KANUPP – IAEA Training

Annulus Gas
Chemistry Control

Annulus Gas System
Course Objectives

- **State the purpose of the Annulus Gas System.**
- **List the major components of the Annulus Gas System. state the purpose of each of these components under normal and abnormal operating conditions.**
- **State the primary objectives of Chemistry Control of the Annulus Gas System.**

Annulus Gas System
Course Objectives

- **With respect to Carbon Dioxide:**
  - **State why it is used in the Annulus Gas System.**
  - **State the possible problems associated with the use of this gas in the Annulus Gas System.**

- **List the Chemical Parameters monitored in the Annulus Gas System. For each of these parameters, state the normal operating range.**

- **For each of the parameters listed above, state the corrective actions that would be performed for out of specification conditions (high & low).**

Annulus Gas System
Course Objectives

- **State the rationale behind Oxygen Addition to the Annulus Gas System. State what other chemistry parameters are affected by oxygen addition to the system.**

- **List the conventional and radiological hazards associated with the Annulus Gas System.**

- **For each of the hazards listed above, state the specific measures that would be taken for protection against these hazards.**

Annulus Gas System
Course Objectives

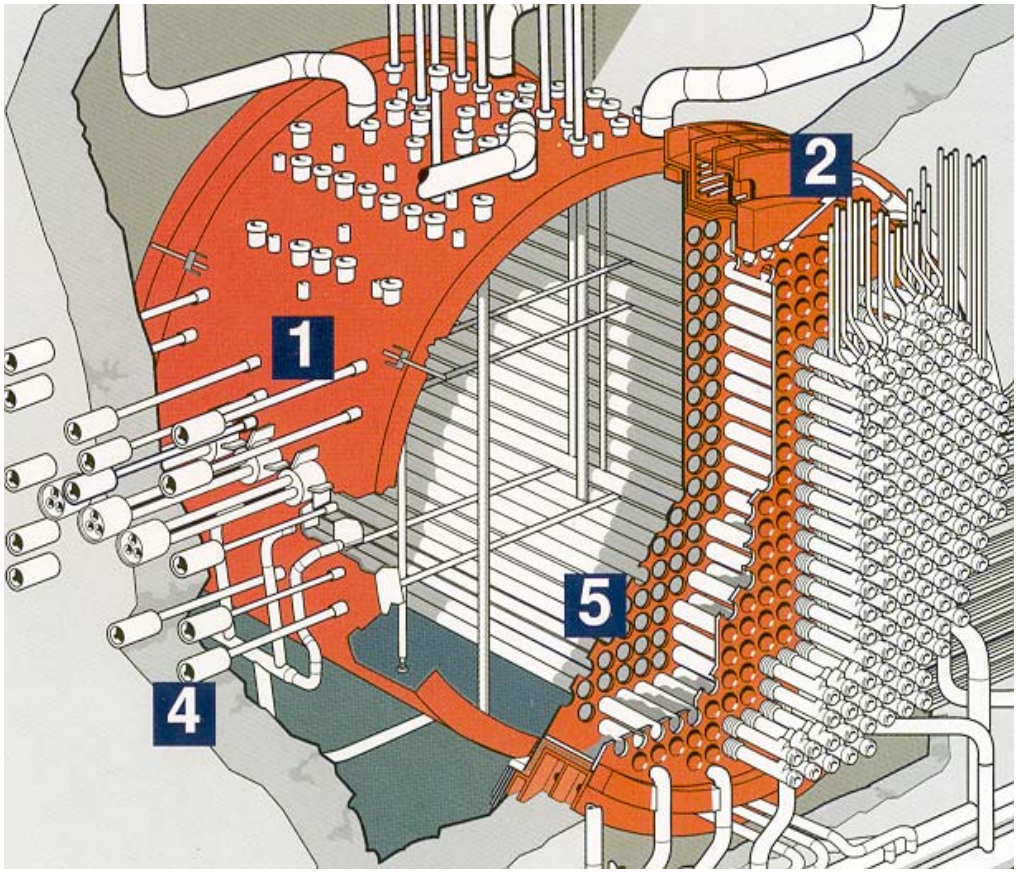
- **State the Chemistry Sampling and Analysis requirements for the following conditions:**
  - **Plant Transient**
  - **Plant Startup or Shutdown**
  - **During Plant Shutdown**
  - **Unavailability of On-Line Instrumentation**

- **Correctly obtain a sample from the Annulus gas System. This will include samples for gamma scan analysis, tritium and gas composition (D_2, O_2, N_2 & CO).**

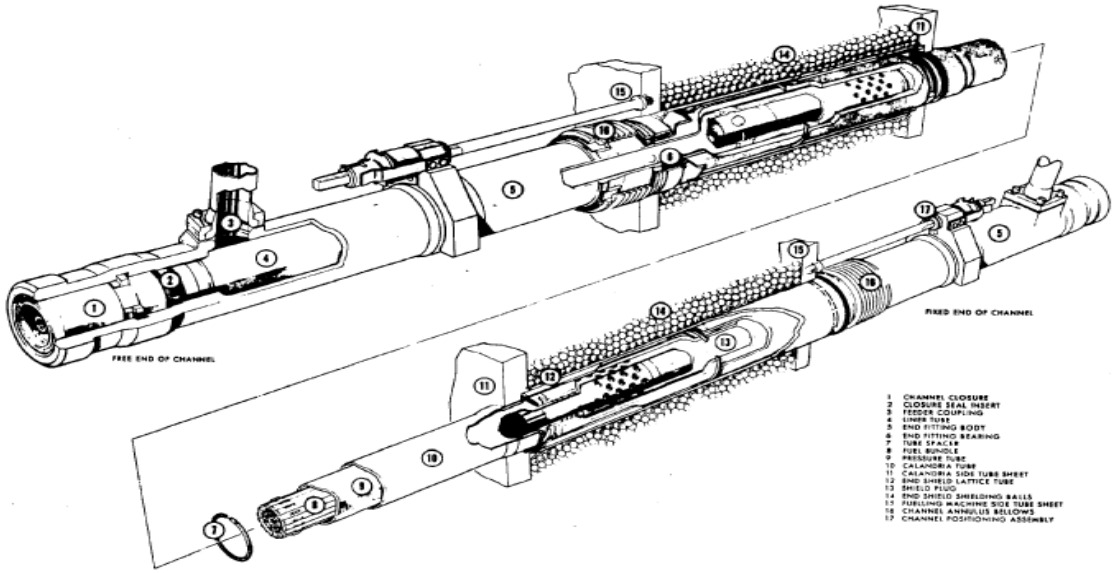
Annulus Gas Requirements

- **To provide a method for the detection of pressure tube leaks.**
- **To promote the maintenance and repair of a protective oxide layer on the outside surfaces of the pressure tubes.**
- **To provide insulation between the hot pressure tube and the cool calandria tube.**

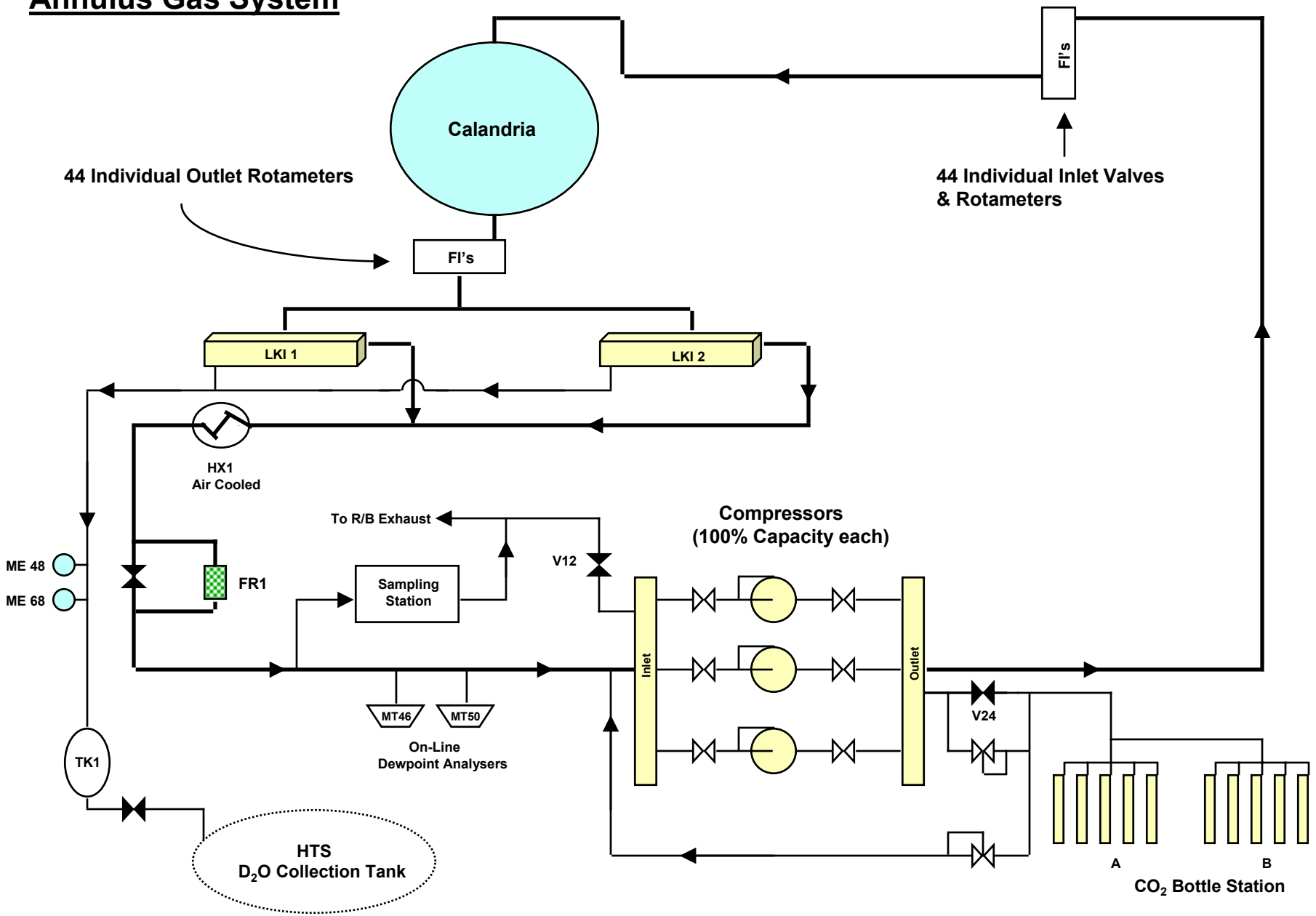
Fuel Channel Assembly



Calandria/Pressure Tube Arrangement



Annulus Gas System



Annulus Gas
Main Components

- **Compressors (3)**
  - Three 100% capacity compressors
  - Normal operation - 1 in service
    1 on Stdby
    1 selected Off
  - Provides flow of 2.6 to 3.0 liters/second

- **CO_2 Addition**
  - Two seperate bottle banks (5 cylinders/bank)
  - One bank in service at a time
  - 99.99% Carbon Dioxide

Annulus Gas
Main Components

- **TK1**
  - Normally left valved out. Valved in to collect water from leak, and then to determine collection rate (MAS program - tanks level transmitters input to MAS program).
  - When full, operations drain tank to HTS D_2O Collection Tank.

- **MT 46 & MT 50**
  - On-Line dewpoint Analysers
  - Input to MAS program to allow for calculation of rate of rise of dewpoint (leak rate).

Annulus Gas
Main Components

- **HX-01**
  - Cools the gas during purging to prevent damage to concrete from overheating at the vault penetration.
  - Cools gas to 65^{o}C.
  - Air cooled.

- **LK1 & LK2**
  - Rectangular stainless steel tanks with viewing ports.
  - Mounted at an angle to allow for drainage.

- **ME 48 & 68**
  - Beetles for moisture detection.
  - Not useful for detection of small leaks.

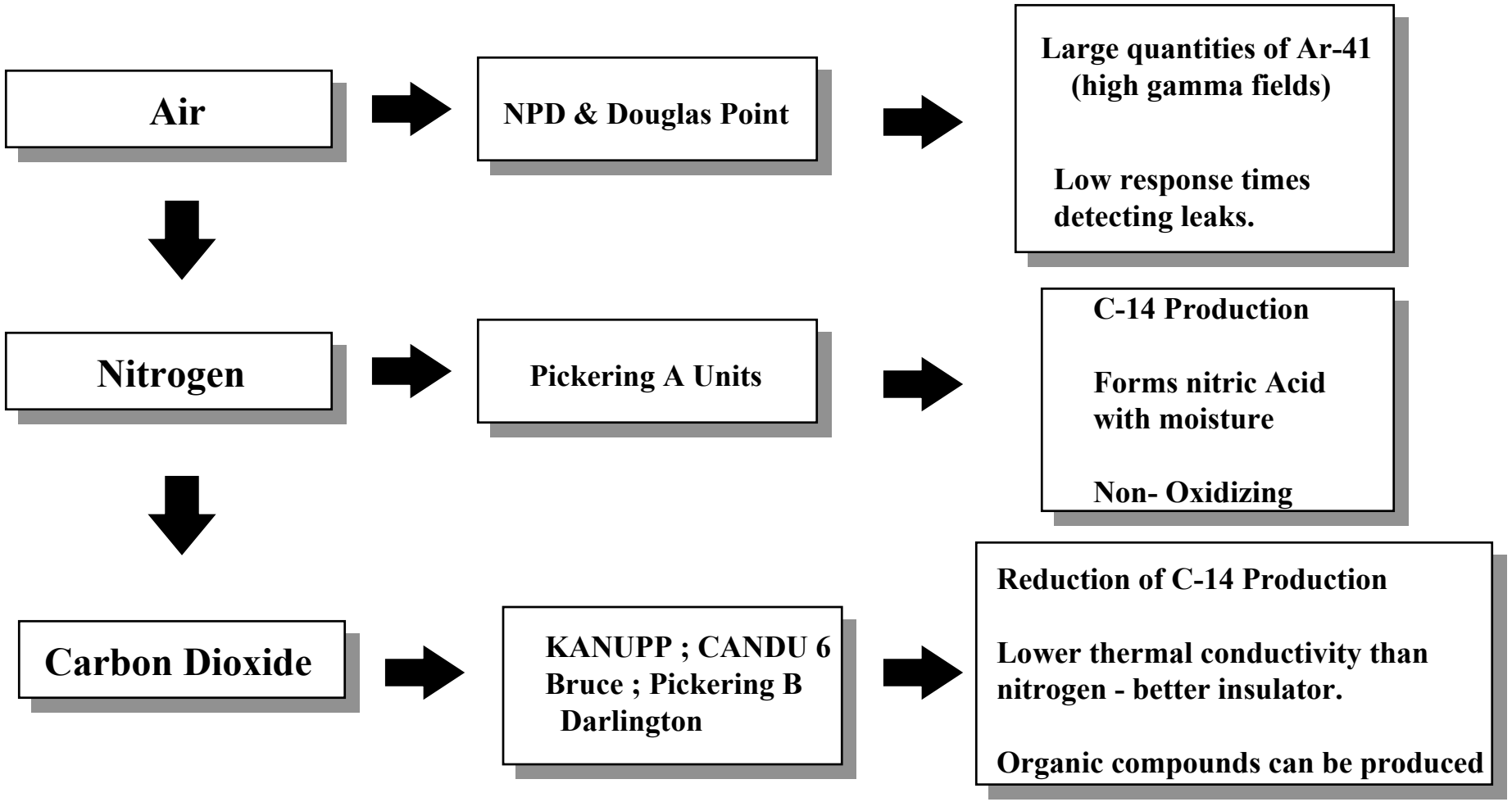
Annulus Gas Chemistry Control

- **To minimize system corrosion.**
- **To maintain a deuterium impermeable oxide layer on the outer surface of the pressure tube.**
- **To prevent the development of high radiation fields, or high radionuclide concentrations.**
- **To detect in-leakage from either the Heat Transport System, Main Moderator System or End Shield Cooling System.**
- **To minimize the production of condensible organic materials.**

System Components

Component	*Material*
Heat Exchanger 3498-HX1	304L Stainless Steel
Pressure Tubes	Zr-2.5% Nb
Calandria Tubes	Zr-2
Fuel Channel End Fittings	403 Stainless Steel
Rupture Disks	Inconel 600
Bellows	Inconel 600
Lattice Tubes	304L Stainless Steel

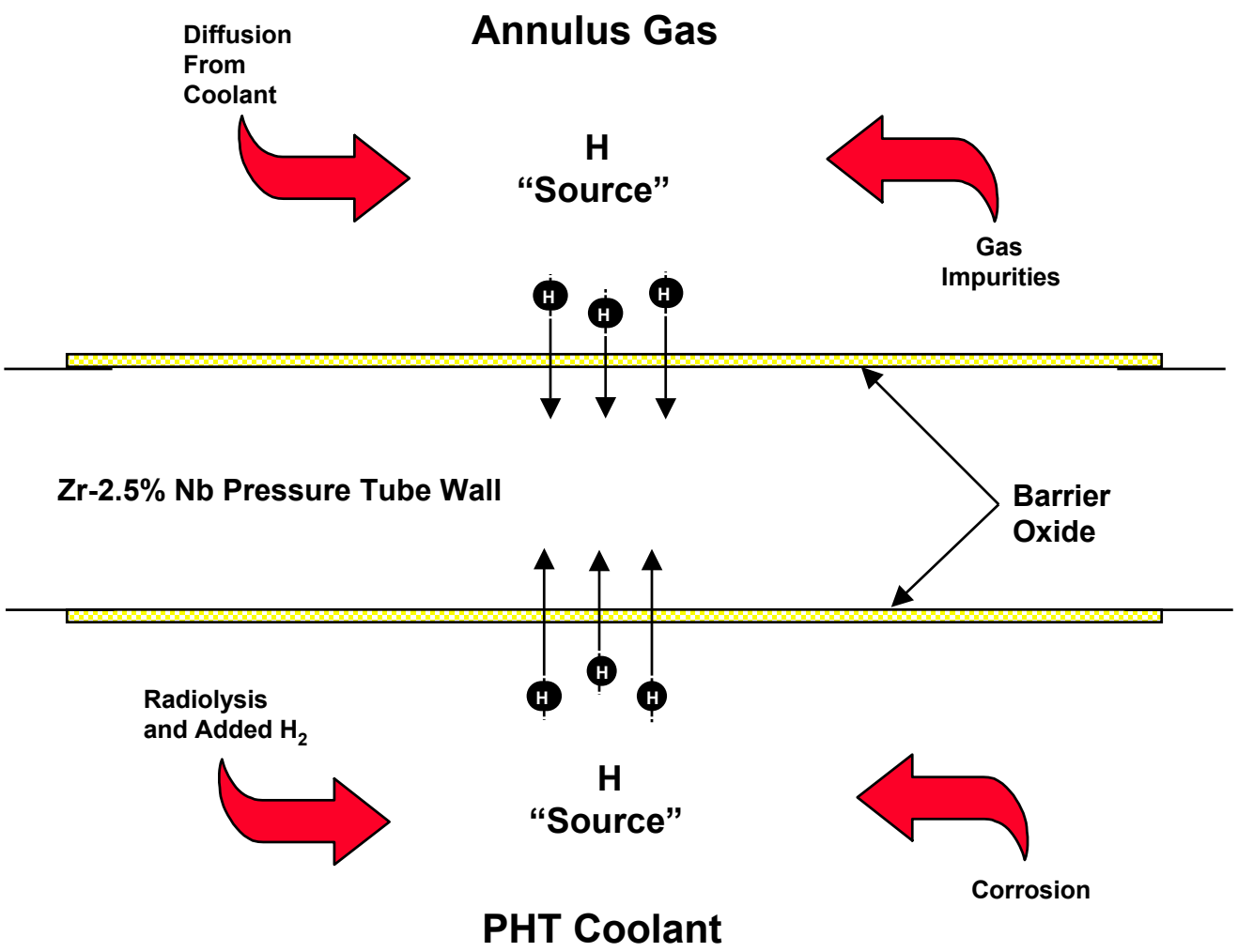
History of the Annulus Gas System



Deuterium Ingress into Pressure Tubes

- **Ingress at the rolled joints.**
- **Ingress along the pressure tube from the Heat Transport Coolant.**
- **Ingress along the pressure tube from the Annulus Gas.**

Pressure Tube Hydrogen Ingress



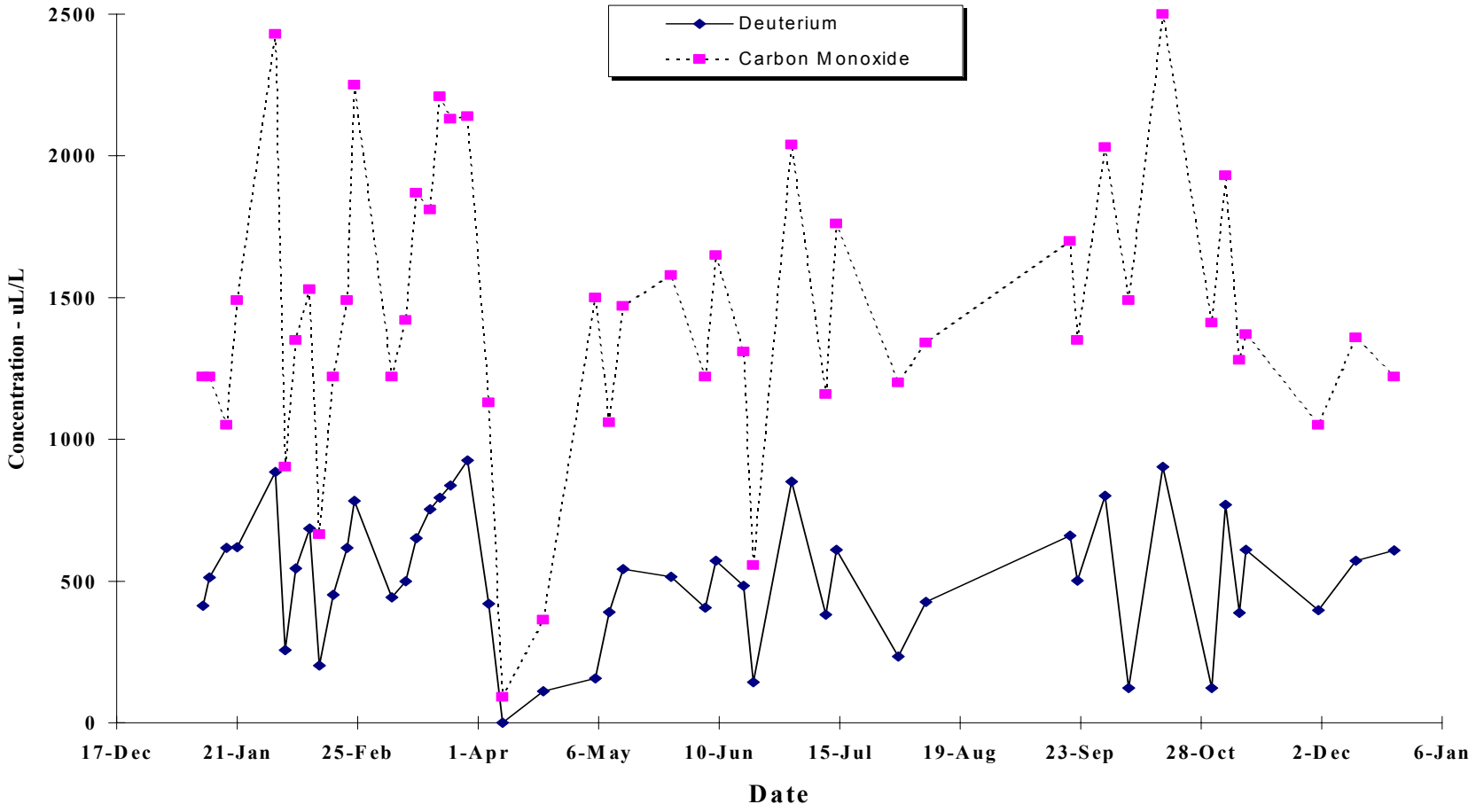
Operation with Carbon Dioxide Only

During normal operation D_2 will slowly enter the annulus gas system (diffusion through the stainless steel end fittings). This D_2 will react with the CO_2 forming D_2O. This will result in a gradual increase in system dewpoint over time. The formation of D_2O and CO is not favoured. This will result in some deuterium remaining in the gas (equilibrium D_2).

$$\mathbf{D_2 + CO_2 \rightleftharpoons D_2O + CO}$$

Point Lepreau Generating Station
1994 Data

Deuterium versus Carbon Monoxide

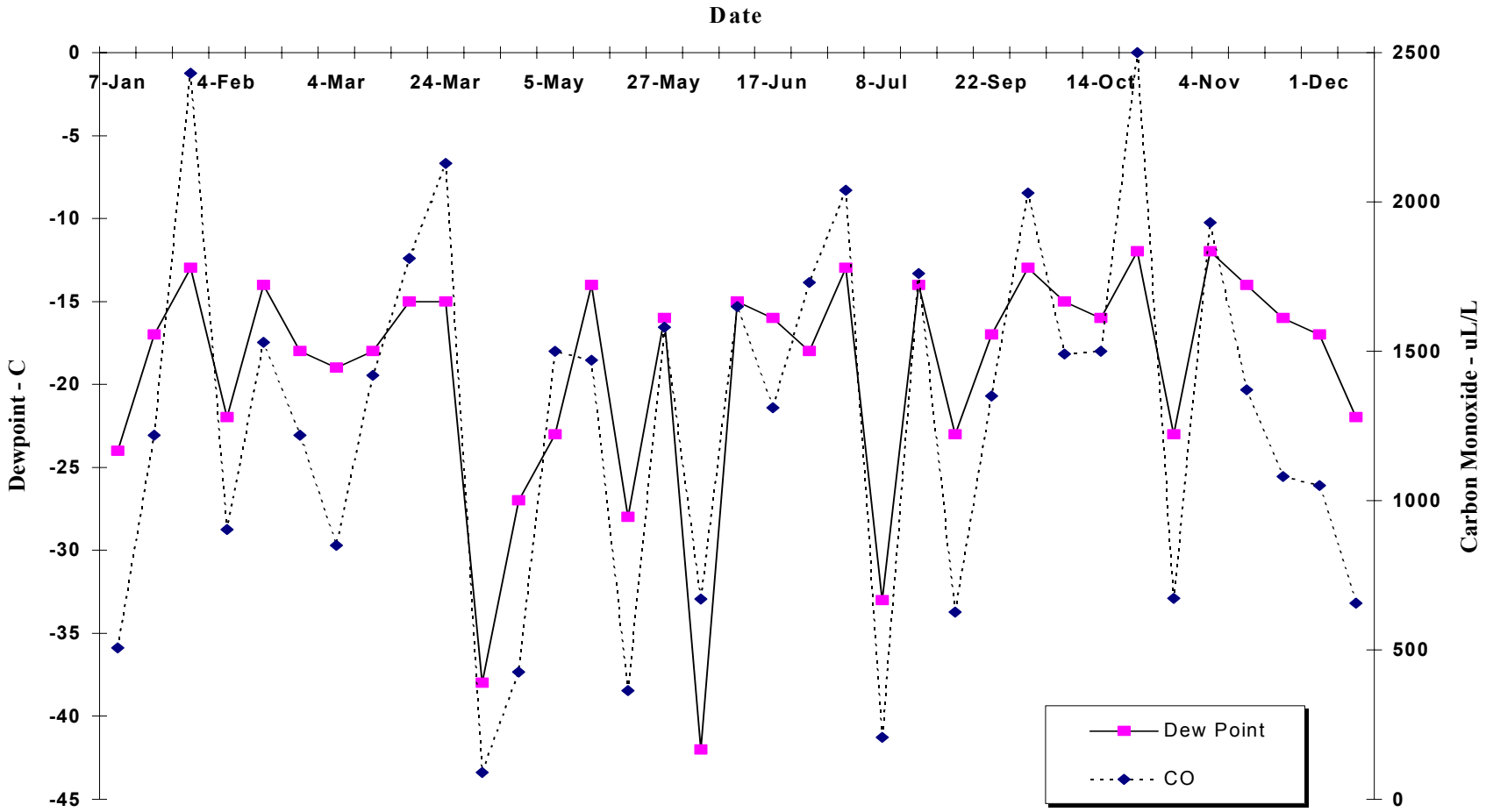


Overhead 19

Annulus Gas System
97146-224

Point Lepreau Generating Station
1994 Data

Dewpoint versus Carbon Monoxide
On-Line Dewpoint - MT-50



Overhead 20

Annulus Gas System
97146-224

Problems with Carbon Dioxide

One possible problem that can arise with the use of CO_2 is the production of organic compounds. These organics can be in the form of polymers which can be sticky or tary in texture. These organics are undesirable because they can result in flow restrictions or blockages in the system.

$$D_2 + CO_2 \longrightarrow D_2O + CO$$

$$3D_2 + CO \longrightarrow D_2O + CD_4$$

It is the methyl compound (CD_4) that is the precursor to Deposit Formation

Deposits have been found at Gentilly 2 and our station. Deposit formation in the Annulus Gas System has resulted in blockage of pigtails at Bruce A.

Carbon Dioxide in the presence of Oxygen

In the presence of oxygen (or if oxygen is added), deuterium is effectively stripped from the carbon dsioxide. Water formation is favoured as the O_2 reacts directly with the deuterium. Deuterium concentrations are typically less than 10 parts per million (vol/vol) when oxygen additions are made to the annulus gas system.

$$CO_2 + O_2 + 2D_2 \longrightarrow 2D_2O + CO_2$$

Increase in Gas Concentrations in Annulus Gas Following Fuel Channel Excursions

- **Air Ingress**
  - External gamma from AGS samples very high, due to Ar 41
  - Increased O2
  - Presence of nitrous oxides
  - May lead to acidic attack on AGS components
- **Organic Deposits following air ingress**
  - Increased H2 / D2
  - Increased Methane
  - Increased Carbon Monoxide
  - May lead to blockage of AGS flow paths
- **Moisture Increase following Pressure Tube Leak**
  - Increased fission gases
  - Dewpoint goes very high - may see D20 liquid in AGS
  - May be indication of imminent burst of PT

Annulus Gas Moisture Content versus Dewpoint

Dewpoint (^oC)	*Moisture Content (mg D_2O/Kg CO_2) 25 KPa (g)*	*Moisture Content (mg D_2O/Kg CO_2) 35 KPa (g)*
-40	**31**	**29**
-30	**97**	**90**
-20	**274**	**254**
-10	**714**	**661**
-0	**1734**	**1606**

Increase in Dewpoint for a 5 Gram per hour leak into the Annulus Gas System

Initial Dewpoint (^{o}C)	Initial Moisture Content	Initial Moisture Content	Final Dewpoint (^{o}C)	Increase in Dewpoint (^{o}C)
-40	29	267	-19.5	20.5
-30	90	328	-17.3	12.7
-20	254	492	-13.1	6.9
-10	661	899	-6.6	3.4
-0	606	1844	+1.5	1.5

Moisture Content in mg D_2O/Kg CO_2