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《Technical Note》

Design on SDS2 On-line Poison Concentration Monitoring in CANDU

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Abstract

At the reference plant(Wolsong unit No. 1) a manual poison sampling system is provided to periodically sample gadolinium from each tank and analyze it in the laboratory to provide assurance that adequate poison cocentration in each tank is maintained.

The AECB required a continuous, on-line monitoring system. On Wolsong unit No. 2, process piping adapter and new instrument loops added to the Liquid Injection Shutdown System(LISS) which is part of SDS2. The new instrument loops continuously monitor SDS2 poison conductivity and initiate an alarm when the poison concentration is too low.

1. Introduction

At the Wolsong unit No. 1 a manual poison sampling system is provided to periodically sample gadolinium from each tank and analyzes it in the laboratory to provide assurance that adequate poison concentration in each tank is maintained. The AECB now requires a continuous, on-line monitoring system. The manual sampling system is also provided for Wolsong unit No. 2 to supplement the on-line monitoring system.

As per this design change it is proposed to add a conductivity probe at the bottom of each poison tank to monitor the poison concentration on a continuous basis and alarm off-normal condition. This feature will reduce the frequency of manual sampling of gadolinium poison. Any major change in concentration can be confirmed by manual sampling.

Figure 1 is a schematic of Liquid Injection System used for Shutdown System No. 2.

2. Major Requirements

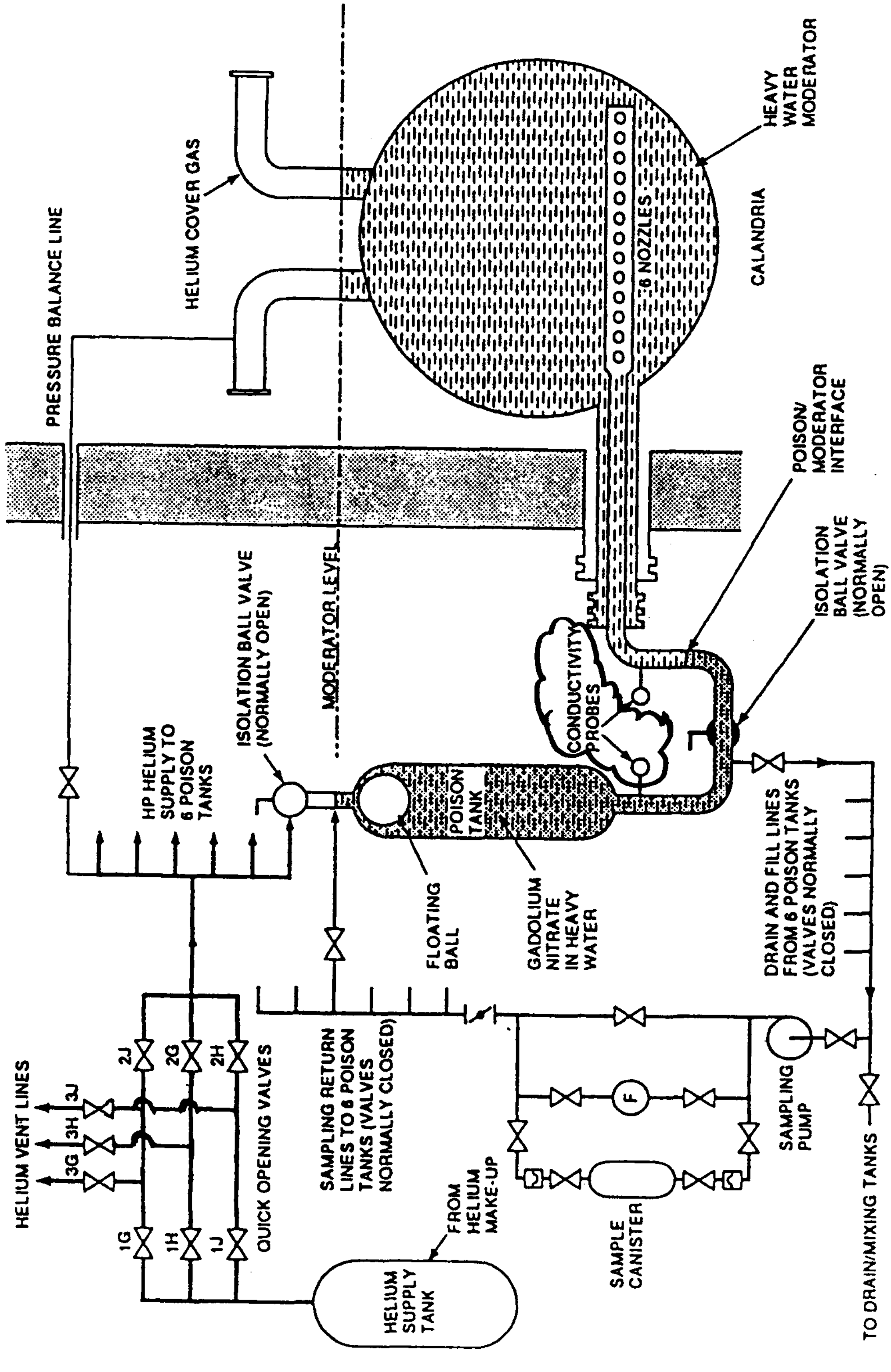
2.1. Licensing Requirements

Section 2. 7b of AECB Consultative Document C-8, "Requirements for Shutdown System for CANDU Nuclear Power Plant" requires that "As far as practicable all failures of shutdown system components which may interfere with proper functioning of the shutdown system shall be annunciated in the Main Control Room(MCR). "

2.2 Functional requirements

The following functional requirements provide clarification of licensing requirements specified Section 2.1 as they apply to this design change.

– All six Liquid Injection Shutdown System(LISS) injection lines(near the bottom of each poison tank) must be instrumented to monitor poison con-


PRESSURE BALANCE LINE
HELIUM COVER GAS
HEAVY WATER MODERATOR
6 NOZZLES
CALANDRIA
POISON/ MODERATOR INTERFACE
ISOLATION BALL VALVE (NORMALLY OPEN)
MODERATOR LEVEL
ISOLATION BALL VALVE (NORMALLY OPEN)
CONDUCTIVITY PROBES
HP HELIUM SUPPLY TO 6 POISON TANKS
POISON TANK
FLOATING BALL
GADOLIUM NITRATE IN HEAVY WATER
DRAIN AND FILL LINES FROM 6 POISON TANKS (VALVES NORMALLY CLOSED)
HELIUM VENT LINES
3J
3H
3G
2J
2G
2H
1G
1H
1J
QUICK OPENING VALVES
SAMPLING RETURN LINES TO 6 POISON TANKS (VALVES NORMALLY CLOSED)
F
SAMPLING PUMP
FROM HELIUM MAKE-UP
SAMPLE CANISTER
HELIUM SUPPLY TANK
TO DRAIN/MIXING TANKS

ductivity on a continuous basis.

- Each poison conductivity measurement must be available in the Main Control Room.
- Low poison concentrations must be annunciated in the Main Control Room.
- Poison concentration display in MCR is required only during normal operation. There is no requirement for displays after a seismic, LOCA or MSLB event.

3. Design Description

3.1. Poison Tank Conductivity Loops

The purpose of instrument loops 63470-C51 through-C56 is to measure the gadolinium concentration in the poison tank 3471-TK1 through-TK6 and, if the concentration falls below a certain value, to provide an alarm. The poison concentration is determined by measuring the poison conductivity and relating this measurement to poison concentration measurement in each tank is automatically adjusted for temperature variations and its effect on conductivity by a temperature compensator provided in conductivity probe.

The effect of temperature compensation is to reduce the spread in conductivity readings as a function of temperature for a given concentration of gadolinium. For example, without temperature compensation, 10℃ and 50℃ readings would be further away from the effective compensation temperature of 25℃.

The transmitter's range is 4 to 20mA, which is equivalent to the range of the meter scale's readings of 0~2000mS/m. The meter is part of the conductivity transmitter.

Each conductivity loop consists of the following ;

- A conductivity probe cell holder, mounted in pipe adapter on the 2-1/2 inch injection pipe just under the poison tank.
- A conductivity probe.
- A conductivity transmitter, including meter mounted on panel 63471-PL1351 in room R-402(Range 0-2000mS/m).
- A 4-20 mA analog output to transmitter the poison concentration indication for each tank to the station computer.
- A CRT and printout communication message in the MCR on detection of low concentration in any poison tank. The DCCs will activate digital outputs when the poison conductivity drops below a certain value, causing an annunciation and printout messages in the MCR.
- A widow alarm in the MCR(SDS2 panel 66110-PL20, for all six loops with a message "Poison Concentration Low". This window lights up if any one of the loops detects low concentration in the poison tanks. This alarm is provided by an alarm unit included in each conductivity transmitter. There is no displays/alarms in the SCA.

When the probe is dirty, the accuracy of the conductivity probe reading can vary by up to 12%. Therefore, the conductivity probes will require cleaning before insertion. After cleaning and wetting the probe, the accuracy of the conductivity reading is about 2%.

The temperature compensator is built into the conductivity probe housing. Thus the probe

follows the temperature of gadolinium solution in the injection pipe which is the same as that in the tank.

The operator can obtain the CRT readings of the poison concentration values remotely in the MCR. The DCC has been selected for display for these Group 2 system loops because the displays are only necessary during normal operations for the operator to verify results and take corrective actions. After a seismic event the reactor building may not be accessible for a while and so the operator will not be in a position to take corrective action.

Abnormal reading may caused by a drop in gadolinium concentration or by a failure of the conductivity probe or a malfunction of the conductivity transmitter. The operator can verify readings by sampling the poison from any tank using the manual position sampling system provided as Wolsong unit No. 1.

3.2 Poison Tank Ball Detection Instrumentation Loops

The purpose of the poison tank ball detection instrumentation loops is to provide an alarm in the main control room(MCR) when the ball in the poison tank is not in its normal position. The normal ball position is at the top of the tank due to the buoyancy of the ball, when the tank is full of liquid.

By raising or lowering the poison level in the tank the operator may verify that the ball is not stuck at the top of the tank and also verify transparency at the window fittings. A common window alarm in the MCR with the message "Liquid Injection System Trouble" lights up when the ball position in any poison tank is low.

The equipment consists of the following;

3.2.1 Ball Position Detection Instrumentation on Tanks

Two diametrically opposed "window" fittings are provided, about 330 mm down from the top face of the top flange of each poison tank.

Each "window" fitting contains a photo-transistor, LED light source, prism to split the light beam, and a lens. The light from the LED source in one fitting is beamed across the tank and, if the light beam is not obscured by the ball, if falls upon a photo-transistor in the second fitting.

3.2.2 Control Panel

A local control panel is mounted vertically in the Room R-402 using the attachment lugs provided around the perimeter of the cabinet. Wiring is provided between the position sensor and the local control panel, and between the local control panel and the MCR room.

The control panel contains the ball position detection circuits, test circuitry, and the alarm relays for the annunciation loops.

4. Hardware Requirements

The following is the description of hardware required for this design change.

4.1 Conductivity Probes

The conductivity probes in combination with the transmitters shall sense the conductivities of gadolinium in D_2O in the poison tanks.

The range of conductivities to be sensed shall be 0~ 2000mS/m. The normal poison concentration is 8000 ppm, of gadolinium which is equivalent to 1170mS/m at 35℃ (normal operating temperature). The probe constant shall be consistent with the requirement of the transmitter.

4.2 Conductivity Transmitters

The conductivity transmitter will provide :

- Means of excitation of conductivity probe
- Means of detecting a signal from the conductivity probe
- Means of providing output signals proportional to the signal received from conductivity probe. The output signals will be of the following items :
  - Indicating meter on the local panel calibrated in units of milliSiemens per meter
  - 4~20mA dc into 225ohm load. This signal is proportional to the conductivity range from 0 to 2000mS/m.
  - Means of automatically compensating for change in the fluid temperature range from 21 ℃ to 93 ℃.
  - The overall accuracy of measurement shall be ±0.5% F.S.

4.3 Conductivity Cell Holder

These are custom designed tee pieces constructed to nuclear class 1 specifications. The run inside diameter and wall thickness are compatible with a 2.2inch schedule 80pipe.

The branch portion is threaded to accommodate the conductivity probe with provision for sealing by means of an "O" ring.

The materials is type 304L stainless steel.

4.4 Equipment Qualification

4.4.1 Seismic Qualification

The cell holder will be part of the LISS piping and will be seismically qualified to DBE "A" as a piping component.

The conductivity probe will be seismically qualified to DBE "A" as it penetrates the LISS piping and is required to maintain the pressure boundary integrity.

4.4.2 Environmental Qualification

There is no requirement for operation of on-line poison concentration monitoring after a LOCA or MSLB. Therefore, field components(conductivity probed and transmitters) are not qualified for harsh environmental conditions.

5. Equipment Location

- Conductivity probe mounting(cell holder) and conductivity probes have been mounted on the 2-1/2 inch injection pipe lines(3471 L101D2-1/2 to 3471 L106D2-1/2) located under the poison tanks(3471-TK1 to -TK6).
- Conductivity transmitters(63470-CT51 to -CT56) have been mounted on existing panel 63470 -PL1351 located in the Room R-402.
  This panel(63470-PL1351) is also equipped with the loop 63470-C31 to-C36 injection line conductivity transmitters(63470-CT31 to -CT36).
- Six relays located in panel 68320-PL139 in SCA have been required for annunciation.
  Spare relays are available in the panel. Six relays located in buffer relay panel 68020-PL231 in CER have been used for interface with DCC and MCR panel annunciator.
- An additional window is required SDS2 MCR panel 66100-PL2 for annunciation of low poison conductivity. Spare window are available on PL2.

6. Comparison with the design for Wolsong 1 to Wolsong Unit No. 2

–Increased Availability

The continuous, on-line conductivity measurements will eliminate SDS2 unavailability due to insufficient poison concentration. Wolsong 1 can accomplish this only by intermittent, manual sampling.

–Greater Redundancy

The operator will have available two methods for determining poison conductivity measurements for comparison purposes.

–Improved Human Factor Engineering

The availability of conductivity measurements in the MCR will allow the operator to anticipate problems before any alarms are activated. Wolsong 1 has no poison conductivity measurement display in the MCR.

7. Conclusion

This paper described the detail design description of the control and instrumentation designed for the actual project(Wolsong 2).

For Wolsong unit No. 2, SDS2 On-line Poison Concentration Monitoring System has been designed to improve taking a sample by periodically for increased availability. Dilution of gadolinium solution contained within the poison injection tanks is potential contributor to SDS2 unavailability. The upgraded system provides continuous monitoring of poison concentration which effectively eliminates SDS2 unavailability contributions arising from this source.

The conductivity loops provide direct inputs to the dedicated SDS2 monitoring system or the station annunciation system and provide the operator with immediate indication of LISS poison concentration anomalies.

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