SUBMARINE WEAPON DISCHARGE SYSTEMS —THE WAY AHEAD

BY

J. L. HARVEY, TD, BSc, CEng, MIMechE
(*Sea Systems Controllerate, Portland*)

ABSTRACT

Submarine weapon discharge systems fitted to all current RN SSNs and SSBNs are of the air-operated water ram type. These have been replaced in the lastest RN SSK class by a new system whose prime mover is an Air Turbine Pump (ATP); other nations are also adopting this new approach. This article briefly describes both types of system and brings out the advantages of the ATP option. It concludes with a description of the UKATP which has just been developed for the MOD by Weir Pumps Ltd.

Introduction

From the mid 1960s until recently, all submarines built for the RN have had an air-operated water ram system installed for discharge weapons. However, in the late 1970s it was decided that the time had come to take a technological step forward for the Type 2400 UPHOLDER Class SSK and replace the slow, fairly noisy but reliable water ram system with a new type whose prime mover was an Air Turbine Pump (ATP). This new system had been installed in the latest US submarines and indeed the US was agreeable to selling ATPs to the RN for incorporation into the UPHOLDER Class. Other nations, notably the Australians and the Dutch, have opted for ATP-powered systems for their lastest submarines and the French are known to be interested in such a system for their next generation of SSN.

This articles explains the fundamentals of each system, draws out the advantages of the more recent ATP option, and concludes with a desription of the new UK ATP (normally written UKATP) that Weir Pumps Ltd have developed under contract for the MOD.

Note: the Current 'teething problems' being experienced by the Upholder weapon handling and discharge system are totally separate from and not associated in any way with the ATP principle of operations.

Requirement

If any weapon discharge system is to be successful in operation it must meet a number of fundamental requirements. These are:

(*a*) To discharge weapons at the correct weapon speed.

(*b*) To discharge weapons at all specified submarine speeds and depths.

(*c*) To be as quiet as possible in order to avoid detection.

(*d*) It must not interfere with own sonar operation.

(*e*) It must maintain submarine trim before, during and after discharge.

Both systems described below meet the criteria, but the degree to which they meet them varies. The ATP system does have a number of significant advantages and these will be covered in more detail later.

Water Ram Discharge System

A simplified layout of a water ram discharge system is shown in FIG. 1. Only one tube has been shown, but in practice each water ram would serve two or three torpedo tubes, each passing through a common water transfer tank (WTT). There would be two totally independent systems (port and starboard) in each submarine.

When the designated tube is ready, HP air at 138 bar is supplied to the forward end of the air ram cylinder, driving the piston and connected water ram aft. Water in the water ram cylinder is forced into the WTT and, via the flap valve, into the torpedo tube. This water is then directed by the tube liner to the rear of the torpedo tube and onto the tail of the weapon thus discharging it. The system then has to be 'recocked' by applying HP air to the aft end of the air ram cylinder to drive the piston assemblies and connecting shafts forward.

The system has no depth limitations as it is fully balanced; firing air pressure is constant for all depths. All firing air is contained within the submarine, with about 20 kg being used per discharge cycle.

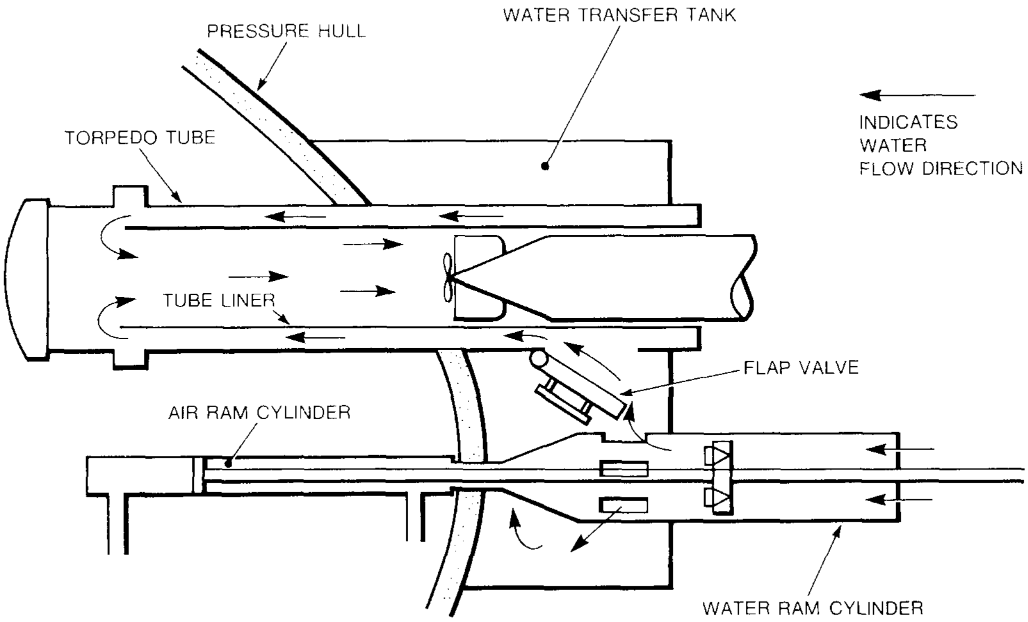

FIG. 1—WATER RAM DISCHARGE SYSTEM

The water ram cylinder must be at least equal in volume to the torpedo tube and has balance/connecting shafts protruding from each end. The whole assembly is thus very long and occupies a considerable amount of space both within the pressure hull and external to it. The unit has to be installed early in the submarine build and remains *in situ* for the life of the submarine.

Air Turbine Pump Discharge System

A simplified schematic diagram of the ATP discharge system is shown in FIG. 2. As with the water ram system each ATP will serve two or three torpedo tubes all passing through a common WTT and again there would be two independent systems (port and starboard) per submarine.

When the nominated tube is ready, HP air at 138 bar is admitted via a programmable firing valve (PFV) to the air turbine inlet. The ATP draws sea water from the inlet duct and forces it into the WTT and then through the slide valve ports into the torpedo tube behind the weapon thus discharging it. The

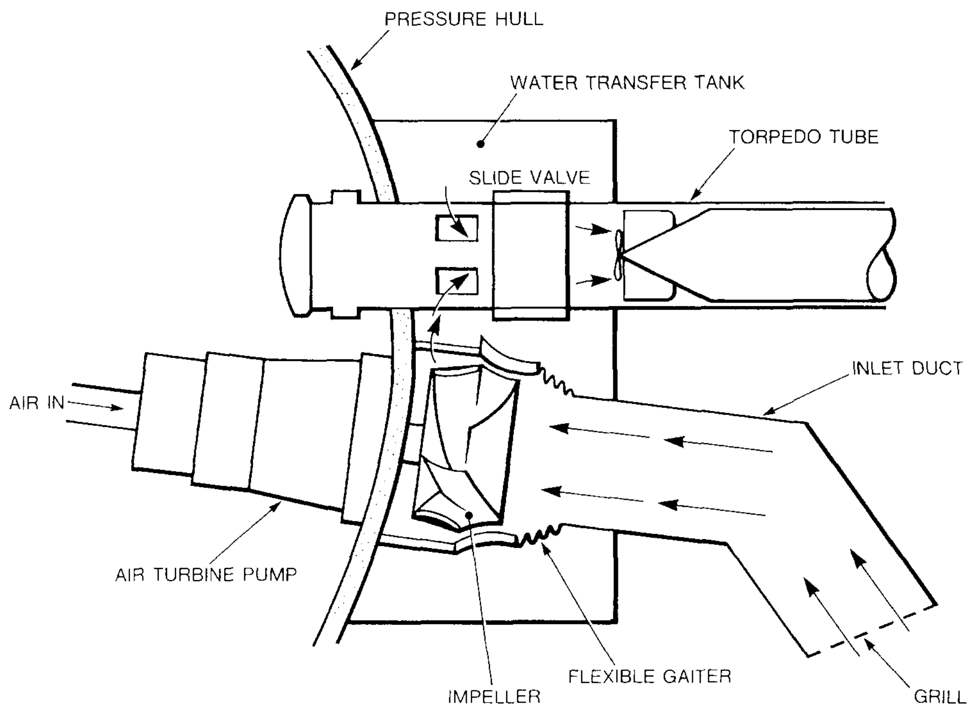

FIG. 2—AIR TURBINE PUMP DISCHARGE SYSTEM

whole firing cycle is very quick and the ATP generates about 2 MW of power during the process. It operates almost entirely in the transient mode for most discharges, reaching a maximum turbine speed of about 12 000 rev/min. The nominal flow rate for the pump is of the order of 37 000 gal/min.

The ATP is a continuous flow device and therefore when coupled with a programmable firing valve can be infinitely varied in its performance to use the mimimum energy consistent with a successful weapon launch for any given submarine operating conditions of depth and speed.

Its acoustic performance is depth-dependent, generally improving with increased depth because cavitation at the impeller is suppressed. However, its acoustic performance at all depths is considerably better than a water ram system. The chance of noise classification is also reduced as its nature is that of a short duration transient as opposed to a series of discreet classifiable tones over quite a protracted period.

During a typical discharge the ATP will use 9 to 14 kg of air, depending on the type of ATP fitted. All firing air is contained within the submarine.

The whole ATP, which weighs about 2 tonnes, is removed at refit for overhaul at the manufacturer's works. It is relatively easy to install/remove although it does require a clear shipping route and some special handling equipment as it is too large in diameter (approx 1 m) to fit between the weapon embarkation rails. It can be installed fairly late on in the submarine build programme.

Summary of Performance Comparison

The main advantage and limitations of each system have already been outlined in the brief description above. For clarity, these are summarized in TABLE I on page 308.

Clearly ATP systems have significant advantages over the water ram type and are considered to be the best way ahead in this field for the foreseeable future.

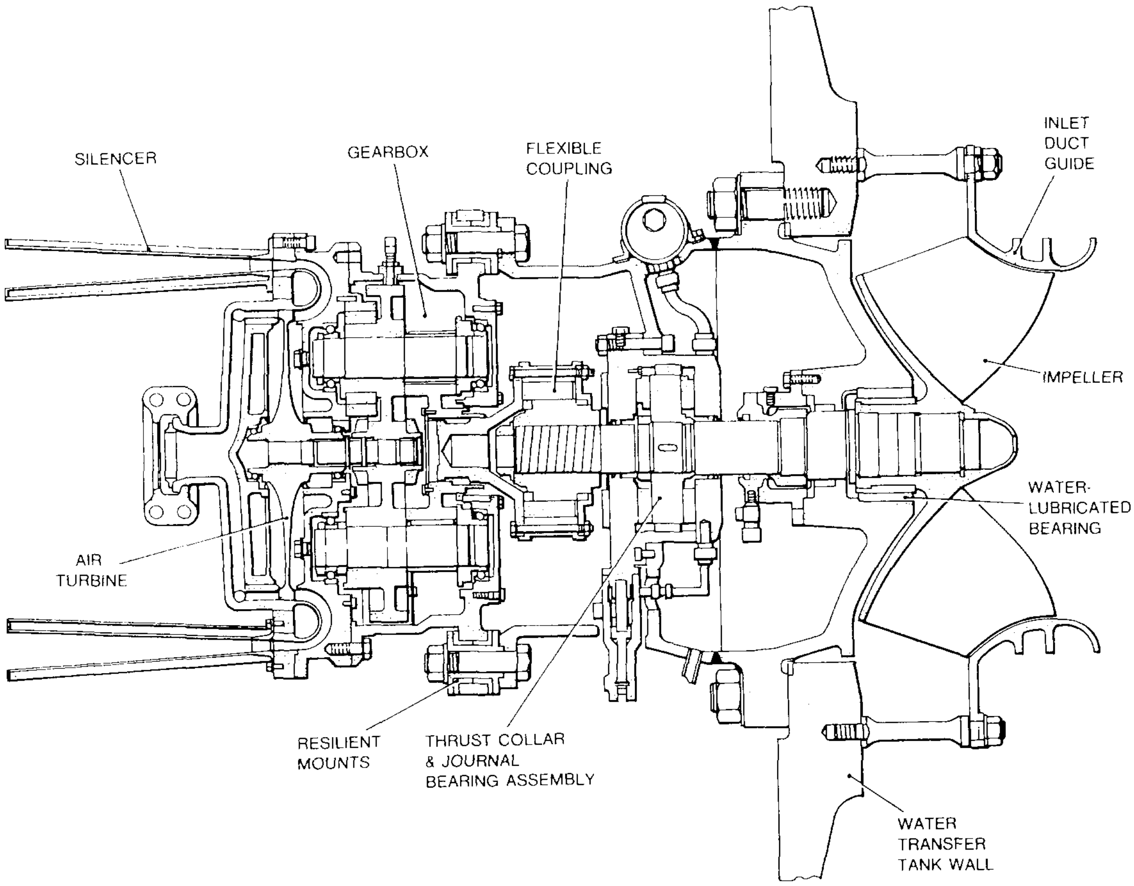

FIG. 3—THE UKATP

Description of the UKATP

The UKATP, which has been designed by Weir Pumps Ltd as a single integrated structure incorporating a pump, gearbox and air turbine, is shown in section in FIG. 3. The pump, which contains its own thrust bearing assembly and shaft sealing arrangements, has a mixed flow impeller which draws sea water from the inlet duct and discharges through a vaneless diffuser into the water transfer tank. The gearbox, which has been designed by David Brown Vehicle Transmissions Ltd, is a three layshaft type double reduction gearbox. The air turbine is a single stage axial flow unit with impulse blading designed for supersonic flow. High pressure air is supplied to the turbine from a pressurized air reservoir through a programmable firing valve to the turbine inlet. The air is then accelerated to supersonic velocity through the turbine nozzle ring towards the turbine rotor blades, imparting torque to the turbine rotor through momentum transfer. On exit from the turbine rotor, the exhaust air passes through a short annular diffuser type silencer.

One of the key considerations in the design of the UKATP was the minimizing of radiated structure-borne noise. Several design features were adopted specifically to meet this objective. The ATP drive pack, which comprises the gearbox and air turbine is mounted on resilient neoprene rubber anti-vibration mounts.

Drive is transmitted from the gearbox output shaft to the pump shaft through a Holset-type flexible coupling. Thus the drive pack is structurally isolated from the pump frame by rubber elements whose properties have been selected to maximize vibration attenuation.

Within the pump module, the hydraulic axial thrust from the impeller is carried by an oil-lubricated tilting pad white metal thrust bearing. The pump shaft is supported radially by a white metal segmental journal bearing running on the outer diameter of the thrust collar, and by a tungsten carbide coated water-lubricated journal bearing situated outboard of the mechanical seal on the hub of the impeller. The use of rolling element bearings, with their associated identifiable vibration signature, has therefore been totally avoided within the pump module.

The ATP has been designed for installation directly into a large diameter hull penetration in the submarine pressure dome. Particular attention has therefore been paid to ensuring that hull integrity can be maintained at all operating depths and also after high level shock. The pump cover has been subjected to a detailed finite element analysis to confirm that it can withstand specified shock levels. Similarly the main shaft seal, which is a balanced mechanical seal with ceramic sealing faces, has been designed following finite elements analysis of its behaviour under shock.

The Future

This article has highlighted the significant advantages that an ATP system has over the water ram. Also described has been the UKATP which, during its final development testing, has been shown to have the potential to be a world leader in its field. Now with the interest being shown by other nations in ATP systems, British Industry is poised to take advantage of possible overseas marketing opportunities.

Acknowledgement

The author would like to thank Weir Pumps Ltd of Glasgow for their description of the UKATP and indeed for achieving the successful design which has made this article possible.

TABLE I—*Comparison of Water Ram and Air Turbine Pump discharge systems*

	Water Ram	*ATP*
Discharge Cycle Duration (secs)	Long (>10)	Short (<5)
Radiated Noise	Series of Discrete Classifiable Tones	Short and Variable. Considerably Quieter Overall
Typical Air Usage for a Single Discharge (kg)	20	US 14, UK 9
Flexibility of Operation	Constant Swept Volume. Gives full Power Discharge Every Time	Continuous Flow. Discharge is Infinitely Variable Using a Microprocessor-Controlled PFV
Installation and Maintenance	Installed Early in Build. Difficult Alignment. Overhauled *in situ*	Late Installation. Easy to Install. Removable for Overhaul
Weight and Space	100%	50%