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《Technical Note》

Design of Improved Detection Instrumentation for the Annulus Gas System for Wolsong 2

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Abstract

The improved and advanced Annulus Gas System(AGS) has been developed for Wolsong 2 to satisfy the requirements of the regulatory body.

The Atomic Energy Control Board(AECB) required a shorter detection time following a small leak from a pressure tube and/or calandria tube. This paper describes licensing requirements, functional requirements and detail design description for the AGS.

The Wolsong unit No. 1 AGS was designed to operate as a stagnant system normally requiring only pressure regulation and having provisions for purging.

The improved AGS involves the adoption of gas recirculation in AGS, duplication of dew point indicators with additional instrumentation and sampling provisions to prompt operator action. The improved system operates in the recirculation mode with continuous dew point measurement for leak detection.

An AGS with improved detection instrumentation is provided.

1. Introduction

The Annulus Gas System(AGS) provides a dry carbon dioxide atmosphere in the channel annuli between the pressure tubes and calandria tubes. The gas acts as a thermal barrier, restricting heat transfer from the primary coolant to the moderator. Gap of annulus gas is shown in Figure 1. A dry, relatively inert gas is used for prevention of corrosion to fuel channel components. The system is designed to detect leakage into the annuli from pressure tubes or calandria tubes. The system maintains a positive pressure in the annuli under normal operating conditions.

The Wolsong unit No. 1 AGS was designed to operate as a stagnant system normally requiring only pressure regulation and having provisions for purging and detecting the moisture using a single moisture sensing element(beetle). Figure 2 is a schematic of the proposed Wolsong unit No. 1 AGS.

The Wolsong unit No. 2 recirculating AGS has been designed to improve its ability to monitor pressure, purge humidity and moisture content of the annulus gas.

High and low pressure, high temperature, high humidity and low flow of the AGS are alarmed in the

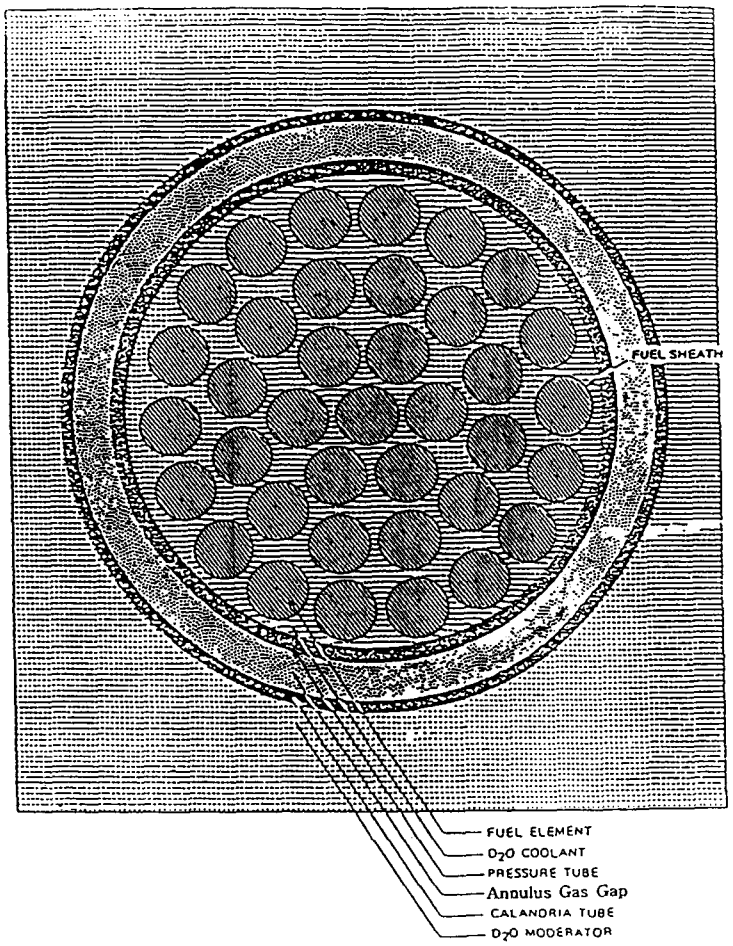

Fig. 1. Gap of Annulus Gas

MCR for operator's action.

2. Major Requirements

2.1. Licensing Requirements

During the process of issuing the the Wolsong unit No. 2 statement of Licensability the AECB stated that the AGS design should be improved such that the detection time is 3 to 4 times shorter than the system originally designed for the reference CANDU 6 Plant(Ontario Hydro Station).

2.2. Functional Requirement

To meet the above licensing requirement, the annulus gas system is to be designed to provide means for recirculating the annulus gas. The AGS design shall meet the following functional requirements:

- To promptly detect moisture in AGS as an advanced indicator of a pressure tube and/or calandria tube leak. The detection of a potentially serious nature of leak should be achieved within four hours from the start of the leak.
- To provide reliable method for on-line dew poin

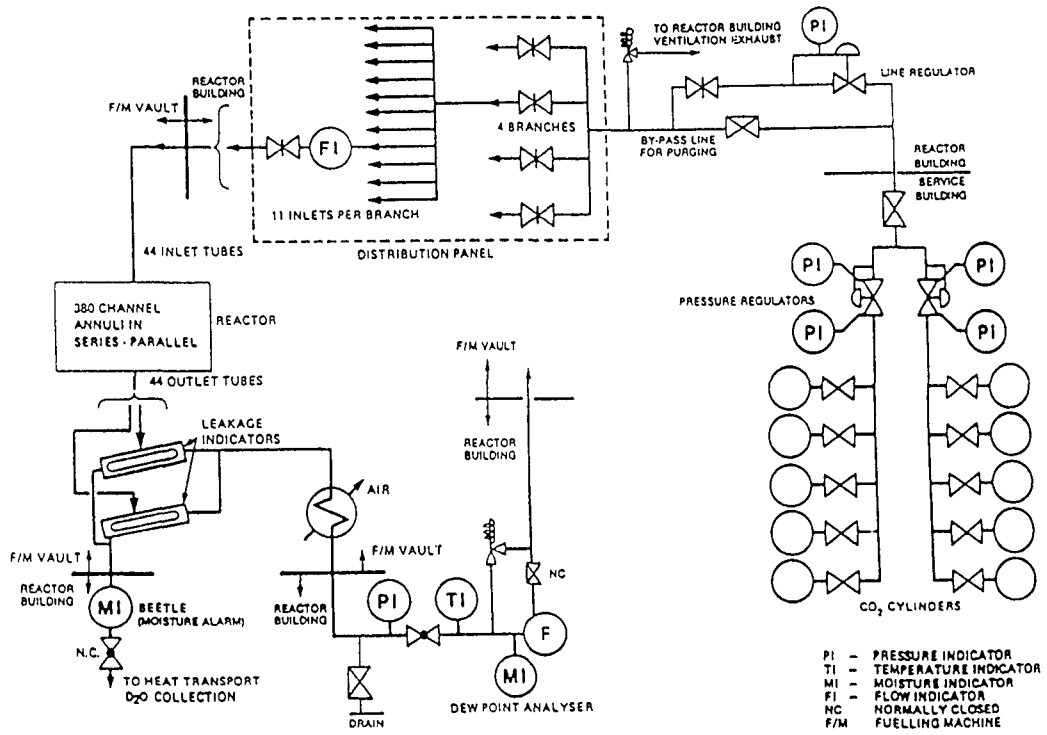

Fig. 2. Schematic of the Wolsong 1 Annulus Gas System

t measurement.

- To provide a chemically controlled medium in the annuli thus maintaining the

protective oxide layer on the outside surface of the pressure tube.

3. AGS Design Description

Each reactor has 380 channels arranged in a lattice. There are 22 vertical rows, containing 6 to 22 channels per row. The channel annuli are connected in a series-parallel arrangement. In each vertical row, alternate channel annuli are connected in series. Each row has two inlet connections, in parallel, to the top two channel annuli and two outlet connections, in parallel, from the bottom two channel annuli. The 44 inlets are connected in parallel, to the recirculating gas supply system and 44 outlets are connected, in parallel, to the drain and the suction of the recirculating compressors.

The 44 outlet tubes are connected to two visual leakage flow indicators. The drains from the indicators are connected to a D_2O leakage collection tank and contain two moisture sensing elements(beetles). The vents from the indicators are connected to an air-to-gas heat exchanger which cools the discharge before sampling. The CO_2 gas is further supplied to the suction of recirculating compressors. Two hygrometers for dew point measurement with an indication and an alarm in the Main Control Room(MCR) on high dew point measurement are provided. An alarm is also provided in the control room on high rate-of-rise of dew point in the AGS.

To permit gas sampling for improved chemistry control and leak location capability, the provisions for cold finger sampler and sample canisters are provided.

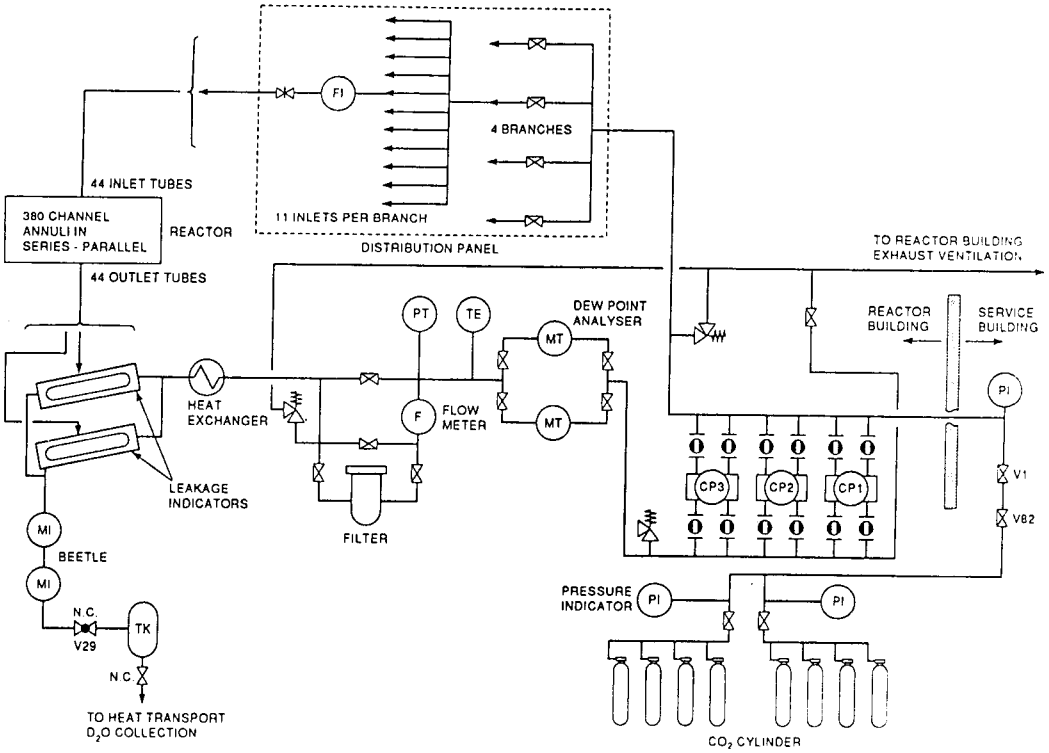

Fig. 3. Schematic of the Wolsong 2 Annulus Gas System

The system pressure and temperature are monitored and displayed in the control room on demand and high and low pressure and high temperature are annunciated. All other measurements and all of the system valves are in normally accessible areas of the plant.

The flow indicators are accessible during operation. The system is protected against overpressure by the relief valves and the small-bore tubing restricts pressure rise in adjacent annuli in the event of failure of a fuel channel pressure tube.

The description of the instrumentation for control and operation of the annulus gas system is given below. Figure 3 is a schematic of the proposed Wolsong unit No. 2 Annulus Gas System.

3. 1 Flow Measurements

3.1.1 Carbon Dioxide Inlet Flow Measurement

Forty-four inline variable area flowmeters, each with an integral needle valve on the outlet, are used to indicate the flow through the annuli during purging and recirculation.

3.1.2 Carbon Dioxide Outlet Flow Measurement

One flow transmitter with an integral on line is located on the outlet side of the Filter.

The flow indicating transmitter's 4 to 20 mA output is connected in series with the 225 ohm resister which provides a 0.9 to 4.5 volt signal to a computer analog input on plant control computers, DCC-X and DCC-Y.

CRT display and trend printout are provided in the MCR. Low and very low flow alarms are also provided in the MCR.

3.1.3 Carbon Dioxide Make-up Flow Measurement

A variable area flowmeter measures and locally indicates the CO_2 make-up flow rate.

An infrared LED optical photo sensor alarm detects the passage of a flowmeter measuring float within a glass metering tube. The optical sensor for the flow switch is attached directly to the metering tube of the flow indication. When the measuring float rises above the setpoint, a relay contact in the optical sensor will open the latch and provide an alarm in MCR via DCC-X and DCC-Y.

3.2 Pressure Measurement

A pressure transmitter measures the pressure in the outlet gas line. The pressure

measurement is available for display on operator demand. A high pressure indicates either a probable leak from the pressure tube and/or calandria tube into the annulus or a supply gas regulation failures.

A low system pressure indicates a probable large leak from the piping system

3.3 Temperature Measurement

Temperature loop is provided to monitor the gas temperature during purging.

The computer generates a CRT display of the measured temperature on operator demand and annunciates a high temperature alarms when the temperature exceeds

setpoint. An alarm indicates that the gas is too hot.

3.4 Carbon Dioxide Dew Point Measurement

To detect D_2O leaks in either calandria tubes or pressure tubes, dew point monitors are provided, to measure the dew point of the CO_2 gas downstream of these tubes.

Two monitors are provided that are connected in parallel for redundancy.

Two dew point sensors sense humidity in two parallel lines. Parallel lines are selected so that one dew point sensor is always in line when the other is valved out for maintenance. The sensors are installed on branch lines to reduce system pressure drop. When the dew point rate-of-rise is more than the fixed setpoint, dew point rate-of-rise high and very high are annunciated in the MCR(see Section 4.1, Program Specification).

3.5 Level Measurement

A level transmitter measures water level in drain tank of the AGS.

The transmitter's high pressure port is connected to the bottom of the tank and its low pressure port is connected to the top of the tank. When the level exceeds setpoints, the high and very high level are annunciated in the MCR.

The drain tank fill-up rate high alarm also occurs if the rate exceeds setpoint.

The fill-up rate is determined by the DCC based on level transmitter inputs.

The drain tank level is available for display on operator's demand on the CRT

(see Section 4.2, Program Specification).

3.6 Leak Detection

Two beetle moisture detection elements located in the process lines monitor the presence of D_2O liquid in drain line. When the liquid collects in the drain line, an alarm is annunciated in the MCR, signifying there is a leak in the annulus gas system.

3.7 Carbon Dioxide Compressor Control

The CO_2 compressors are controlled by handswitches in the MCR. If the running compressor fails, the very low flow alarm will alert the operator to turn on

the standby compressors.

4. Program Specification

This program specification serves as a guide to software programmer to prepare the Plant Control Computer, DCC software for the AGS.

Each Computer Analog Input signal is automatically checked for rationality by the DCC, i. e, the signal is checked to see if it lies in the allowable, or rational range(0~5.0 Volt). The irrational analog input due to power supply or transmitter failure, etc. , shall be alarmed by the CRT and a message shall be printed out.

If both dew point readings are rational, compare the two rational measurement.

If they are more than irrational setpoint apart, provide CRT and printout message indicating the discrepancy

If one or both readings are irrational, do not compare.

4.1 Functional Description

One of the functions of the annulus gas system is to detect pressure tube and calandria tube leaks. For this purpose, in the recirculating annulus gas system, the humidity of the CO_2 gas is monitored by two parallel dew point sensors.

The CO_2 recirculation flow is monitored by a flow indicating transmitter with a range of 0~10 %.

In the case of a tube leak, the condensed moisture from the annulus gas system is collected in a drain tank. The water level in the tank is monitored by a level transmitter.

Using these analog signals, the DCC calculates the rate of rise dew point and tank level and annunciates when the calculated values exceed the setpoints.

4.2 Dew Point rate-of-rise alarms

The sampling time of the dew point rate-of-rise alarms shall be 30 seconds, i. e, the variable paramet ers shall be sampled, calculated and compared once every 30 seconds.

4.2.1 Actual Dew Point rate-of-rise calculation

If both dew point readings are rational, the program shall use the higher of the two readings. If only one reading is rational, the program shall use the rational reading. If both readings are irrational, suspend the dew point rate-of-rise

calculation and provide the "irrational dew point" alarm message.

The program shall calculate the actual dew point rate-of-rise "T_r", over the dew point instrument range of $-40℃$ to $0℃$, according to the following equation :

$T_r = 10 \times (T_t - T_{t-6})℃/h$

where

T_t is the present dew point reading in ℃, and

T_{t-6} is the dew point reading in ℃ 6 minutes earlier.

There will be no calculation of dew point rate-of-ris e during the first 6 minutes after the program is turn on.

Current actual dew point rate-of-rise shall be available for the operator to call up on the CRT display. Graphical trend display and printouts shall be also available on demand for the historical record.

4.2.2 High and Very High Dew Point rate-of-rise annunciation

The program shall compare the actual dew point rate-of-rise "T_r" with the following dew point rate-of-rise alarm setpoints ;

If $T_r > 2$ ℃/h, high dew point rate-of-rise alarm shall be initiated.

If $T_r > 4.5$ ℃/h, very high dew point rate-of-rise alarm shall be initiated.

The alarm shall be in the form of CRT annunci-

ation.

The alarms shall reset themselves when the actual dew point rate-of-rise falls below the setpoints.

4.3 Drain Tank fill-up rate alarm

The drain tank is valved out during normal operation and remains empty except for a small amount of D_2O left at bottom of the tank to prevent nuisance "irrational level" alarms, during normal operation. The tank is valved in only when moisture is directed by a beetle and the reactor is shutdown to the zero power hot state.

Drain tank fill-up rate "L_r" shall be calculated according to the following equations;

If L_t or $L_{t\text{-}6} < 20$ mm, $L_r = 0$ kg/h

If L_t and $L_{t\text{-}6} > 20$ mm, $L_r = 10 \times (L_t - L_{t\text{-}6}) \times 0.009078$ kg/h

where:

L_t is the present drain tank level in mm,

$L_{t\text{-}6}$ is the drain tank level in mm 6 minutes earlier, and 0.009078 is conversion factor from the drain tank.

If $L_r > Ls$, initiate alarm :

where :

Ls is the alarm setpoint, variable from the keyboard with a range of 0 to 10 kg/h.

Ls is initially set at 2 kg/h.

The alarm shall reset itself when the actual fill-up rate falls below the setpoint.

Current drain tank fill-up rate shall be available for the operator to call up on the CRT display. Graphical trend and printout shall be also available on demand for historical record. After the alarm is initiated, the program shall continue calculating and trending the drain tank fill-up rate.

There will be no calculation of the drain tank fill-up rate during the first 6 minutes after the program is turn on.

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

The AGS has been redesigned to meet the revised functional and performance

requirements. This entails the following off-reactor changes :

- The recirculation mode is the normal mode of operation of the system. This reduces the leak detection time.
- A second hygrometer in parallel with the first one has been added for redundancy, particularly if a hygrometer is isolated for maintenance. An indicator and alarm are in the MCR for high dew point, very high dew point and high rate of increase of dew point.
- A beetle has been added to the inlet header to the drain tank for more rapid annunciation of a leak at the inlet side of the channel annulus.
- A connection for a cold figure sampler has been added for condensing a sample of moisture which may be present in the gas.
- The drainage line to the Primary Heat Transport(PHT) D_2O Collection System contains a drain tank and a sampling connection.

6. Conclusions

This paper described the detail design description including program specification designed for the actual project.

For Wolsong unit No. 2, Annulus Gas System has been designed to improve a stagnant system for a shorter detection time.

Recirculating system reduces leak detection time (within four hours from the start of leak, compared with about 12 hours if the system is stagnant mode) thus enabling identification of the leaking channel at an early stage. This allows more time for corrective

measures to be taken before a crack reaches the critical length. Reduced leak detection time also minimizes the flooding of the adjacent annuli, thus decreasing drying time.

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