During these trials, two incidents occurred, one due to a transducer failure subsequently identified as a manufacturing error—a bearing with excessive clearance—and the other a sheared 'M' wire. Both these incidents led to loss of the A/B wires. One further incident occurred due to difficulty in station-keeping which led to the wires spooling off the drums and not therefore attributable to the design of the RAS system.

FIG. 8 shows the assembly known as the 'Pod' unit, a large drum-like gearbox with hydraulic drives to the M, A, and B winches mounted in tandem on the upper face. In the ship, the whole of this assembly is housed on the upper deck.

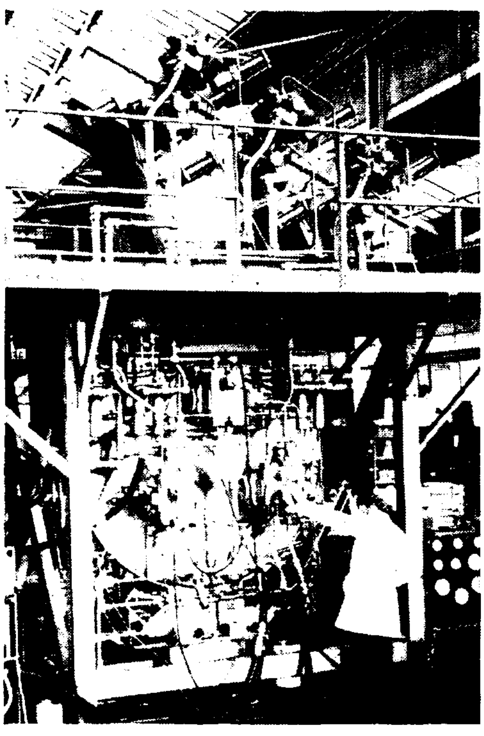

FIG. 8—THE POD UNIT

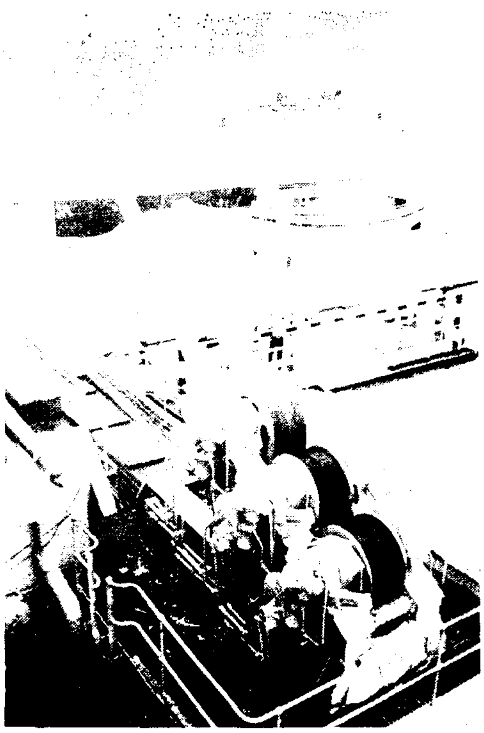

FIG. 9—THREE-DRUM WINCH ASSEMBLY

FIG. 10—SUPPLY ARM

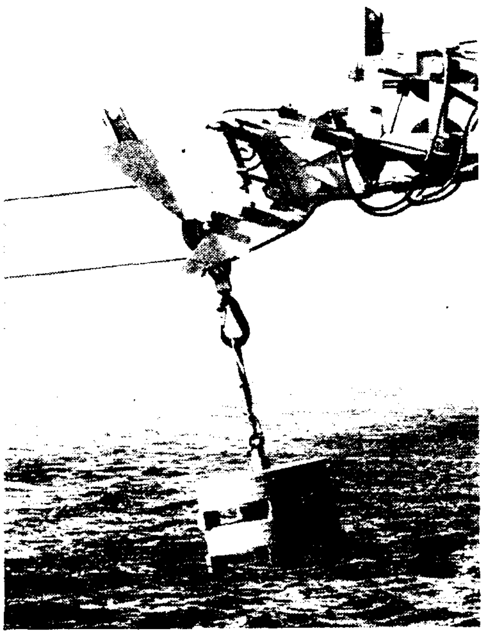

FIG. 11—SUPPLY HEAD

FIG. 12—SUPPLY HEAD

The complexity and mechanical design of the hydraulics is evident but this will be tidied up in later models. FIG. 9 shows the three-drum winch assembly viewed from starboard looking towards the supply arm and its frame. At the foot of the frame are the tension-measuring units for the A/B winches. The A/B wires pass up to the frame of the supply arm and down through the arm to the supply head shown in FIG. 10. The 'M' wire is shown in this illustration being the upper and thinnest of the wires. The supply arm contains hydraulically-operated latches to capture the load; it is able to move about its horizontal axis to align itself to the direction of the A/B wires as the loads are traversed, and also about its vertical axis to accommodate the station-keeping errors. The supply arm can be moved upwards and then elevated to the horizontal position (FIGS. 11 and 12) to provide the necessary height to clear intervening heaped seas between the supply and receiving ships.

The rig operator has control of the A/B wire tensions and the traverse speed. The traverse speed is automatically ramped down to a creep speed as it approaches the receiving ship and the supply ship. With the inhaul and outhaul lines as used in an ATW system absent, the load is closely controlled during all phases of its movement. The tendency for a load to move towards the deckedge when a conventional jackstay is slackened is eliminated.

Matching RAS System with Handling on Receiving Ship

This system is a major advance over any other in its capability to transfer loads in extreme sea states but the deck conditions in a small ship are now the limiting factor of any replenishment system. Having proved this capability, the realization of its potential must now rest on the design of simple handling systems in the receiving ships which must positively capture high-priority loads in extreme sea states and move them into their storage spaces. The R.N. with the receiving arms fitted to more recent designs has the rudiments of such a system but needs now to investigate how best to take the next step in the development of a complete replenishment system.