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Proceedings of ICONE10
10th International Conference on Nuclear Engineering
Arlington, VA, April 14-18, 2002

ICONE10-22572

# THE IRIS SPOOL-TYPE REACTOR COOLANT PUMP

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## ABSTRACT

IRIS (International Reactor Innovative and Secure) is a light water cooled, 335 MWe power reactor which is being designed by an international consortium as part of the US DOE NERI Program. IRIS features an integral reactor vessel that contains all the major reactor coolant system components including the reactor core, the coolant pumps, the steam generators and the pressurizer. This integral design approach eliminates the large coolant loop piping, and thus eliminates large loss-of-coolant accidents (LOCAs) as well as the individual component pressure vessels and supports. In addition, IRIS is being designed with a long life core and enhanced safety to address the requirements defined by the US DOE for Generation IV reactors. One of the innovative features of the IRIS design is the adoption of a reactor coolant pump (called "spool" pump) which is completely contained inside the reactor vessel. Background, status and future developments of the IRIS spool pump are presented in this paper.

Keywords: *IRIS, Reactor Coolant Pump, Spool pump, Canned motor pump, Generation IV, Integral reactor*

## INTRODUCTION

The Westinghouse Government Services Co., Electro-Mechanical Division with Westinghouse Electric Co. Science and Technology Department is assessing the feasibility of using a spool-type reactor coolant pump (RCP) that can be totally contained within the IRIS reactor vessel. This advanced reactor coolant pump (RCP) has been adopted as the reference for the IRIS reactor, with the backup design being the canned pump similar to the type used in AP600. The "spool type" pump that is envisioned for IRIS, is an extension of marine applications requiring high flow rates and low developed head. Similar applications are being developed for chemical plant applications.[1-3] In its simplest form, the spool type RCP motor and pump impeller consist of two concentric cylinders, where the outer ring is the stator and the inner ring is the rotor that carries high specific speed pump impellers. This pump has several advantages over typical RCP's that have the pump/impeller extending through a large opening in the pressure boundary with the motor extending outside. In the case of canned motor pumps, the motor casing becomes part of the pressure boundary and is typically flanged and seal welded to the mating pressure boundary surface. The spool type pump would be located entirely within the reactor vessel eliminating the need for the high pressure casing, large vessel openings and closure flanges; only small penetrations for the electrical power cables and for water cooling supply and return piping are required. Furthermore, the use of high temperature motor windings and bearing materials are being investigated in order to eliminate even the need for cooling water and the associated small piping connections. In addition to the above advantages deriving from its integral location, other advantages of the spool pump result from its geometric configuration which is amenable to provide medium inertia/coastdown, and flow run-out capability which will contribute to mitigate the consequences of LOFAs. Because of the low developed head, spool pumps have never been candidates for nuclear applications. The integral configuration, low pressure drop IRIS can accommodate these pumps and take advantage of these characteristics. The status of the IRIS spool-type RCP development, and an outline of on-going and future design efforts for its application to IRIS, are described below.

## DESIGN BACKGROUND

The Electro-Mechanical Division of the Westinghouse Government Services Co. (WEMD) has been designing, manufacturing, and testing canned motor pumps (one of its primary products) for both fossil and nuclear power generation service for over 50 years.

The critical nature of these applications demands high reliability, and quality. To date, WEMD has designed, manufactured, and delivered over 1700 canned motor pumps. Almost all of these units have operated without repair or maintenance over their life. These units were originally developed to meet the rigorous demands of circulating high-temperature, high-pressure, radioactive fluids in pressurized water nuclear reactor systems with zero leakage. Besides nuclear applications, these canned motor pumps (CMP) were found to be ideal for non-nuclear applications and were installed as fossil boiler circulating pumps for very high pressure and temperature applications with supercritical water. In the late 1960's, the division's experience in canned motor pumps was extended to the design of an external drive device for a US Navy deep submersible vehicle. The design requirements were challenging: develop a highly reliable motor/pump device that could work in seawater with no auxiliary support systems in an extreme pressure, temperature, and fluid environment. Throughout the 1970's and 1980's, canned motor pumps were further developed to meet even more stringent customer design requirements. In the mid 1980's, this technology, combined with the long history of canned motor pump design refinements, resulted in a fluid moving device called the Integral Motor/Propeller (IM/P)™, (see Figure 1), which is the fore-runner of today's spool type pump.

Figure 2 identifies the IM/P™ basic components. All of the primary canned motor pump components are present but they are reconfigured.

The first of two key items of the spool pump technology is the canned and hermetically sealed rotor and stator. As in the canned motor pump, they permit the motor to operate in literally any fluid without sealing problems. The other key item is the use of process fluid lubricated bearings which eliminate the need for rotating seals and a lubrication system.

A complete IM/P™ consists of a canned motor, comprised of the rotor and stator with the rotor winding surrounding the propeller, the bearings, and the frame and support structure. The motor can be either an induction or a synchronous unit, depending on size and power. The stator core is a laminated design with an application specific winding. The number of motor poles and the class of insulation

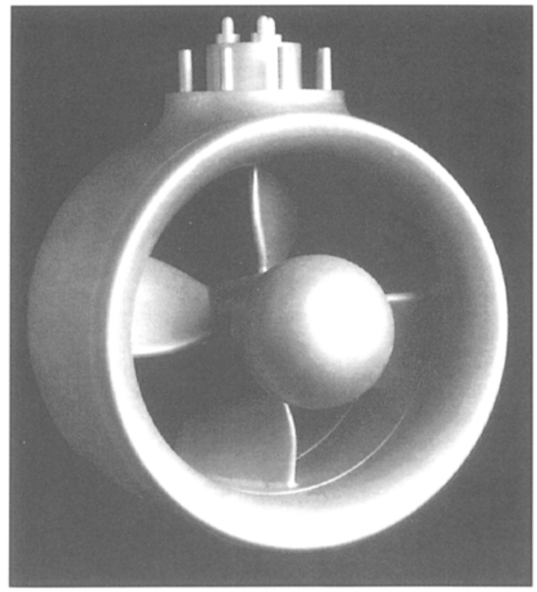

Figure 1 Westinghouse Electro-Mechanical Division IM/P™

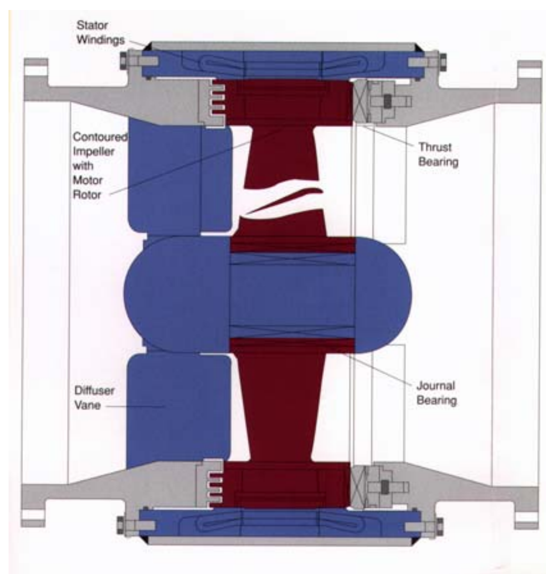


Figure 2 Westinghouse EMD IM/P Basic Components

depend on the pump operating requirements. The rotor, like the stator, is again hermetically sealed with a can. The rotor for an induction machine typically uses steel laminations and a standard copper squirrel cage winding; while the rotor for a synchronous machine typically uses a wound field with a brushless exciter for larger motors. Another alternative is a permanent magnet synchronous rotor. Power leads to the stator pass through the same type of hermetically sealed terminal glands used in the canned motor pumps.

The bearings, radial and thrust, can be located either on a stationary rotor hub or on the rotor rim in a hub-less arrangement, depending on the loads from the potential applications. The uniqueness of this reconfiguration can be best demonstrated by reviewing the benefits of the seal-less technology over current pumping and thrust generating technologies.

By integrating the electric motor with the impeller, the IM/P™ achieved a number of advantages over conventional marine propulsion devices that used a traditional propeller/shaft/motor arrangement. These same advantages apply to the use of a spool type pump in the IRIS reactor vessel, namely:

- Powerful, compact, lightweight (no high-pressure pump casing is needed)
- No dynamic mechanical pressure vessel penetrations (no shaft penetration through the pressure boundary with attendant seal injection and lubrication systems required)
- No large pressure vessel flanged connections (no penetration for the impeller/diffuser bowel, only an electrical penetration through the reactor vessel is required)
- Direct water cooled and lubricated bearings (no seal support system required)
- Direct water cooled motor (no water or air cooled cooling system)
- Rugged, reliable, easy to maintain (no seal inspection/replacement or periodic maintenance required)
- Reduced hydraulic and mechanical vibration (fully supported rotor, no cantilevered shaft/impeller/diffuser)
- Canned hermetically sealed rotor and stator (no periodic maintenance)

The IM/P™ design and deployment have provided WEMD with a large experience base on which to base the development of spool-type pumps for an application like IRIS. Designs from 32 hp to 350 hp have been built, and qualified in tests exceeding 10,000 hours, and have operated for years with almost no maintenance issues. Conceptual designs are being developed for units as large as 50,000 HP.

**"Spool type" Pumps**

Figure 3 illustrates an IM/P™ device used as a pump to provide axial flow with no piping penetrations. It is sealless, rugged, and is expected to be as highly reliable as any canned motor pump. This in-line concept eliminates the need for a large penetration in the pressure boundary for the impeller and power shaft; thus eliminating shaft seals and penetration seals. Concerns about fluid leaks are minimized since only a small penetration for power input is required.

Figure 4 shows the application of the in-line spool pump to the IRIS design conditions. The currently defined pump flow rate and developed head are:

- Pump Flow (1 of 8) 14065 gpm (588.4 kg/sec)
- Developed head 78.5 ft @ Thot (328°C)

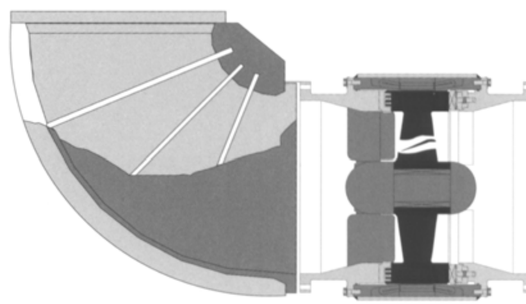

Figure 3 Westinghouse EMD Axial Flow Pump, Typical Industrial Application

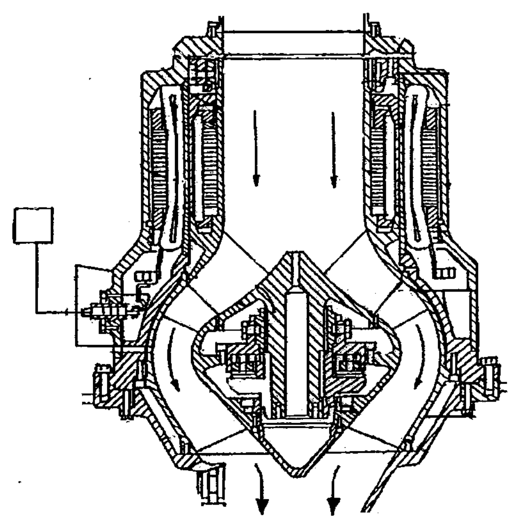

Figure 4 Example of Spool-type Pump with Mixed Flow Hydraulics

 

These parameters indicate that some mixed flow need to be provided. Thus the spool pump concept will be modified from a strict axial flow pump, by adding a bulbous section to provide radial flow and to generate the required developed head. One radial bearing will be below the motor portion, and the other bearings would be typically located in the hub. Further design work is necessary to finalize the size of the unit, when the system head and flow requirements are refined.

Because the pump is located in the hot fluid portion of the IRIS reactor vessel, the winding insulation system and the critical bearing design must be able to operate in a ~625°F (329.4°C) and ~2235 psig (15.5 MPa) water environment. WEMD has developed the technologies to meet these conditions, including a winding insulation system designed to operate in a 500°C environment, and a number of bearing configurations that have been shown by test to be acceptable. However, additional development is necessary as discussed in the next section.

### IRIS Spool-type Pump Development Efforts

In order to adapt the spool-type pump technology for application as the IRIS reactor coolant pump, several design development activities are required. This development effort includes the use of high temperature motor stator and rotor windings that can operate inside the IRIS reactor vessel without the need for external cooling water and cooling coils within the motor. Also, the material used for the hydrostatic, water lubricated bearings must be verified by test, since the IRIS water temperatures are somewhat higher than current bearing materials are designed for.

WEMD has designed and performed canned motor pump testing utilizing a 500°C (932°F) insulation and bearing system. The test report concludes that:

> "the motor has been successfully demonstrated; thereby, proving feasibility of eliminating plant auxiliary cooling for the main coolant pump and adding to plant reliability. The design utilized commercially available materials."

The report however recommends:

> "Additional tests should be performed in order to verify long term durability and reliability prior to acceptance of this motor for nuclear applications. Thermal cycling, starts and stops, and extended periods of run at full operating temperature are required."

A detailed plan, which includes vibration testing, thermal cycling, radiation aging, and material availability confirmation is being developed to finish the qualification effort.

The bearing materials used in the referenced testing above are fairly common hard/soft material couples. The bearing design included additional features to address the relative growth of the bearing surfaces to maintain the critical bearing clearance. Since the time of this testing, design advances on thermal bearing issues and hard on hard bearing designs have been developed and delivered. A study is being conducted to establish the best design and material selection fit for a spool pump application such as this.

## CONCLUSIONS

The IRIS RCP requirements are unique in that these 8 units will be located in the upper portion of the reactor vessel, above the steam generators. Thus, the units ambient temperature and pressure will be ~625°F and ~2235psig. WEMD has developed technologies that can accommodate these conditions. Although preliminary design to size and configure the unit has not yet been initiated, the feasibility of such a spool pump unit is considered possible with developed technologies for winding insulation materials, and other prior efforts on low viscosity fluid bearing designs. Methods of addressing mixed flow spool pumps, and additional inertia or NPSH requirements also exist.

WEMD IM/P™ marine technologies continue to operate successfully every day, and new applications continue. Spool pump applications in the petrochemical industry continue to be developed to resolve hazardous material release concerns. This new application of WEMD canned motor pump technologies to IRIS has the potential to successfully address one of the key IRIS requirements, i.e., to integrate the primary system inside the vessel with a minimum number of penetrations.

## ACKNOWLEDGEMENTS

The financial support of the IRIS program (NERI Grant DE-FG03-99SF21901) by the US DOE is gratefully acknowledged. Contributions by the IRIS consortium members, and specifically WEMD's support for the application of the subject pump technology for IRIS, were invaluable to the progress of the project.

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