SPECIALIZED EQUIPMENT FOR THE NUCLEAR AND HAZARDOUS ENVIRONMENT INDUSTRIES

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ABSTRACT

Since 1971 British Nuclear Fuels plc (BNFL) have owned and been responsible for the operation of the nuclear fuel reprocessing factory at Sellafield in West Cumbria. The Company provides a full fuel cycle service to the UK Generating Boards and is increasingly active on a World wide basis.

Radioactive discharges to the sea from Sellafield have always attracted much public attention and the Company have adopted a policy of significantly reducing them although they have always been well within the Authorized Limits.

As part of the policy BNFL completed the construction of a major new effluent treatment plant for treating pond purges in 1985. Over the first two and a half years operation this plant has achieved an overall availability of over 99%. A further major new plant is now being designed, for operation by the early 1990's, to treat a range of low active effluents and medium active concentrates, mainly for the removal of alpha activity.

To meet the very stringent limits for radiation exposure to operators and maintenance staff BNFL have developed a wide range of remotely maintainable equipment for use in these plants which in the case of the effluent plant already in operation has proved to be highly reliable.

BACKGROUND

British Nuclear Fuels plc (BNFL) provide a full nuclear fuel cycle service to the UK Generating Boards and many overseas customers in, for instance, Europe and Japan.

A major part of this service is the reprocessing of spent fuel which commenced at Sellafield in West Cumbria in 1952 when the first plant was commissioned. A second facility, brought on line in 1964 to reprocess uranium metal fuel from the UK civil magnox reactor program, will continue to operate until the early years of the next century. A plant to reprocess oxide fuel, the Thermal Oxide Reprocessing Plant (THORP), is being constructed for operation by 1992.

Prior to the reprocessing, fuel is stored in ponds. Storage and the subsequent reprocessing result in the generation of radioactive liquid effluents. The highly active liquors are stored in stainless steel tanks and will, with the commissioning of the Windscale Vitrification Plant (WVP), be converted into glass for long term storage and disposal. The medium active liquors are evaporated and stored to permit short lived isotopes to decay. These concentrates used to be discharged to sea, after storage, but since the early 1980's no such discharges have been made. Low active effluents are discharged to sea well within Authorized Limits.

For many years BNFL have adopted a policy of reducing the levels of activity discharged to sea and significant improvements have already been made. In 1985 the Site Ion Exchange Effluent Plant (SIXEP) was brought into operation to treat the purge waters from the ponds.

The storage of the medium active concentrates is only an interim measure and further treatment is not required. Additionally, one fifth of the low active effluent, not treated by SIXEP, accounts for the majority of the activity currently discharged to the sea. Treatment of this effluent would substantially reduce the total discharge of activity to sea and a new plant to remove alpha activity and some beta activity from this stream and from the stored concentrates is being designed. This plant, the Enhanced Actinide Removal Plant (EARP), is scheduled to be in operation by 1992.

It is largely through the design construction and operation of these plants which handle large volumes of effluent per day and operate under pressure that BNFL have developed a range of equipment which can be operated and maintained within very low radiation dose uptakes.

All of the equipment is supported by an extensive development program while much of it has operated for many years at very high reliability, over 99% plant availabilities have been achieved.

PLANT REQUIREMENTS

After careful consideration of the alternatives available BNFL decided that the most appropriate process for SIXEP was based on sand pressure filtration and ion exchange in pressurised columns while for EARP floc precipitation with ultrafiltration being used for the separation of solids and liquor was selected.

Both these processes must operate under pressure, typically up to ten bar, and require high flow rates, up to ten thousand cubic metres per day, thus requiring the use of pumps.

Process control, non routine operations and the provision of duplicated plant items all lead to the requirement to have effective isolation in the form of valves. In the case of a plant such as EARP there are items of plant eg. ultrafilters which will have an operating life less than the plant design life and hence require replacement.

For many years BNFL have been designing plants such that the average radiation exposure to the workforce was no greater than 5 mSv/y with a maximum exposure figure for any individual of no more than 15 mSv/y. These figures compare with the legislated maximum exposure of 50 mSv/y.

Recent draft recommendations suggest a maximum exposure of 15 mSv/y and hence, as can be seen, BNFL have been designing and have operational experience of equipment which more than meets the very latest proposed figures.

With the design requirements to limit average radiation exposure to 5 mSv/y since vessels, tanks and pipework are all fabricated to the very highest standards and require little or no maintenance the major areas of concern to the designer are areas such as the pumps, valves, ultrafilters, etc.

TYPICAL PROCESS

A typical process for one of the effluent plants would be ultrafiltration which is shown in Fig. 1. In this simple illustration the requirement is to provide an ultrafilter module and to circulate liquor through it at high pressure and high velocity. As cross flow filtration takes place new feed must also be pumped into the circuit at a similar pressure. Valves are required for the control of new feed to the circuit and for the control of retentate take off as well as those that would be required for non routine operations. The permeate flow from the circuit must be measured as a control parameter and to ensure that the process is working satisfactorily it is necessary to provide a gamma monitor in the retentate circuit.

Hence a small part of an overall process plant leads to the requirement for four different types of equipment all of which will require maintenance.

REMOTE MAINTENANCE CONCEPT

The same concept has been adopted by BNFL for a whole range of remotely maintainable plant items as shown in Fig. 2.

The essential feature of the system is that the plant item is housed below permanently installed concrete shielding and to provide access through which the parts requiring maintenance can be withdrawn into a shielded flask, as shown in Fig. 3, without exposure of the maintenance staff to any significant radiation levels. The main containment body requires no maintenance and is of the highest quality fabrication utilising castings or forgings, as appropriate, and is fully welded into the plant. The functional unit, valve or pump, etc. is sealed to the body below the level of a drain. The drain line is connected to a liquor detection system and serves two purposes; firstly it gives early indication of seal failure and secondly in the event of complete seal failure ensures that the upper containment body does not become pressurized. Hence there can be no danger of loss of containment above the concrete shield level into the working area or exposure of personnel to active liquors.

The length of the upper containment body can be made to suit any required plant cell layout.

PLANT CONFIGURATION

The adoption of this remote maintenance concept to valves, pumps, ultrafilters, flowmeters and gamma monitors allows the process requirement shown in Fig. 1 to be converted to a fully shielded plant configuration meeting the requirements of very low radiation exposure levels. A typical arrangement would be as shown in Fig. 4 which also shows the overall leak detection system.

The SIXEP plant incorporates 250 process valves and 16 pumps designed to this concept. The plant has operated at over 99% availability for three years and there have been no failures of either the valves or pumps.

REMOTELY MAINTAINABLE PUMP

A range of pumps to handle aqueous effluent at flows of up to 11,000m^3 per day and at pressures of up to 10 bar have been developed and are in service in SIXEP while a pump to handle ferric floc at a viscosity of 7 poise has been developed and will be used in EARP.

A general arrangement of the pump is shown in Fig. 5. The pump is a single stage centrifugal design and can be driven through a variable speed coupling to give a very high degree of process control.

The removable section has been designed for decontamination and maintenance in a fully shielded facility using remote manipulators. The bearings and seals which are the items most likely to require maintenance have been designed as modules for ease of removal and replacement.

In active environments when pumping from process tanks it is often essential that the pump suction line does not penetrate the tank wall. For this application the pump has been developed with a static priming device using a fluidic diode developed by BNFL.

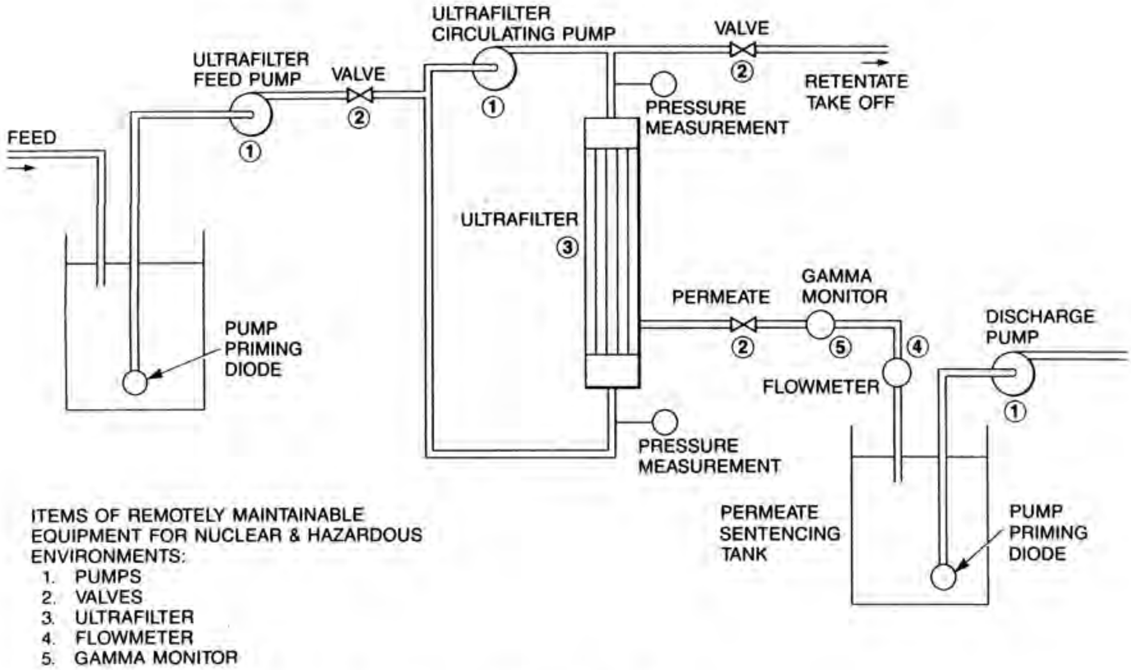

Fig. 1. Simplified Process Flow Diagram.

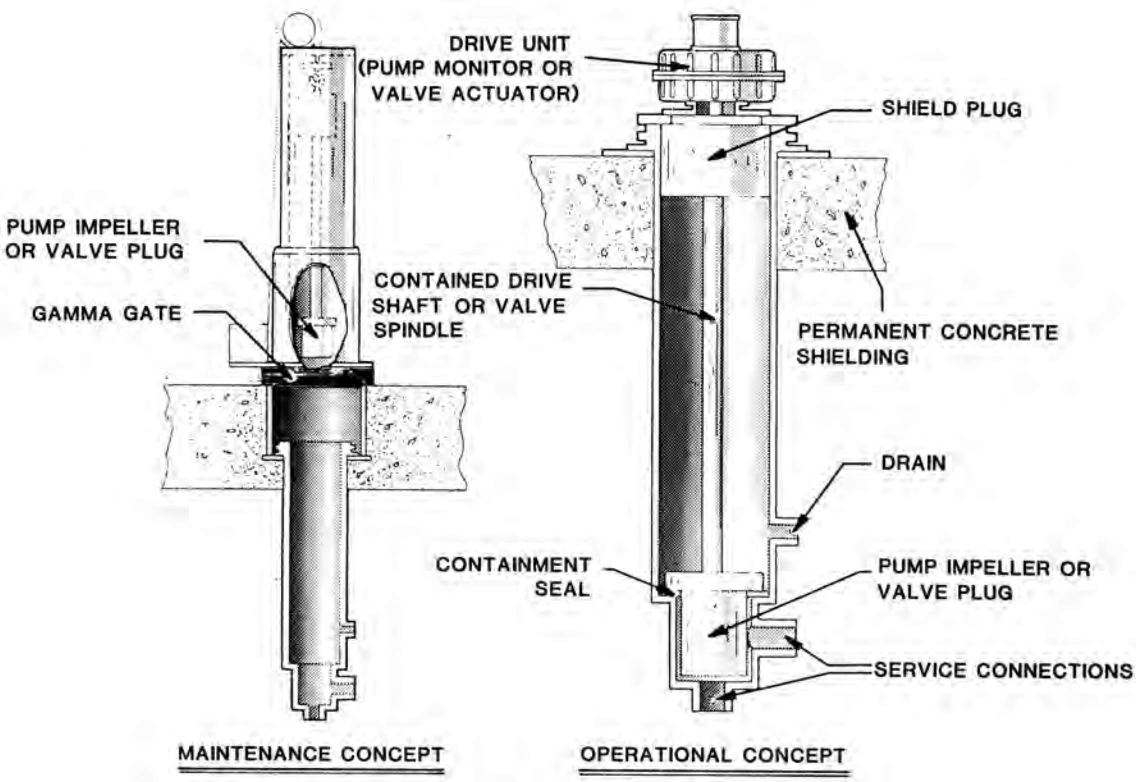

Fig. 2. Remote Maintenance Concept.

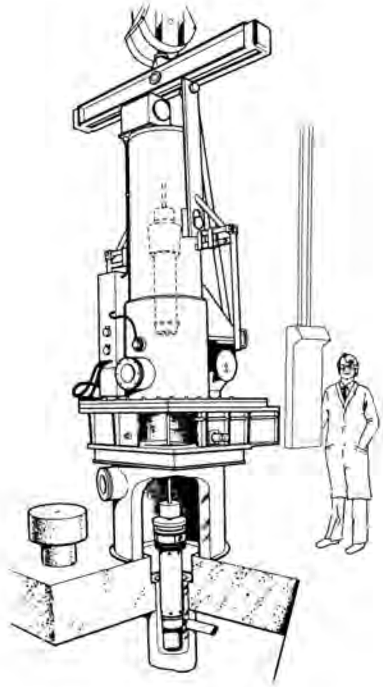

Fig. 3. Maintenance Flask.

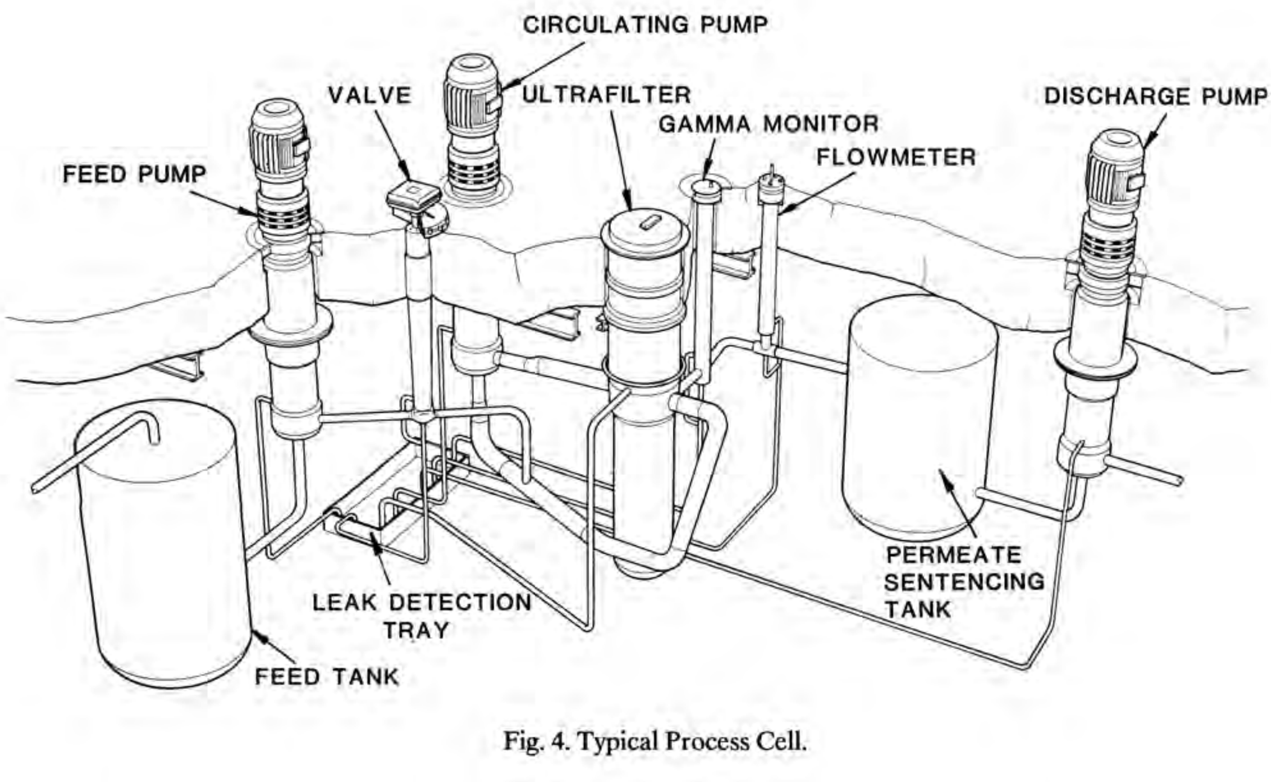

Fig. 4. Typical Process Cell.

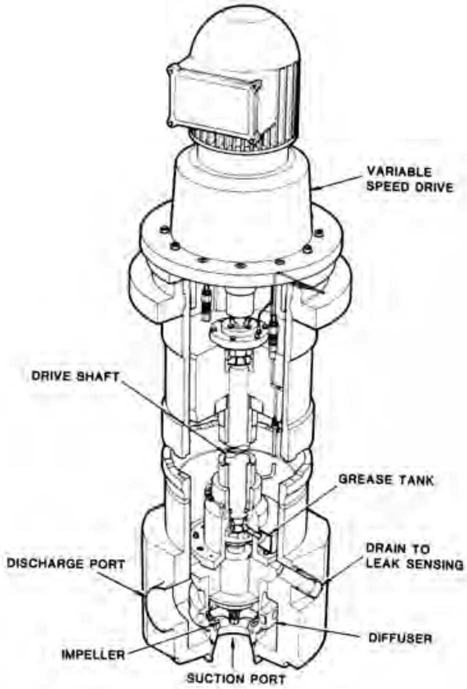

Fig. 5. Remotely Maintainable Pump.

REMOTELY MAINTAINABLE ULTRAFILTER

A remotely maintainable ultrafilter unit, as shown in Fig. 6, has been developed for use in the EARP project.

A single module has a filtration capacity of approximately 70m^3 per day and is made up of 750 membrane tubes with a length of 1.2m and an internal diameter of 6mm.

In EARP the units will be used for dewatering a ferric hydroxide floc from about 30 ppm iron to 100 gm per litre iron thus giving a solid phase suitable for direct encapsulation in cement and an aqueous phase suitable for discharge after monitoring. The development work has not only concentrated on ascertaining process operating conditions such as flow, pressure drop and decontamination factors but has also proved techniques for in service cleaning and out of service chemical cleaning.

The unit being adopted for initial operation of EARP uses graphite membranes coated internally with zirconium oxide. Other membranes have, however, been tested and the unit can be used for less onerous filtration duties in the range of one micron and upwards using commercially available membranes such as sintered stainless steel.

REMOTELY MAINTAINABLE VALVE

The remotely maintainable valve has been based on a well proven taper plug valve unit with a seal of ultra high molecular weight polythylene. The working part of the valve has been designed into a removable cartridge unit such that all adjustments can be carried out prior to installation of the valve into the plant, either initially or following remote maintenance.

Valves of either two or three way configuration at diameters of up to 200mm and pressure ratings of 15 bar are available and have proven their reliability over a number of years in SIXEP.

Fig. 7 shows a typical two way valve.

REMOTELY MAINTAINABLE GAMMA MONITOR

The SIXEP process application requires a high sensitivity on-line gamma monitor capable of detecting fault conditions and shutting the plant down. The application has been solved using a remotely maintainable unit as shown in Fig. 8.

The unit uses an intrusive germanium semi-conductor detector cooled by liquid nitrogen, Gamma photons are detected and analyzed by a multichannel analyzer which identifies the quantity of each nuclide present. The SIXEP application specifically looks for Caesium 137 but has been used operationally to detect other nuclides such as cobalt and rhuthenium.

Reliability and accuracy over a period of three years has proved to be exceptionally good due in part to the detailed development work carried out.

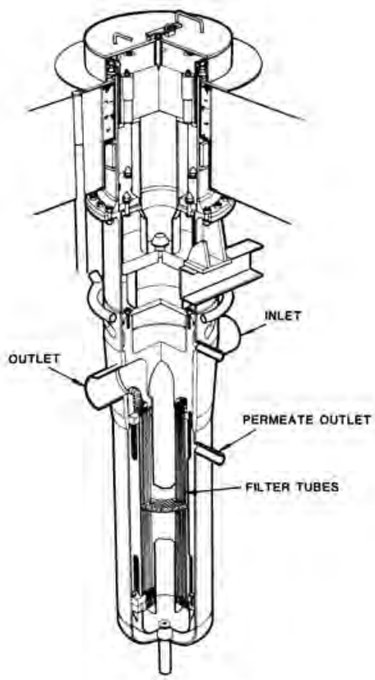

Fig. 6. Ultrafilter.

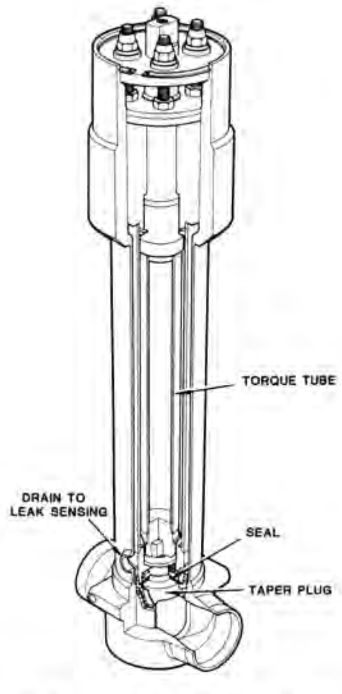

Fig. 7. Remotely Maintainable Valve.

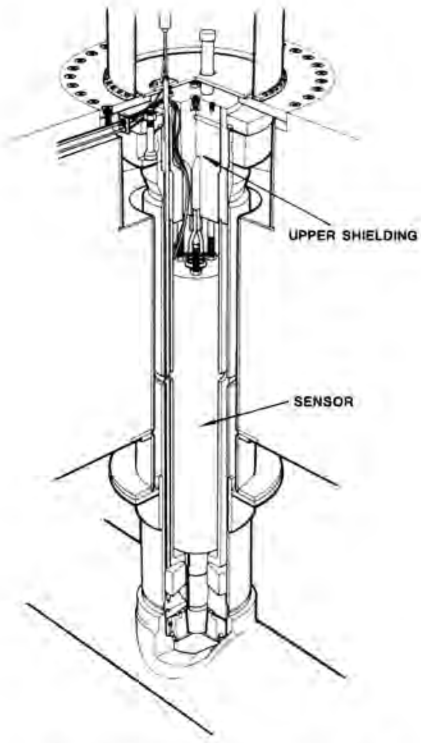

Fig. 8. On-Line Gamma Monitor.

REMOTELY MAINTAINABLE FLOWMETER

Figure 9 shows the remotely maintainable flowmeter developed for and used in SIXEP. It employs a relatively conventional turbine flowmeter measuring head. The SIXEP units measure flows of up to 12,000m^3 per day.

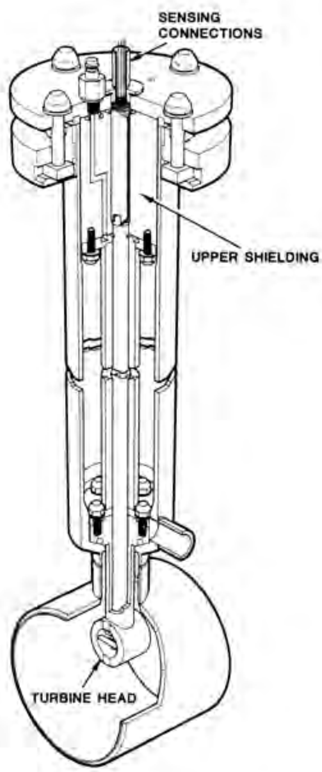

Fig. 9. Flowmeter.