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KINECTRICS' DTRF/HWM 2005 PLANT CONDITION ASSESSMENT REPORT

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KINECTRICS

Plant Condition Assessment for the Darlington Tritium Removal Facility (TRF), and Heavy Water Management (HWM) Systems

Kinectrics Report: K-011146-PCA-0001-R2

May 2005

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Kinectrics Inc has prepared this report in accordance with and subject to the Master Services Agreement (MSA) between Kinectrics Inc and Ontario Power Generation Inc dated January 1, 2002

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KINECTRICS

To: Nalini Valliere
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1 EXECUTIVE SUMMARY

There are two main components of Heavy Water Management (HWM) at OPG:

- Tritium control by D_2O detritiation
- D_2O isotopic control by D_2O recovery, cleanup and upgrade.

Systems for cleanup, upgrade and detritiation of heavy water are the critical parts of the heavy water management cycle. Efficient management of these components also requires adequate D_2O storage and handling capability [1]. At Darlington, the TRF works with the Upgrader for heavy water management. Unlike other OPG stations, water recoveries at Darlington are not segregated, and therefore Upgrader product is usually only acceptable for moderator makeup, because the tritium concentration is too high for PHT makeup. The TRF, by removing tritium, maintains moderator and PHT tritium concentrations below their OP&P limits (Darlington moderator OP&P limit is 15 Ci/kg, and the PHT limit is 1.2 Ci/kg).

The recent evidence of low reliability has focused attention on the Darlington Tritium Removal Facility (TRF) and has highlighted that it is a key facility for heavy water management. It is the only source of reactor grade, low-Curie make-up water for the PHT system at Darlington and it is essential for ensuring that all stations meet their OP&P limits. The decreased reliability of this aging facility has serious consequences for management, storage, segregation, and diversion of heavy water.

This report assesses components in the heavy water management system, including the TRF and Upgrader, and summarizes significant problems that have contributed to downtime. The state of degradation and mechanism of degradation are described and the expected remaining life is indicated.

The report was prepared using OPG documentation such as reports, summaries prepared by OPG staff and information such as SCRs contained within various databases. Interviews with a cross section of staff provided additional information. The major forced outages at the TRF were reviewed both to identify systems that were major contributors and to determine common issues.

The TRF, after 15 years of operation, has experienced significant degradation in key systems:

- Air Cleanup System (ACS)
- Electrical and instrumentation systems
- Cryogenic adsorber system
- Drain and Purge System (DPS) pumps
- Recombiner
- Deuterium Make-up System

- Upgrader system
- Chilled Water, Steam and Low Pressure Service Water (LPSW) supply systems
- Roof and blowout panels on the TRF building

The Low Tritium Cold box and High Tritium Cold box and contents require inspection to assess remaining service life. While the Cryogenic Refrigeration System (CRS) has been a major contributor to unreliability because oil has migrated to cryogenic areas, this appears to be an operational issue and is not primarily a result of equipment degradation.

The TRF/SUP Computer System components are relatively new (acquired by ABB in late 1996 and installed at Darlington in November 1998). However, different components have displayed different reliabilities since commissioning.

Recommendations for Improvement

Short-term steps to improve TRF reliability are mainly procedural.

- Minimize or if possible, eliminate oil ingress to the CRS by revising operating procedures to stop pumping oil around the circuit when the CRS is warming or when the turbine has no load (not extracting energy); brief all operators on revised procedures and have them acknowledge their understanding. [*Note added in proof – this has been completed during the most recent shutdown of the DTRF*]

- Change oil in the turbine system only after analysis indicates that it is warranted rather than changing the oil on a schedule.

- Ensure that turbine oil of the right specification is used and investigate if drying the oil reduces contamination.

- Evaluate extension of scheduled maintenance intervals for the H_2 compressor and if accepted, increase the intervals between maintenance cautiously from 8,000 h upwards.

- Perform root cause analysis for the DPS Metal Bellows pump failures to eliminate the cause of failures.

Medium to longer-term steps to improve plant condition require replacement of components (e.g. in the Adsorber Unit). Many of the components in the plant are not replaceable on a "like for like" basis because they are obsolete, and replacement requires design engineering and the ECC process.

Replacement parts for some of the specialized equipment at the DTRF are not currently available within OPG and due to the increased rigor in the procurement processes at OPG an analysis of the level of work involved in obtaining spare parts should be undertaken.

The TRF and HWM systems already have many of the processes in place to manage plant resources: the next step is to better integrate the processes, optimize activities, and improve communications between functional groups.

The Life Cycle Management project also requires results from the Maintenance Improvement Initiative project, which is aimed at asset preservation. The project aims to improve configuration management, prepare maintenance procedures where they are missing, and build complete Bills of Material.

It is felt that the problems with the metal bellows pumps in the DPS system and the lack of reliability of the DMS system are two areas that should have a more detailed root cause evaluation done to determine why the problems exist within those systems.

The authors believe that this assessment of the plant condition is sufficient to use within the Equipment Reliability methodology as a starting point in following the steps within the area of Life Cycle Management. The Equipment Reliability methodology is a system that is based on the principal of continuous improvement and thus is a cyclic process that keeps coming back to assess if the situation is still as it was previously.

2 INTRODUCTION

This report assesses the current condition of Heavy Water Management Systems including the Tritium Recovery Facility (TRF) and the Upgrader at the Darlington Nuclear Generating Station with the objective of identifying and ranking areas for improvement.

Since 2001 the TRF has gradually moved from *white* to *yellow* to *red* in plant health reporting mainly because of poor capacity factor, lack of spare parts, and the large number of functional failures. The System Health rating for the TRF has been *red* for the past two years. The Upgrader is *yellow*.

Figure 1 shows that the performance of the TRF has been erratic over the last four years with unpredictable forced outages. Since commissioning 15 years ago, the plant has experienced a number of significant outages; both planned and forced. These outages are listed in approximate chronological order as follows:

- Repair of seized VPCE Liquid Ring Compressor.
- Replacement of Charcoal Catalyst in CAT 1601 (equilibrator in CD4) with Pt/Alumina; changes to the piping configuration in the HTCB, which involved cutting and welding tritium-contaminated equipment.
- Replacement of the tube bundles in all eight VPCE evaporators and one feed evaporator due to stress corrosion cracking of the original bundles; stainless steel tubes were replaced with Inconel-625 tubes.
- Replacement of filter FR-3116 in the CRS with a filter having a coarser mesh size.
- Drying the DU molecular sieve after flooding by seal tank water from the Liquid Ring Compressor.

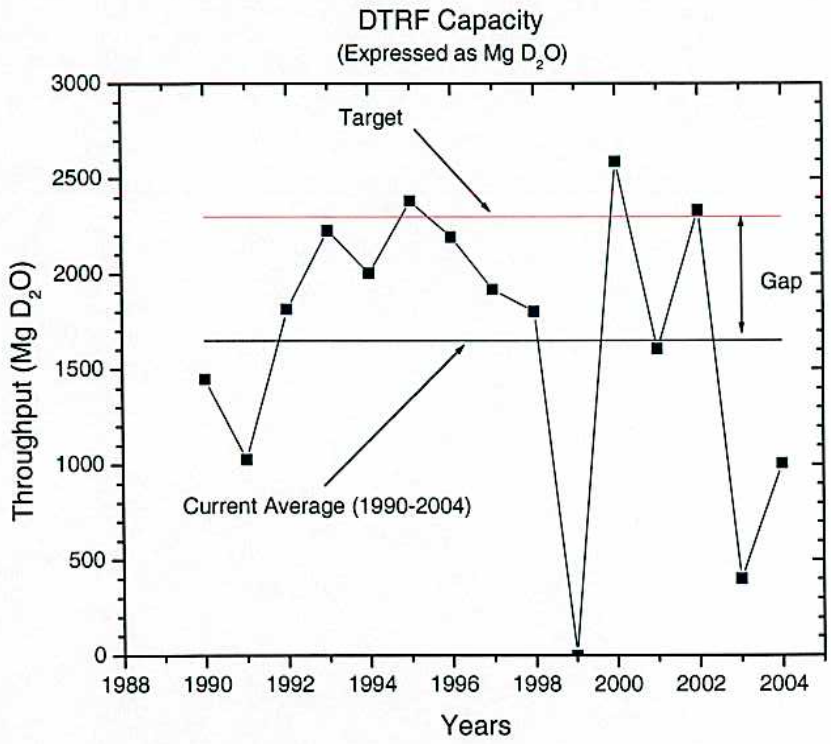

Figure 1: DTRF Capacity Trend

- Replacement of leaking superheater tube bundles.
- Replacement of Fisher valves in the VPCE and DU because the bellows failed (about 96 valves replaced).
- Replacement of the obsolete and trouble-prone control computer system in 1999 with a Fischer and Porter System 6 computer system.
- Cleaning the CRS system piping by flushing with solvent to remove oil contamination.
- Repair and inspection of cracks in VPCE superheater nozzles.

In February 2005 an unplanned outage was caused by plugging in the CRS (by oil carryover) and has resulted in actually cutting out lines within the CRS to drain oil. The root cause of some of the material has not yet been determined.

Each outage has lasted for significant time periods ranging from a few months to up to 18 months.

Development of a life cycle management plan (LCM), aimed at improving the reliability of this facility is important to OPG. The focus of this report is to consolidate and update previous assessment efforts and thereby provides the most current condition of plant systems. This will form the basis for the Life Cycle Management Plan.

3 WORK SCOPE

The scope of this assessment covers both the TRF and Upgrader system; Darlington is the only CANDU station with a tritium removal facility. Conventional CANDU stations have no tritium recovery facilities.

The Life Cycle Management Project being executed by Kinectrics has the following deliverables in this phase:

- Plant Condition Assessment (PCA) Report and establishment of priorities
- Aging Report
- Obsolescence Review Report
- Critical Equipment Matrix review and update
- Outline of the Life Cycle Management Plan.

This report addresses the first deliverable and assesses the condition of subsystems and components in the TRF and HWM system including electrical and I&C, auxiliary systems, low-pressure service water, HVAC, and building structure. Kinectrics, as an outside party, critically reviewed existing work by OPG in this area and used this information in preparing this report. Kinectrics undertook no testing or inspection of systems or components during the assessment. For each system, the following are provided:

- System description
- System Condition Statement—a summary of the significant problems that have been experienced by the system and the present state of the system and its contribution to downtime
- Degradation—the state of degradation and the mechanism of degradation
- Remaining Life—the estimated remaining life of the system.

4 METHODOLOGY

The intent of this project is to compile and review operating and performance histories of the TRF and Upgrader including outage reports, equipment maintenance history, manufacturers' service guidelines, current inspection and maintenance activities, relevant industrial operating experience, and previous plant condition assessments.

This report was prepared using existing documentation available from OPG either as reports or summaries prepared by OPG staff, or information contained within various document handling database programs either in use within OPG or existing as legacy systems. Documents up to 1 January 2005 were part of the study. The study did not include any inspections of equipment except for a plant walk down.

Throughout this report, equipment and components are classified in "good" condition if three conditions are met:

1. No SCR's were found.
2. No comments were made about the equipment during interviews.
3. Engineering experience on the part of the authors suggested that the equipment should still be in working condition to the end of the TRF design life.

A stronger statement on equipment and component condition is only possible with inspection.

Many documents have been used during the preparation of this report:

1. Darlington Tritium Removal Facility, Experience Manual, 1990
2. Significant Event Reports (SER database), 1988-1998
3. Station Condition Records (SCR database), 1998 – 2004
4. Plant Operating Flow sheets
5. Critical Equipment Matrix, 2002
6. Inspection record for the DTRF, 1995 to 2003
7. Plant Condition Assessment, 2002 (where no changes have occurred since 2002, portions of this report have been repeated in this analysis)
8. Plant Aging Matrix, 2002
9. TRF Long Term Outage Schedule, 2002 to 2007
10. COG OPEX database
11. OPG Nuclear Procedure – Critical Equipment Identification & Categorization, 2004
12. OPG Nuclear Procedure – Obsolescence Identification & Strategies Evaluation, 2000
13. System Performance Monitoring Plan, Heavy Water Management & Upgrader (SUP), 2000
14. In-Service Inspection Program for the DTRF, 1995
15. An Assessment of the Risks to OPG Operation Due to a Prolonged Outage of DTRF, 2003
16. PM task list for the TRF and the Heavy Water Management building
17. Predictive Maintenance list of scheduled tasks for the TRF
18. Summary of Work Orders on the TRF 1998-2005
19. System Health Summary for Heavy Water Management and Upgrader (SUP), Dec. 31, 2001 to present

Detailed interviews with a cross section of staff augmented the documentation review. The team held interviews in the last quarter of 2004 with key staff associated with the plant. The following staff positions were interviewed:

1. Engineering Services Staff (Head Office) (3)
2. DTRF Technical Section Manager
3. Senior Technical Engineer and System Responsible Engineer (4)
4. Operations (2)
5. Control Maintenance (2)
6. Mechanical Maintenance (2)

5 GENERAL OVERVIEW OF THE PLANT CONDITION

5.1 Overview of TRF Equipment, Maintenance, and Organizational Problems

In 2005—based on plant start-up in 1989—the TRF reached the middle of its expected design life of 30 years. Ontario Power Generation requires the TRF to operate reliably to the end of 2018 and has imposed a further requirement that lifetime be extended to 2022. The objective of this study is to develop a plan for reliable, sustainable TRF operation that meets lifetime requirements and targets an average throughput of 2300 Mg/year D_2O. The current average throughput for 1990-2004 is 1690 Mg/year and operation has been erratic over the last four years.

At present, the technical and operational problems encountered in the TRF arise from equipment aging, obsolescence, and lack of spare parts. The plant has little redundancy, so that a problem in any one system may force an outage in the entire plant. Moreover because isolation systems are not installed on some sections of the process, hydrogen safety requirements demand that hydrogen be removed from equipment before maintenance is performed.

While the TRF operates reliably at steady state, difficulties are encountered during transients such as start-ups. Initial conditions in the system are not always consistent and the cryogenic refrigeration system sometimes has difficulty in reaching target temperatures; therefore small changes to start up procedures are necessary to accommodate specific operating conditions that are encountered. For example, trace impurities in the process gas impede establishing the desired liquid level in the final distillation column. Establishing these levels can take 2-6 weeks, depending on the concentration of residual He^3.

The TRF still faces some high priority issues:

- The Air Cleanup System (ACS) has been inadequately maintained and has shown design deficiencies. The system is required during accidents. Preventive maintenance records only show calibration of tritium monitors and relief valves. It is only since 2003 that a Semi-annual test of the ACS has been in place (recently changed to an annual test). This tests the dryer bed regeneration cycle, operation, recombiner temperature and damper operation.

- Electrical and instrumentation systems are old and may break down. Spare parts are either unavailable or have limited availability.

- The low tritium (LTC) and high tritium (HTC) distillation columns have not seen a full PM program because there are no moving parts. The LTC design should reduce protium in the gas by sending a small side stream to the recombiner, but the line appears to have been plugged since the TRF was commissioned; on-line protium extraction cannot be performed. This process itself is not a critical function and is not a high priority issue, as it does not affect the reliability of the plant. It does contribute to the recommendation that there should eventually be inspections within the cold box.

- The cryogenic adsorber system operates with only one functional bed. When this adsorber needs regeneration, feed is stopped for a few days, the unit regenerated and the adsorber returned to operation. Operation with only one adsorber carries a risk. At present, resources have not been assigned to design and build replacement adsorbers.

- The Drain and Purge (DPS) pumps do not operate reliably and replacing the original SRTI Wobble pumps by Metal Bellows pumps has not improved reliability. The Recombiner unit must be operated manually because the control loops do not operate satisfactorily. The seal on the Recombiner has vented frequently and this has the potential to emit activity.

- Operation of the Deuterium Makeup System (DMS) has been unreliable and has been a bottleneck to system start up. Electrolyte level control is inadequate and has allowed electrolyte into vent lines.

Redesigning systems can solve some problems. Equipment obsolescence has formerly been a driver for redesign and upgrade—such as acquisition of the new computer system—but a complicated Engineering Change Control (ECC) process exacerbated by resource limitations make such solutions difficult to implement. In many cases equipment cannot be replaced "like for like" and substitution requires design engineering and the ECC process.

In 2002 the TRF organization started a Maintenance Improvement Initiative project aimed at asset preservation. The scope of this project was to improve configuration management, prepare maintenance procedures where they were missing, build Bills of Material and compile the Critical Equipment Classification List. The project was partially completed, but was later cancelled due to lack of funding. This project has now been restarted.

The current Preventative Maintenance (PM) program covers all rotating machinery, hydrogen monitors, tritium monitors and relief valves. However, there are gaps. For example WEKA cryogenic valves do not have a PM program because little information is available. Nevertheless, station personnel consider the current PM plans adequate.

An inspection program has been developed for plant components but production pressures impede completing the work. The inspection program needs a higher priority within station activities.

Planned work, especially for outages, and FIN (Fix It Now) work are performed by the same people. Generally FIN work takes priority, and planned work is delayed.

The TRF does not have an outage management group. The same group that plans day-to-day activities also plans outages, and lack of resources may hamper outage planning.

The Upgrader has worked well. Care is taken with the chemistry of the Upgrader feed water to prevent corrosion of the packing and this has greatly reduced the need for

outages to clean distributors. It may be necessary to increase the level of preventative maintenance on this equipment (see Section 11.2).

Obtaining spare parts is a time consuming process. The parts system within OPG has changed and the number of approved suppliers has been reduced. More stringent requirements for pressure boundary parts and the requirement that approved suppliers are registered with the TSSA have increased the difficulty in finding qualified suppliers and have increased procurement time. The more stringent requirements have also resulted in a purge of older parts from stores. The TRF does not have adequate resources to purchase parts within the rules of the new system.

Obsolescence is a severe problem at the TRF and as the plant ages, obtaining parts and suppliers will become more difficult.

5.2 Out of Scope Findings

During this assessment, the team obtained information considered to be relevant to the performance of the TRF but is outside the scope of the study. Therefore, this information has not been investigated further, but is listed here since it is relevant to the evaluation of TRF operation.

- Staff at the TRF are dedicated to good performance of the facility, despite the challenges to maintain operation.
- The safety record at the TRF is good.
- When the facility operates correctly, the TRF has the capability of detritiating water to meet the design capacity. The tritium removal process can be considered mature and proven.
- The TRF is given a low priority within the Station and the resulting resource shortage hampers the plant. This lack of resources affects the ability of the plant to implement necessary design changes to equipment.
- A change to the procurement process at OPG has had the short-term effect of reducing spare parts and the number of approved suppliers available to the TRF.
- Station outages can adversely affect essential utilities, such as steam, and shut TRF operation. This subjects the TRF to the stress of additional start-up transients.
- Repeat errors, such as metal bellows pump failures, or oil in the turbine loop, suggest that communication within the facility needs improvement.
- TRF performance is threatened by loss of skilled maintenance, operating, and design support staff. The facility requires long term succession planning to capture tribal knowledge and operating experience.

5.3 TRF System Assessment

The assessment is divided into separate sections as follows:

- Front End Systems—tritium removal from D2O
- Cryogenic Distillation Systems—tritium extraction and purification
- Auxiliary systems—TRF operation support
- Service systems (Chilled Water, Ventilation)
- D_2O management systems
- TRF/SUP Computer Control System
- Instrumentation & Control Equipment
- Building and Structures

6 ASSESSMENT OF TRF FRONT END SYSTEMS

6.1 System Description

The TRF front-end systems consist of the following components:

- **FTS (Feed Treatment System/Liquid Collection System) SCI 39310**—eliminates solids, dissolved gases, and organic contaminants from the D_2O feed stream.

- **FPS (Feed and Product Storage) SCI 39340**—stores and transports feed and product heavy water using batch tanks.

- **VPCE (Vapor Phase Catalytic Exchange) SCI 39320** – a multistage countercurrent system, with co-current flow of heavy water vapor and deuterium gas within each stage, which removes tritium from feed D_2O by transferring tritium into deuterium gas in the presence of a catalyst.

- **DU (Dryer Unit) SCI 39320**—removes heavy water vapor from the deuterium-tritium gas using regenerating molecular sieve dryer beds; prevents ice formation in the cryogenic system.

- **DMS (Deuterium Make-up System) SCI 39330**—provides deuterium gas to the TRF by splitting heavy water into deuterium and oxygen gas using an electrolyzer.

- **RS (Recombiner System) SCI 39360**—oxidizes deuterium and hydrogen gas to water either during regeneration of the adsorber unit, or during shutdown and startup activities.

- **DPS (Drain and Purge System) SCI 39360**—handles process or purge gas during maintenance or preconditioning.

6.2 System Condition Statement, Degradation and Remaining Life

6.2.1 FTS (Feed Treatment System) SCI 39310

Evaporator EV1101 and Collection Tank TK2201. The evaporator and collection tanks have been contaminated with gamma-emitting radionuclides (mainly Co-60) originating in moderator water. In 1999, an assessment of a chemical cleaning process concluded that the process was not effective, lead blankets have been used to minimize gamma fields around the evaporator and collection tanks as part of worker radiation protection measure. Radionuclide accumulation in the FTS has not contributed to downtime and is more of a nuisance than a contributor to loss of capacity.

Decontamination of the evaporator and collection tanks is needed to protect workers from radiation. Decontamination is possible either by water lancing or ultrasonic cleaning. Water lancing, however, may be difficult to perform, because it requires cutting the pressure boundary.

Pumps. Current performance of D_2O transfer pumps is satisfactory. No problems are anticipated. No major degradation mechanisms exist, other than mechanical wear, since pumps are commonly used in low temperature and low-pressure service conditions. With regular maintenance, pumps are expected to reach the design life of the TRF.

Charcoal Beds. Charcoal adsorbers ADS1101 and 1102 have high pressure drops, most likely due to break down of charcoal particles. The effectiveness of the beds for organics removal needs to be evaluated.

Degassing Columns. No major issues have been identified for the Degassing column.

6.2.2 VPCE (Vapor Phase Catalytic Exchange) SCI 39320

VPCE Superheaters and Tube Bundles: Stress corrosion cracking in the VPCE during early operation has been attributed to residual chlorides leaching from the VPCE catalyst. In 1995, tube bundles in HX1204 and HX1205 failed, which resulted in H_2O ingress to VPCE stages. Two tube bundles of HX1204 and HX1205 were replaced—Inconel tube bundles replaced the 316SS tube bundles—and some tubes were plugged to remove them from service. Failure of these tube bundles was not considered a generic issue, but subsequent inspections of super-heaters have indicated similar defects. In 1999, monitoring detected 40% through wall defects in some super-heater tubes[1]. The supplier has increased quality assurance on manufacturing tube bundles. Due to high temperature service conditions (about 200°C), tube bundle replacement for six superheaters (other than HX1204 and HX1205) will most likely be required during the period 2007 to 2011.

Process Side Nozzles: In March 2003, a tritium leak was discovered and traced to superheater HX1206. Helium leak testing eventually located the leak at the weld at the outlet nozzle of HX1206 shell (SCR D-2003-02204, D-2003-02780). All other nozzles in the

[1] Monitoring information comes from the 2002 Condition Assessment

system were then inspected and were found to be in good condition. An investigation suggested that steam leaks into HX1206 shell were the primary origin of chlorides and hence were the root cause of stress corrosion cracks. The platinum-charcoal VPCE catalyst, which initially contained high chloride levels, may only be a contributing factor. [3]

Steam Side Gaskets: Three steam leaks from the superheater gaskets have occurred. Because there is no radioactivity, these can be repaired with manageable downtime[2].

VPCE Evaporators: Tube Bundles and Vessel Body. In 1990, all 316 SS tube bundles in evaporators were replaced because stress corrosion and crevice corrosion were found at the tube-sheet joints; the bundles were replaced with Inconel 625 tube bundles. Since then, inspections show no sign of deterioration of the tube bundles. The performance of evaporators has been satisfactory. During the TRF outage in 2001, the top part of the internals of the VPCE evaporators were visually inspected via the inspection ports and no abnormal condition was found.

Sight Glasses and Gaskets. During the 2001 outage, sight glasses on the VPCE evaporators were opened for inspection and silicone gaskets were found damaged. Some sight glasses also showed signs of corrosion, with deep grooves at the bottom of the glasses (SCR D-2001-05032). The defective sight glasses were replaced either with spare sight glasses or with stainless steel metal plates. Gaskets were also replaced with a new material, which did not perform well (SCR D-2003-06536). The stainless steel plates were replaced and all sight glasses and gaskets were returned to original condition in July, 2003. Silicone gasket material was reapplied and, with careful control of the chemistry in the evaporator, performed better. Therefore with a gasket inspection program coupled with proper chemistry control, no substantial degradation is anticipated.

The VPCE Evaporators are expected to last to the end of the design life of the TRF.

VPCE Condensers. Performance of the VPCE condensers has been satisfactory. No inspections have been performed on these exchangers to date. Based on earlier inspection results of similar condensers in the CRS system, no problems in the VPCE condensers are anticipated. With adequate monitoring and scheduled inspection, the VPCE Condensers are expected to last until the end the TRF design life.

Catalyst Pots. Scheduled inspection on the vessel shells both in 1995 and in 2001 showed no degradation in wall thickness. All catalyst pot nozzle welds were UT inspected in 2003. The performance of catalyst pots has been excellent. The VPCE catalyst pots are believed to be in good condition. The catalyst pots are expected to last until after the design life of TRF and the catalyst, because of the clean process environment is expected to last until the end of TRF life.

VPCE Deuterium Compressors. See comments on the dryer compressors

[2] Superheater gaskets are scheduled for replacement in 2006

6.2.3 DU (Dryer Unit) SCI 39320

Dryer Units ADS1301 and ADS1302. During early TRF operation (1990-1997) dryer beds flooded because water carried over from the DU compressor seal water tank. After each flooding, the molecular sieve was dried and this contributed to downtime.

Previous occurrences of flooding were attributed to deficiencies in the old computer control system, which occasionally set the DU system valves incorrectly (not fully proven). After replacement of the control computer in 1999, flooding is no longer considered an issue. Additional improvements have also been implemented such as slowing the closing of some motorized valves, which has helped reduce flooding. However, after the power blackout in 2003, water was found in the DU outlet filter FR1301 (SCR D-2003-08366); this is believed to be the result of drawing moist gas from DU seal tank via FR3101 to the DPS[3]. Moving a water return line from the condensers to above the liquid level in the LRC seal tank or the proposed installation of a check valve on the chiller CD1302 drain line has been suggested[4], but an assessment must be made by the plant.

Dew Point Performance. The performance of adsorber beds ADS1301 and ADS1302 has been acceptable, and the dew point of the outlet D_2 gas maintained at -80°C or lower. However, the dryers are not achieving the same dew point that they were able to achieve at commissioning because molecular sieves have aged. Improvements in dew point meter calibration and gradual deterioration in valve seat leakage (SCR D-2003-08562) complicate the assessment. The dryer unit dew point meter used to read "off scale low," but now reaching -80°C is difficult. The observed trend in dewpoint measurement has been increasing from initial values of -90 to -95°C to -78 to -82°C now. A rising dewpoint in the gas eventually leads to a large load on the cryoadsorber.

The time to reach a correct dewpoint on the dryer is inconsistent. On some start-ups the time is short; other start-ups take almost a month to move from -76°C to -80°C dewpoint. The operators have learned to keep the beds isolated and dry during an outage to reduce drying time.

Molecular Sieve and Support Condition. The molecular sieve has not been replaced since plant commissioning. Since the dryers are in a clean operating environment, the lifetime of the desiccant is expected to be much longer than in other typical industrial applications. The pressure drop across the dryer has not changed over the years despite possible aging. However, there are no sampling ports on the dryer to check the molecular sieves. The bottom of the dryer bed has been inspected by boroscopic examination and deposits and caking are seen. Fine powder is produced and has been found in valve seats. With replacement of molecular sieve, it is anticipated that ADS1301 and ADS1302 will last for the remaining of the TRF life.

DU Regeneration Heater. The performance of the DU regeneration heater has been satisfactory. There has been no in-service inspection of this heat exchanger to date. Leakage from the regenerator heater gaskets has been reported (SCR D-2004-00780).

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[3] Opinion of the System Engineer.
[4] Notes from Engineering Services Staff

However, it was considered that this issue has not contributed to TRF downtime. Because of high temperatures (about 200°C), the DU regeneration heater will likely be replaced after about 20 years of operation due to stress corrosion.

Liquid Ring Compressors. The liquid ring compressors have performed well. The OEM supplier (nsb gas processing) was contacted and they indicated that the low tolerance parts of these pumps are the critical parts as the pumps age. In the pumps at the TRF, these parts are the port plate and the impeller. If cavitation has occurred during operation, rebuilding the pump may become important. Traces of cavitation can be easily recognized visually[5]. During detailed discussions with another compressor manufacturer[6] it was suggested that the low clearance areas of these types of compressors should be rebuilt after ten to fifteen years of operation; the TRF has reached this time for the compressors. Minor vibrations have been observed on the liquid ring compressors, but this was considered normal. Under certain conditions such as high-pressure differentials, the vibration level in the compressors appears to be high and this is being investigated by the Vibration Group at Kinectrics. In common with similar rotating equipment, routine replacement of seals is recommended, although these compressor seals appear to have an unusually long lifetime. With proper maintenance and an inspection program, it is anticipated that the liquid ring compressors will last until after the end of TRF life.

Valves. Fisher pneumatic valves are used in TRF front-end systems. Bellows failures were detected on several Fisher valves in early 1999 (SCR N-1999-00736). By the end of 1999, all Fisher valves were refurbished and redesigned bellows installed. Based on this refurbishment and on anticipated valve degradation mechanisms, the majority of these valves should be in good condition. Based on the previous valve bellows failure incident, it is anticipated that some of the Fisher pneumatic valves (~30 valves), particularly the ones that are operated frequently in the FTS and DU, will require another refurbishment after 10 years of service (i.e., 2007 to 2011).

Velan manual bellows valves are in good condition. However, a bellows failure of one Velan valve occurred in 1995, but this failure was considered an isolated event due to a manufacturing defect. A bellows inspection program is planned to determine if replacement of Velan valve bellows is necessary. Furthermore, it is anticipated that Velan valve bellows will also require replacement or refurbishment during the remaining life of the TRF.

6.2.4 DMS (Deuterium Make-up System) SCI 39330

DMS Electrolysis cell

Availability. The DMS is essential for start up especially if the shut down required burning the inventory in the system. Therefore, although it is an auxiliary system to the main process, it is a critical system for start up. However, during operation, it is not needed and remains on stand-by. Electrolysis cells best operate continuously on a

[5] The authors are not aware if cavitation has been looked for on these pumps.
[6] Discussions with GARO, Italian manufacturer of the hydrogen liquid ring pumps used at the Wolsong Tritium Removal Facility.

reasonable load. They are expected to have reduced reliability when operated intermittently and left on standby, full of electrolyte, for long periods of time[7]. Currently there is a lot of research going on in the area of intermittent operation of electrolysis cells associated with the hydrogen economy and powering these devices from wind turbines. No definitive results are as yet available. A change in operation of the unit has been proposed[8] where a proposed lay-up of the DMS is proposed when not in use and bottled D_2 gas is used for process makeup.

The DMS has been unreliable when required on start up and has been a bottleneck (see SCR D-2003-10615). The electrolysis cell has the following identified issues:

- The DMS is tested once per month on call-up. However, the test may not be adequate because reliability of the DMS is inadequate.
- The DMS is obsolete and is based on old technology, which is still supported by the vendor. The vendor can supply the updated system, if required.

The DMS will probably need replacement, at a cost of significant design effort[9].

Membrane. Despite a number of module failures, root cause has not been investigated (SCR D-2001-06617). Factors that contribute to membrane failure are high temperatures, high current densities and high electrolyte concentrations. The electrolysis membrane module failed in 2001, and a new unit replaced the defective module in early 2002. During plant operation, the unit remains on standby filled with high concentration electrolyte. This may possibly lead to membrane degradation and KOD crystallization from the electrolyte solution. This is an area requiring further study. The electrolyzer manufacturer has recommended that the electrolyte be drained when the DMS is not operating for a period of time (greater than the 30 days in the operating manual).

Level Control. Electrolyte level control has failed and has overfilled the electrolysis module causing KOD electrolyte ingress to vent lines (SCR D-2000-01800, D-2001-05900). The level control system allows overfilling the tank because it is possible for the level switches to reset after the level goes above the setpoint. This eventually can push electrolyte into piping.

Pressure Control. A general problem in the DTRF is that regulators on the instrument air lines protect valve actuators, but these regulators have not been inspected; failure of the regulator should not affect the valve actuators, if relief valves have been installed in all cases, downstream of the regulators. In the DMS system in particular, if PRV1807 were to become unstable it will affect the upstream back PRV transient response and could affect the pressure control on the DMS[10]. Delta P causes stress on the membranes.

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[7] The System Engineer has noted that the manufacturer of the system, Teledyne states that system shutdown periods of up to 30 days require nothing beyond the normal isolation of facility services.
[8] Engineering Services Staff
[9] A DMS replacement project has been identified in the station 5-year plan.
[10] The authors.

Oxygen Analyzer. The Teledyne oxygen analyzer does not work properly as installed: the cell experiences back-pressure, for which it was not designed. The cell needs to be changed regularly.

Combustion Sensors. The combustion sensor on the cells can only be reset five times[11]. Other than a paper label that is not always updated, there is no counter or other device to ensure that no more than five resets have been made.

Control. The DMS has experienced an unusual upset event that may have been rapid flame propagation[12]. The Control Maintenance technicians have indicated that when the manufacturer's representative was at site, he limited the current to the electrolyzers (and hence limited deuterium production rate and possibly cell temperature) by using a potentiometer on the board. However, according to the System Engineer this change was to bring the system back to the specifications in the operating manual. Since these changes have been made and the back pressure regulators set, there have been attempts to limit the number of operational power adjustments made on this equipment. This should lead to better operation.

It is recommended that a detailed examination be done of the current problems with the DMS system operation prior to the design effort required for the replacement of this equipment. This is necessary so that in replacing the equipment the existing problems can be avoided more effectively. The authors believe that the current operating scenario, (intense use on startup and then long periods on standby), for the DMS will continue into the future. Thus the new equipment must be designed for intermittent operation, quick startup and long standby periods.

6.2.5 DPS (Drain and Purge System) SCI 39360

DPS Pumps. The Metal Bellows pumps do not operate reliably and a root cause analysis is required to improve operation. The pumps have failed for a variety of reasons such as manufacturing defects (SCR D-2002-08373), or inadvertent closure of isolation valves on the discharge side. For example, a valving error resulted in equipment damage to two of the DPS compressors (SCR D-2001-03707). In another incident CP2102 failed and damaged system rupture discs (SCR D-2001-03644).

Both the bellows and bearings have failed (SCR D-2003-07693, D-2004-03584), and the compressor shaft on CP2101 has failed on a few occasions (SCR D-2001-04255, D-2002, 06090, D-2002-07058). Over 7 modifications have been made to these pumps including strengthening the components (shafts have been changed due to specification errors). At present, the downstream metal bellows pump, which acts as a compressor, shows excessive noise.

A review and investigation of the operation of the DPS is required.

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[11] Information obtained from interviews with the Control Maintenance technician.
[12] The System Engineer has indicated this has not been proven nor investigated

6.2.6 RS (Recombiner System) SCI 39360

RS TK1701 Liquid Seal Vent Line and Flowmeters. The RS system operates on manual control for O_2 and D_2 flow, because the mass flowmeters in the system have not worked properly since commissioning. While the system does operate satisfactorily in this mode, during start-ups, pressure transients occasionally break through the liquid seal on the vent line, which results in high tritium emission to the vent stack. Increasing the "U" leg of the liquid seal and upgrading control of the flowmeters can minimize start-up pressure transients. Strict adherence to a procedure for topping up the liquid in the existing seal leg would also mitigate against emissions. Redesigning the seal leg should also be considered.

The product water has a pH around 2 – 2.5. This is an improvement from early TRF operation when air in-leakage, or a high level of nitrogen impurity in the oxygen supply resulted in pH values of around 1 – 1.5.

The stack flowmeter (FI1715) control logic assumes that all gases are oxygen. This is an unacceptable assumption, because there could be high excess hydrogen and no oxygen at the flowmeter. To rectify this situation, an oxygen sensor should be added to ensure that oxygen is supplied to the RS.

Nitric acid formed during operation of the recombiner system is corroding the carbon steel vent piping. Replacement of the vent piping is anticipated following prolonged RS operation. The RS is expected to last until after the design life of TRF.

Tank TK1401 Isolation. Provision for positive isolation of TK1401 from the FTS/VPCE/DU systems during a TRF outage can save restarting time, since the LTC inventory need not be burnt in the RS. Tank TK1401 is expected to last until after the design life of TRF.

7 ASSESSMENT OF TRF CRYOGENIC DISTILLATION AND REFRIGERATION SYSTEMS

7.1 System Description

The TRF Cryogenic Distillation and Refrigeration Systems consist of the following components:

- **AU and LTC (Adsorber Unit and Low Tritium Distillation Column) SCI 39410.** The AU cools the D_2 and DT gas and removes traces of nitrogen, oxygen, and heavy water vapor prior to distillation. The LTC consists of a single column, which enriches the less volatile tritium as a liquid deuterium-tritium mixture. The tritium-depleted deuterium gas leaving the top of the column is recycled to the VPCE.

- **HTC (High Tritium Distillation Columns) SCI 39420.** Three distillation columns in series along with a catalytic converter enrich the deuterium-tritium mixture into tritium with a purity >99.8%. Depleted deuterium returns to the LTC column.

- **CRS (Cryogenic Refrigeration System) SCI 39440**. This consists of a cold gas turbine and reciprocating compressors to provide the necessary refrigeration at 25K to distill the hydrogen isotopes in the LTC and HTC columns.

- Each of the above systems is housed within its own cold box (CB), which is maintained at high vacuum (10^{-3} Pa).

The main components of the systems are 304L SS piping, stainless steel distillation columns and vessels, aluminum plate-fin heat exchangers and transition pieces between heat exchangers and piping, and carbon steel for the non-cryogenic areas of the CRS.

7.2 System Condition Statement, Degradation and Remaining Life

7.2.1 AU and LTC (Adsorber Unit and Low Tritium Distillation Column) SCI 39410 and HTC (High Tritium Distillation Column) SCI 39420

ADS (AU). The cryo-adsorbers ADS 1401 and 1402 do not operate as specified in design parameters. ADS1402 only cools to 90K (the original design adsorption temperature was 65K[13]). Poor thermal contact between the temperature diode and the outside surface of the adsorber vessel or poor thermal insulation could account for poor cooling. This will not be resolved until an inspection is performed.

Occasionally because of poor nitrogen cooling, adsorber 1402 is at about 100K. It can operate in this manner for up to 6 months without regeneration, since the pressure drop does not increase over this period.

The adsorber can operate as a cryotrap and freeze residual water vapor on surfaces. Since the dryer unit is operating at a reasonably low dew point, it is possible that residual water vapor is trapping both on the cryo-heat exchanger and on particles within the adsorber vessel without plugging the unit.

ADS 1401 cools to 80K as expected but plugs quickly, indicated by a high pressure drop. Silica gel in ADS 1401 may have deteriorated during an event in which a significant amount of water was carried over into the adsorbers[14].

The system can operate with the current state of the adsorbers (ADS 1402 on a long cycle and ADS 1401 on a short cycle), but it is apparent that the design margin has been reduced. The silica gel is present to remove trace nitrogen from the gas stream and if there has been significant damage to the silica gel beads then the adsorption performance will be reduced. If ADS 1402 were to undergo similar damage or deterioration then the TRF would require a long outage to replace the adsorbers. The adsorbers are custom designed vessels, and replacing the adsorbent is difficult.

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[13] *[reference: DTRF Process Design Description, Sulzer, 4-04-DTRF-008-2, 1981]*

[14] Narrow pore silica gel is intolerant of liquid water. Dropped into water, narrow pore silica gel beads violently shatter into powder giving the impression of the water boiling [2].

A project to replace the adsorbers has started but has not been completed[15].

LTC and HTC. These systems are in good operating condition. The heat exchangers are made of aluminum, the columns are fabricated from 316L SS and the systems are operated in a clean gas environment. They are normally operated under cryogenic temperature and low-pressure conditions. The plant is designed for fewer than 100 thermal cycles. It is not expected that thermal cycling will exceed the design criteria and limit the lifetime of these systems. The LTC and HTC systems are expected to last for the design life of the TRF. Some of the liquid-hydrogen piping from the CRS to the LTC and HTC equipment is contaminated with oil. This could create a partial flow blockage problem in piping or heat exchangers (e.g. the less than adequate steaming flow to EV1501[16]). Thus more frequent CRS filter inspection and replacement may be required[17].

There are few moving parts in the LTC and HTC system, and this system is not expected to be a major contributor to TRF unavailability. This has been confirmed by operating experience.

Oil diffusion pumps on the cold boxes are obsolete but work well. Occasionally, a significant quantity of roughing pump oil has been found in diffusion pumps and vent piping.[18] The analyzers on the system may also be obsolete, but have not contributed to down time.

A small H_2 leak is suspected in the high tritium cold box, but has not hindered operation (SCR D-2003-08983). A leak is inferred from the off-scale reading on the hydrogen detector on the vacuum pump outlet, but it has not been possible to confirm this leak[19].

The startup procedure for the cryogenic systems is not consistent. Establishing steady operation of the HTC is difficult; trace impurities such as helium can blanket the condensers in the HTC and make it difficult to establish levels. Operators are given some flexibility to try new ideas to try different approaches, based on previous experience. Establishing correct operating levels in the final columns can take up to six weeks.

There is a minor chronic leak of tritium at valve flanges, e.g. at MV1415, PSV1407, PSV1408, PSV1409, PSV 1410; flange gaskets require replacement (SCR D-2003-10026, D-2003-10027, D-2003-10028, and D-2003-10030).

A level control problem in the HTC may be related to calibration problems with level transmitters (neon pressure transducers). One of the condensers may have contamination from oil carried over from the CRS.

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[15] It is scheduled for completion in the 2006 outage
[16] System Engineer
[17] The hydrogen piping in the LTD is scheduled for inspection in 2006 to assess the blockage issue.
[18] The System Engineer, recommends the use of dry roughing pumps
[19] A Work Order has been raised to investigate this issue.

7.2.2 CRS (Cryogenic Refrigeration System) SCI 39440

Performance of the TRF has been compromised by lack of adequate refrigeration. Most of the problems with the CRS occur during startup after both planned and unplanned shutdowns. These problems are mainly a result of ingress of impurities such as air, water or oil, which either partially or completely block the CRS.

During evacuation and backfilling of the CRS, air can leak into the system through leaking mechanical joints and relief valves. Unlike the configuration in the distillation columns (LTC and HTC), the CRS has not installed a rupture disk before relief valves. Inadequate purging of the system, resulting in blockage by frozen residual nitrogen, also causes problems.

During the early operation of the TRF, filter FR3116 was replaced with one having a more open mesh to reduce blockage. This allowed continued operation of the system and increased refrigeration delivered to the condensers in the LTC and HTC. In the 2005 outage, FR3115 was also replaced with the same 20 micron element as FR3116. The high pressure drop across FR3115 was confirmed to be caused by oil frozen at the inlet. A blockage resulting a pressure drop as high as 100 kPa has been observed on turbine filter FR3101 (SCR D-2003-09654); the cause of the blockage is unknown.

Oil ingress to the CRS has caused two extended forced outages of the TRF (including the February 2005 outage), and has required opening the CRS to remove oil. The oil has at times been removed by flushing with isopropanol. During the present outage, about 22 liters of oil were collected at various parts of the CRS by cutting and draining the low points in piping. The low molecular weight oil found widely inside the cryogenic part of the CRS is likely a degradation product of historical turbine oil. The CRS test heater and JT heater can accelerate the oil degradation. The Mylar insulation around the test heater was hardened; the melting point of Mylar is about 250 °C. About 250 ml of water/oil mixture was found at the J-loop. The origin of the water is still not known but it is likely originating from the Oil Skid because water is found nowhere else but at the J-loop (a few drops of water were also found inside the turbine).[20] The manufacturer recommends that the oil skid idling time must be minimized to less than 30 minutes in order to minimize oil ingress. The CRS oil skid had been left idling for up to three weeks with the turbine isolated. This operating condition can lead to oil ingress and changes to operating procedures have now been implemented to minimize the idling operation of the oil skid.

The CRS turbine has a manual valve on the discharge side and a control valve on the inlet side. This presents a potential for operator error if the valves are not closed in the correct sequence.

The presence of water in the CRS downstream of the turbine also indicates that the oil brake system is the likely source. Changing the turbine oil on a regular schedule has the advantage of protecting the moving parts, but has the disadvantage that it introduces impurities such as water into the CRS brake system at every oil change, unless the oil is

[20] From the System Engineer

completely dry. Although a molecular sieve trap (ADS3201) is built into the oil system, the trap has not been effective since it may have saturated over the years.

Discussions with another operator of a similar refrigerator have indicated that they rarely add oil to the brake system. They have only changed the oil once in 15 years of operation and only top up the oil reservoir if it is low[21].

CRS Compressors. The hydrogen compressors are in good condition, and should last for the design life of the plant, as long as regular maintenance is continued. Piston skirt wear has been noted after 8,000 running hours, and component replacement is required on a regular basis; typical wear components are the compressor suction and discharge valves (32 per compressor), and carbon wear rings. Annual replacement of the wear parts and inspection of the other components will ensure continued operation. A manufacturer's representative is usually on site for service of the compressors. The present 8,000-hour maintenance interval can be extended accordingly by monitoring of the compressor valve temperature. A sudden temperature rise at the compressor valves is an indication of valve problems. This increase should be done in increments of no more than 2000 hours over a 4-year period with the suggested increased monitoring. Increases to the maintenance intervals must ensure that piston skirt wear is also acceptable during the operating period.

The cooling water system on the CRS is contaminated with particulate matter and biological growth, and this contamination interferes with flow measurements. As a subsequent fix for flow measurements improvements to inter-stage temperature monitors would allow reliable temperature measurements to be used to confirm that adequate cooling flow is available to the compressors and intercoolers. Minor process gas leakage has been observed at the intercooler CLR3411 outlet flange, because an incorrect O-ring was installed (SCR D-2002-06724). The correct O-ring was installed in 2002.

Valves. The majority of the cryogenic valves are manufactured by WEKA. It is expected that they will deteriorate due to aging. A program to monitor valve condition and life should be implemented; there is no regular maintenance program on the cryogenic WEKA valves.

The stem tips of these valves may have a limited lifetime; there are signs that the valves pass across the seat. Replacement of valve stem tips will be required before end of plant life. Valves have not been refurbished (to February 2005), but with refurbishment it will not be necessary to replace all the valves.

Auxiliary Compressor. This is in good operating condition, showing no signs of material deterioration. This equipment sees limited use (although since 1998 it has been used to assist in evacuation of the process), is always kept in good operating condition, and should be able to last for the life of the plant.

CRS Turbine. During the early years of operation, numerous turbine failures occurred. These failures were eliminated by improvements to the control system, and to operating

[21] Conversations with Michel Gagne, BOC Magog.

procedures, and by increased operating experience. Following restart of the TRF in October 2001, a turbine failure occurred, causing loss of cooling (SCR D-2001-05632, D-2001-06084). The root cause analysis indicated that the turbine failed because oil pressure was low. PRV3208 on the oil skid was found to be passing, because foreign matter in the oil—a plastic cap inadvertently left behind during maintenance—interfered with operation of the valve (SCR D-2001-06408). PRV3208 was refurbished, and the damaged turbine was replaced with a spare unit. The TRF was then successfully restarted. The turbine unit normally provides satisfactory service, and with regular rotor and bearing replacement, is expected to last the design life of the TRF. There are plans to install flowmeters on the CRS oil skid supply lines, in order to monitor the turbine oil supply condition.

Maintenance of the CRS is focused on moving parts. Spare turbines are kept in stock and the turbine can be replaced in case of failure. Similarly, the oil pump (swash pump/gear pump) is replaced rather than repaired.

Turbine Oil Supply Pump. Bearing failures—mainly caused by fatigue and wear—have resulted in oil pump failures and motor damage. The motor is custom built and is no longer available from the OEM. Because replacement parts or motors are not available, complete replacement of the system may be needed before end of plant life.

Additional monitoring capability on the oil skid would be useful to provide diagnostic measurements on performance; for example, an ultrasonic flowmeter on the oil line could monitor performance of the oil pump and performance of the swash pump (H_2 gas)[22].

Heaters. Electrical heaters in the cryogenic systems have performed reliably, except for the heaters associated with the CRS; the usual cause of failure is burnout of heating elements. Heaters HTR3111 and HTR3112 on the J-T loop in the CRS are planned to be replaced in the near future. They have previously caused some minor problems (SCR D-2000-03002). Heater HTR3111 has been placed out of service since 2001 on the basis that turbine speed and HTR3112 can provide better control of cooling loads.

Temperature control has improved since air pressure to TCV3111 was adjusted; this control valve responds to the temperature downstream of the turbine at the outlet of HX3104 and regulates the flow into HX3106, the J-T heat exchanger.

Heat Exchangers in the CRS system. These are performing well and there have been no signs of operating problems. They are high quality (custom made) aluminum plate-fin heat exchangers for cryogenic applications. Operating experience, both internal and external, suggests that there are no issues expected with cryogenic heat exchangers. Contamination or rapid changes in temperature are some of the few failure mechanisms for these heat exchangers. The heat exchangers are expected to last for the design life of the TRF.

For non-cryogenic equipment in the CRS, potential degradation mechanisms are fouling and micro-biologically induced corrosion (MIC). Eddy Current Inspection (ECI) of the

[22] Authors

cooler tubes has been performed as part of the In-Service Inspection (ISI) program. Heat exchangers are in good condition. Some fouling in service water piping to the heat exchangers has been found, but this is not of concern. Under current operating and maintenance conditions, heat exchangers in non-cryogenic applications in the CRS will last for the plant life.

CB Vacuum Systems. The pumps associated with these systems can be replaced as required as part of the normal equipment maintenance strategy. Elastomer O-rings in the vacuum systems have cracked; there is no regular program to inspect or change them. Start-up delays have occurred because of cold box vacuum leaks (SCR D-2003-08076). The oil in the Alcatel roughing pumps has occasionally been found in places like diffusion pumps, vent lines and the HTCB analyzer tubing. These pumps also have a high maintenance cost.

8 ASSESSMENT OF TRF AUXILIARY SYSTEMS

8.1 System Description

The TRF Auxiliary Systems consist of the following systems:

ACS (Air Cleanup System) SCI 39520. Removes airborne tritium (element or oxide) from designated TRF rooms after an acute tritium release, thus reduces emission to the environment. The ACS can also be used to decontaminate the purge gas streams from the TIS, DPS, GBCS and HTCB vacuum pump discharge.

GBCS (Glovebox Cleanup System) SCI 39530. Removes tritium (elemental or oxide) from glovebox argon atmosphere in case of an acute release. The system also removes moisture, oxygen and nitrogen from the gloveboxes, while at the same time providing sufficient argon flow to remove heat generated by the immobilization process and process equipment.

TIS (Tritium Immobilization System) SCI 39720. Receives concentrated tritium gas from the final stage of the high tritium cryogenic distillation column, and transfers it to the Immobilized Tritium Container (ITC).

ITC Activation System SCI 39790. Activates the titanium sponge in the ITC's by controlled heating of the ITC under vacuum.

ITC (Immobilized Tritium Container) Storage Vault SCI 39780. Provides safe and secure storage of the loaded ITC's.

8.2 System Condition Statement, Degradation and Remaining Life

A number of legacy issues exist with respect to operation of the ACS; these include, but are not limited to, the leak tightness of ACS dampers, condition of process controllers, and the ACS testing program (SCR D-2001-00735). The testing program came into use in 2003.

8.2.1 ACS and GBCS Turbine Blowers

Currently the blowers are operational, but they often require time-consuming maintenance. A work program is planned to replace them by more reliable and maintenance-free blowers. According to the mechanical maintenance staff, GBCS blower F2 ran for days without gas flows. This is not recommended as it creates unnecessary wear and overheating.

8.2.2 ACS and GBCS Dryers

The performance of dryers has been good. Based on this good performance and on minimal degradation of the desiccant, continued reliable operation of this subsystem is anticipated for the remaining life of the TRF.

8.2.3 ACS and GBCS Recombiners

During commissioning tests there were indications that the recombiner did not operate properly due to insufficient catalyst and in the early 1990s, more catalyst (five times the original quantity) was added. Based on operating experience of similar recombiners used in the other reactor systems, it is anticipated that no major degradation of the ACS and GBCS recombiner catalyst will occur during the remaining life of the TRF.

8.2.4 ACS and GBCS Valves

Although the ACS and GBCS are currently operational, ball valves on the dryer skid experience passing and need replacement or refurbishment. The ACS return dampers (butterfly valves) exhibit insufficient sealing and a new design should be considered for replacement.

Ball valves on the dryer skid (for both ACS and GBCS) and butterfly wafer isolation valves (for ACS only) leak across the seat and assessment and implementation of a valve replacement is necessary as soon as practical. With a good valve inspection and maintenance program, new valves should last for the remaining life of the TRF. In the ACS the valves have been in one position for a long time; they are not stroked regularly, and therefore may fail during operation. GBCS valves are seizing through lack of use.

8.2.5 GBCS O_2 and N_2 Removal Beds

These beds are functional and can be put into service when required. Similar to the dryer desiccants, no replacement of bed adsorbents is necessary.

8.2.6 ACS and GBCS Control Systems

The control systems are currently functional, but they are primarily based on a local control panel. In particular, dryer regeneration cycles are controlled by motor driven, programmable, multi-cam step-switches, which often need to be reset for the regeneration cycle to proceed. A work program is planned to upgrade the I&C system, so that the ACS and GBCS can be controlled remotely from the TRF main control room. The

control systems are out of date and spare parts and components are difficult to obtain. New control systems should last the remaining design life of the TRF.

8.2.7 GBCS Magnetic Blower

The performance of the magnetic blower has been good[23]. No degradation of blower components is anticipated with proper routine maintenance. It is anticipated that the blower will last for the remaining design life of the TRF.

8.2.8 TIS Components

The TIS is a robust system, whose reliability and operation has been good. Glovebox 2 is used for tritium immobilization about 60% of the time since it contains additional equipment. Glovebox 1 is used for the remainder of tritium loadings. The main problems experienced with the TIS have been difficulty of obtaining spare parts due to obsolete equipment, instrument failures, dose hazard associated with the tritiated oil of the rotary vane pumps, and failure of the turbo pumps. To maintain the TIS, parts have been scavenged from the TAP system. The TAP system, built for dispensing tritium into sales containers, was never commissioned in order to enable operators to focus on the core business of heavy water detritiation. The large number of components in the TIS could cause problems because coincident failure of key components required for tritium assay and immobilization will not allow tritium draw off from the HTC.

Equipment such as metal bellows pumps; Nupro PVs and Jordan PSVs have not received detailed preventative maintenance. Despite the lack of PM, the Nupro PVs have operated reliably and no major valve problems have been identified. Potential degradation is anticipated due to wearing of valve seats or fatigue of bellows. A valve inspection program should be performed to determine if overhaul or replacement of TIS valves is required to ensure the valves operate reliably for the remaining design life of the TRF. There have been no problems associated with leak tightness of fittings and the system has been disassembled only to a minor degree.

The TIS circulation pumps have not been used. The TIS has experienced one or two motor failures of the metal bellows pumps[24]. Potential degradation is anticipated due to motor winding aging or overload. It is anticipated the circulating pumps, with proper maintenance and spare parts, will last for the remaining design life of the TRF. Maintenance work on the turbo pumps is difficult and time-consuming due to the need for periodic re-balancing. Although several turbo pumps have failed, performance has improved after the bearings were replaced with permanently lubricated ceramic bearings.

Rotary vane pumps operate with an oil charge, and this oil becomes contaminated with tritium, and presents a dose hazard and high risk of spreading tritium contamination. Therefore, PM is no longer performed on these pumps at the manufacturers recommended intervals; the oil is topped up as required and the pumps are run to failure.

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[23] This blower is used as the main blower for the GBCS.
[24] These circulation pumps have never been required to assist tritium immobilization.

These pumps should be replaced by oil-free (dry) vacuum pumps, which are available on the market (providing the pumps meet the requirements for tritium service).

Although the inside surfaces of the gloveboxes are contaminated with tritium[25], the glovebox windows are normally removed for ease of equipment maintenance. The ITC airlock heaters, which are used for about <10% of ITCs, have not required replacement. With the exception of a failure of the bellows used to connect the TIS to an ITC, there have been no other problems with the ITC airlocks. The glovebox O-rings have not had any PM and as a result many are noticeably cracked. Rupture disc RD407 has burst on at least 7 occasions due to seat leakage across valve PV404 during warm-up of the HTC. Operating procedures have been changed to ensure that manual valve V404 is closed to prevent the TIS from being exposed to high pressure.

During the filling of an AECL ITC in the TSC airlock, a stack release of tritium was experienced. The tritium may have originated from purging of the process side of RD407 resulting in residual tritium being flushed to the stack during purging of the TSC airlock (SCR D-2004-05910).

8.2.9 ITC Activation System

The ITC Activation System is used to activate the titanium sponge in the ITCs by heating the ITC under vacuum. A controller on the ITC Activation oven has failed. Poor performance of an ITC recently (longer time to immobilize) resulted in a recommendation to expedite repairs to the activation oven controller (SCR D-2004-06234). The controller was to be replaced using the NICR (Non-identical component replacement) process in ECC but is now scheduled for 2006.

8.2.10 Immobilized Tritium Container (ITC) Storage Vault

The storage arrangement of ITCs in the vault is not optimized. At the current rate of tritium removal, the vault will not be able to hold lifetime production of the TRF[26].

9 ASSESSMENT OF TRF CHILLED WATER, STEAM AND LOW PRESSURE SERVICE WATER SUPPLY SYSTEMS

9.1 Chilled Water System Description

The Chilled Water System in the D_2O Management Building is required to supply water from 6 to 9°C to the Heavy Water Upgrader equipment, D_2O supply equipment, Tritium Removal Facility heat exchangers and unit coolers, Control Room, computer Room and I & C Equipment Room Air Conditioning System.

[25] Smear records do not substantiate this statement, there is disagreement between various people on the level of contamination within the glovebox
[26] Increase in rack space is scheduled for the end of 2005.

The Chilled Water System consists of the following major components:

RFU1 and RFU2 are used to provide refrigeration for chilled water.
Pumps are used to circulate the chilled water for process cooling.
Valves are used for bypass and process isolation.
Compressors are used for compressing the refrigerant gas.

9.2 System Condition Statement, Degradation and Remaining Life

9.2.1 RFU1 and RFU2

RFU1 has been replaced because of poor reliability. The RFUs degrade by corrosion and motor winding aging. Nevertheless, RFU1 is expected to last for the life of the plant.

RFU2 operates reliably, but uses Freon R12. The MOE requires Freon R12 replacement around 2007. While RFU2 can be used as a stand-by for RFU1, it must be replaced in order to conform to MOE guidelines.

9.2.2 Chilled Water System

The RFU1 refrigeration unit has been replaced with a unit that is too large when system load is low such as during winter months. Tube bundles on chillers have not been pulled for inspection.

9.2.3 Valves

Valves have served the system well so far, but wear and corrosion have been observed. Some replacement is needed. There is potential for degradation due to wear on seats or leak through stems. With some replacement, the remaining valves are expected to last the remaining design life of the TRF.

9.2.4 Piping flanges and seals

Corrosion of lines and bolts has been noted, but corrosion is not extensive. There is potential for degradation due to aging of seals. With some replacement, the remaining flanges and seals are expected to last the remaining design life of the TRF.

9.2.5 Compressors

Corrosion and motor aging may lead to degradation. The RFU1 compressor is new, and will last for the plant design life. The RFU2 compressor will last with a good PM program, but the complete unit must be replaced to comply with MOE guidelines for Freon use.

The Chilled Water System is a closed loop system and there are signs of biological growth in the system. This growth enters the flow indicators and reduces the flow sufficiently to signal the plant to stop operation. The system has been flushed and the TRF now has a biocide addition system.

9.3 Steam and Condensate System

The steam and condensate system has a problem with water hammer caused by two-phase flow and differences in temperatures between various condensates. Steam from the plant is poorly regulated especially on shut down; a relief valve is observed to open frequently on shut-down.

9.4 Low Pressure Service Water System

Low-pressure service water uses lake water and as a result has biological growth and some zebra mussels. External corrosion is evident beneath pipe lagging and may be caused by high humidity in the room. Replacement of carbon steel bolts in the plant has been planned but not executed. Materials are available, but resources are insufficient to complete the task. There is an SCR on the Low Pressure Service Water low flow tripping the TRF and the crud build up. Although no problems are anticipated for continuing service, refurbishment of corroding pipes may be required.

9.5 Re-Circulating Cooling Water System

This cooling water system is contaminated with particulate matter and biological growth. This has caused some problems with the flow measurement devices.

10 ASSESSMENT OF TRF AND D_2O MANAGEMENT BUILDING VENTILATION (SCI 73690)

10.1 System Description

The ventilation system removes heat, provides general ventilation, provides purge air to areas where leakage of hydrogen isotopes may occur, minimizes contamination inside the building, and minimizes the release of contaminants to the environment.

The system consists of the following components:

- **Supply Air Fans** draw outside air through intake louvers and distribute air through ducting to all areas of the D_2O Management Building and the H_2 Compressor Room of the TRF.
- **Heating and Ventilating Units HVU1 and HVU2** draw outside air and distribute air by means of ductwork to all areas of the TRF except the H_2 Compressor Room.
- **Air Cooling Unit ACU1** provides additional ventilation in the VPCE Room by removing heat generated in the process.
- **Steam Heating Coils, Face and Bypass Dampers** heat outside air to about 15°C in winter, before air is distributed to various areas of the building.

- **Exhaust Fans** exhaust air from all areas of the building.
- **Exhaust Filter Units** consist of a steel housing, a bank of pre-filters, HEPA filters, and charcoal filters that minimize the release of contaminants to the environment.
- **Dampers** allow proper system flow and pressure balance.

10.2 System Condition Statement, Degradation and Remaining Life

10.2.1 Supply Air Fans

The Supply Air Fans operate satisfactorily. Therefore, problems are not identified for continuing service as long as they are properly maintained (e.g., bearing and parts lubrication). In the ventilation system, fan motors require frequent maintenance and there is difficulty balancing the air flows between the TRF and Upgrader systems.

10.2.2 Heating and Ventilating Units HVU1 and HVU2

HVU1 and HVU2 perform well. However, about 5 years ago, ammonia, a breakdown product of hydrazine, corroded the copper coils of the heating sections. Carbon steel coils replaced the copper coils, and no further corrosion problems have been encountered and no major degradation is anticipated. The HVUs are expected to last until the end of the TRF design life.

10.2.3 Air Cooling Unit ACU1

Current performance of ACU1 has been good. No problems or degradation for ACU1 are anticipated. ACU1 is expected to last until the end of the TRF design life.

10.2.4 Steam Heating Coils, Face and Bypass Dampers

Operation is satisfactory. Copper coils were replaced; see 10.2.2 above. The Steam Heating Coils and Face and Bypass Dampers are expected to last until the end of the TRF life.

10.2.5 Exhaust Fans

The exhaust fans F3, F4, F7 and F8 had bearing failures about 5 years ago. To reduce the torque exerted on the bearings and hence minimize bearing failure, the number of belts in each exhaust fan was reduced from 7 to 5. With proper preventative maintenance (e.g., routine bearing and belt replacement), it is anticipated that the exhaust fans will last until the end of the TRF design life.

10.2.6 Exhaust Filter Units

The performance of these units has been good. Prefilter and HEPA elements are routinely changed as part of the general maintenance program. The charcoal filters have not required change. No problems are anticipated for continuing service. With proper maintenance (e.g., routine changes of filter elements), it is expected that the filter units will last until the end of the TRF design life.

10.2.7 Dampers

Inlet louvers with dampers are provided in the south walls of the LTC Expansion Tank Room. When the dampers are opened, the LTC Expansion Tank is exposed to outdoor conditions. However, these louvers do not close completely. This could create D_2O freezing problems, particularly during the winter months. There has been no in-service inspection of the dampers, and there is a potential for degradation and malfunction due to aging. Dampers in the LTC Expansion Tank Room need replacement because of leakage and aging.

10.2.8 Vent Lines

Some carbon steel vent lines from the Recombiner outlet and the Analyzer Room are connected to Ventilation Exhaust and have experienced severe corrosion. The carbon steel lines should have been made from stainless steel.

Rust formation in the vent lines blocks the flow and causes overpressure. Some of the vent lines are equipped with relief valves. An inspection program is in place to monitor wall thickness of these vent lines and to look for signs of corrosion deposits. Some vent lines such as the Recombiner lines need replacement after a few years of service in a nitric acid environment, which is formed by combustion of nitrogen and oxygen in the Recombiner. Because the line from the TIS relief valves is connected to the downstream side of the exhaust fans, there is a potential backflow through the relief valve discharge line into the room during the relief valve change out. To eliminate backflow through the TIS relief valve discharge line, changes to operating procedures will be used to ensure that exhaust fans are not running during relief valve change out.

10.2.9 Exhaust Stacks

There are three exhaust stacks in the Heavy Water Management and TRF Buildings. No inspection has been done on these exhaust stacks to date; the stacks may degrade with time.

11 ASSESSMENT OF HEAVY WATER MANAGEMENT (HWM) & STATION UPGRADER (SUP), (SCI 38410/38430/34510)

11.1 System Description

The Heavy Water Management system and Station Upgrader essentially consist of the following components:

- **The D_2O Supply System (38110)** stores reactor grade heavy water coming from either the Moderator System or the Primary Heat Transport (PHT) System. It consists of eight stainless steel tanks with a total capacity of 747 m^3. It is used to stores heavy water from unit Moderator System drainage and from the PHT system. The 8 tanks are segregated, 4 for PHT water and 4 for Moderator water. Incoming high Curie heavy water feed and the outgoing detritiated heavy water product processed by the Tritium Removal Facility are both handled by the system.

- **The D_2O Cleanup System (38410)** purifies the recovered downgraded D_2O using an oil and water separator, UV oxidation unit; charcoal filters, ion-exchange columns and D_2O transfer pumps.

- **Spent Resin Handling System inside the D_2O Management Building (34510)** receives the spent charcoal and demineralized water from the D_2O Cleanup System filter (38410-FR1) into a 5 m^3 storage tank (34510-TK4) and also receives the spent ion exchange resins and demineralized water from the D_2O Cleanup System ion exchange columns into a 10 m^3 storage tank (34510-TK3). Spent ion exchange resin and charcoal from 34510-TK3 and –TK4, are transferred to the TRILLIUM transport containers for off-site disposal.

- **The D_2O Upgrader (38430)** uses vacuum distillation to remove light water from a mixture of light water and heavy water, and produces a sufficiently high isotopic concentration of D_2O to be used in the moderator and Heat Transport systems.

- **Downgraded D_2O Transfer System (38500)** transfers and stores downgraded heavy water collected in the station during normal operation. The system consists of a 10 m^3 tank reserved for oil contaminated heavy water and two 25 m^3 tanks reserved for downgraded heavy water.

11.2 System Condition Statement, Degradation and Remaining Life

11.2.1 General Comments:

The Heavy Water Management and Upgrader systems have been performing well but are showing signs of deterioration. Health Reports have been prepared on these systems over the past four years. The rating of the system for the past two years is yellow (marginal). This marginal rating is given because the clean-up systems cannot provide sufficient feed water to the Upgrader system. The moderator and PHT isotopics have continued to meet the targets of ≥99.96% and ≥99.00% D_2O, respectively. The SUP capacity factor has progressively declined from 91% to 65.4% (June 30, 2004) in part because of a UV oxidizer used for feed chemistry control and because downgraded feed D_2O for upgrading was not available, i.e. the processing rate was greater than the demand. The UV oxidizer operates well but it requires two days to process 20 Mg of water in comparison to the rest of the clean-up system, which requires only 4 hours. The bottleneck in the UV Oxidation system arises because it recirculates water. Recirculation

is necessary since initial output of water does not meet the specification for organics. This is a new system and may require optimization.

In general, a UV oxidizer not meeting specifications may be due to a number of reasons:[27]

- UV oxidation by itself is not effective on all organics
- UV oxidation can require a long residence time, that may result in recirculation
- The UV lamps in the unit can age, resulting in reduced output
- The lamps can become coated with time and may require cleaning
- Lamp(s) can malfunction

Successful control of the chemistry of the feed water to the Upgrader resulted in continuous operation since 1988 without the distributor plugging. However, in 2004 during an inspection, distributor plugging was observed.

The UV oxidation system destroys organic impurities and results in water with high conductivity and low pH (possibly the result of carbonic acid from the CO_2 dissolved in the water). Carbon dioxide is formed during the destruction of organic material. The UV oxidation product goes back to the D2O Cleanup Product tank and is not necessarily reprocessed in the IX system.

The spent charcoal tank must be emptied. The tank fills above the recommended half-full level as a result of problems with level indicators. Emptying this tank, which has been a high priority item for years, has not yet been addressed. If this tank is not emptied soon, it will cripple operation of the Upgrader.

An action to modify the Upgrader sampling cabinet has been in progress for years. Ergonomics of the sampling ports discourage taking water samples and this results in using crude indicators, such as visual inspection, for corrosion monitoring.

The Storage and Inventory system lacks adequate storage capacity to support the station during outages. The HWM system handles a large number of drums and for want of storage space, temporarily stores the drums in available spaces such as corridors, stairways and other empty spaces leading to housekeeping issues [1].

11.2.2 The D_2O Cleanup System

Valves are in good condition but all valves and elastomers degrade with age. Elastomer replacement has been performed on critical valves, and other replacements are planned as part of the Plant Seal Replacement Program.

Oil and Water Separator. The unit was commissioned, but it never operated because downgraded D_2O collected from the moderator and heat transport systems is relatively oil free. Performance of the oil and water separator is yet to be demonstrated.

[27] Discussions with Dr. A. Rudolph and Dr. S. Dias at Kinectrics

UV Oxidation Unit. The unit reduces organic contaminants in downgraded D_2O from 40 ppm to less than1 ppm TOC. The performance of the UV Oxidizer has been verified during commissioning, but new issues have arisen. The effluent water has high conductivity, low pH, and occasionally high peroxide concentrations. To reduce the high conductivity and to raise the pH, water is processed through ion-exchange columns in the D_2O clean-up system. This processing results in a faster spending of costly ion-exchange resins and longer clean-up times, which reduces Upgrader capacity factor.

D_2O Cleanup Pumps. Current performance of D_2O transfer pumps 3841-P1 to -P3 has been good. No problems are anticipated for continuing service. No major degradation mechanisms can be identified, since pumps are normally used in the low temperature and low pressure service conditions.

11.2.3 Spent Resin Handling System inside the D_2O Management Building (34510)

Ion Exchange Columns and Filters. The performance of ion exchange columns and filters is satisfactory, and should continue as long as spent resins and filters are replaced during maintenance. However, two operational problems remain.

1. To prepare spent ion exchange resin and charcoal for disposal, the two are slurried in the storage tanks (4510-TK3 and -TK4) and pumped to TRILLIUM transport containers. Due to poor design configuration (i.e., a long pipe run of ~100 feet and flow restrictions), high pressure pumping (~ 1200 psi) is required to flush the transfer lines. Nevertheless, residual spent ion exchange resin and charcoal remain in the transfer lines and block flow.

2. The second operational problem has been traced to the tank being full of charcoal. This prevents the system from being used as intended (it prevents the fluffing up of the charcoal with demineralized water before slurrying. This could be fixed by limiting the level of the charcoal to a maximum of 50% of the tank[28]. The tank level indicators also read offscale high

The current method of slurring spent ion exchange resin and charcoal in the tanks and pumping the slurry to transport vessels requires review and redesign. These problems need to be solved because the ion exchange resins maintain feed water chemistry at the correct levels, and feed water that does not meet the feed water quality cannot be processed in the Upgrader.

11.2.4 D_2O Upgrader

D_2O Upgrader Pumps. These pumps are built with double seals and are supplied by Hayward Gordon. The pumps provide adequate service but the maintenance effort is high. The pump failure rate (one or two pump failures per 3 to 4 months) is larger than generally acceptable industrial standards. Operating experience indicates that the pump oil seals are also prone to failure. At the advice of the pump supplier, different viscosity oil was used as lubricant, but the situation has not improved. A work program is planned

[28] Opinion of the System Engineer.

to resolve this issue. These pumps may need replacement during the remaining life of the TRF.

Distillation Towers. The performance of the distillation towers has been relatively trouble-free. A chronic problem of heavy water distillation that has also occurred at other nuclear sites such as BND and PND, is that distributors plug. Darlington has been able to reduce plugging of distributors by strictly controlling the chemistry of feed water to the Upgrader. However, a recent SUP Tower Visual check noted that several distributor nozzles are plugged to the point where downcomers are overflowing on Sections 5 and 6 of Tower 1 and Sections 19, 21 and 24 of Tower 3. Tower 3 is scheduled to be opened during the next outage. While chemistry control of feed water has allowed long operation, it is clear that plugging has begun and the distributors need to be cleaned. Tower packing will last to the end of the design life of the TRF providing no major contamination of the system occurs. The packing is phosphor bronze with an oxide coating, this coating is vital to the correct operation of the packing within the tower and it can be damaged by poor water chemistry and oil ingress. It is possible to regenerate the coating but the process is difficult.

Heat Exchangers. The performance of heat exchangers has been satisfactory. They are expected to reach the design life of the SUP.

Evaporators and Reboilers. The performance of evaporators and reboilers has been satisfactory. They are expected to reach the design life of the SUP.

Turbine Flowmeters. These flowmeters do not provide reliable control for feed, top and bottom material flows. This is a generic issue that has also occurred at PND and BND. The "automatic mass balance" scheme for the distillation cascade cannot be performed and the overall mass balance is set manually. Investigation of more reliable and accurate meters, such as Coriolis flowmeters, has been made and an implementation program should be planned.

Vacuum Pumps. Liquid ring vacuum pumps P14 and P15 have operated reliably.

Miscellaneous Systems. Other systems such as various collection sumps, D2O recovery and ALW have not been included in this report.

12 ASSESSMENT OF HEAVY WATER MANAGEMENT & TRF BUILDINGS, (SCI 23800/23900)

12.1 System Description

The Heavy Water Management Building is an L-shaped building, which houses the D_2O Station Upgrader (SUP), D_2O storage drums, other equipment and associated systems such as instrument and control systems necessary to support the intended functions. The extreme south of the high portion of the building contains the D_2O Upgrader columns. The remaining lower portion of the building is intercepted by the adjacent TRF building. Roofs subjected to weather at various elevations are

Upper roof at El. 143 m for D_2O Upgrader Area,
Roof at El. 121 m for Air Conditioning Equipment Room,
Lower roof at El. 115 m and
Roof at 104.5 m for Loading Bay.

The TRF Building is a rectangular shaped building, which houses the process equipment and associated systems for the Tritium Removal Facility. The TRF Building is adjacent to the Heavy Water Management Building at the southeast location. Roofs subjected to weather at various elevations are

El. 138 m,
El. 128 m,
El.118 m and
El. 112 m (general roof, covering about three quarters of the entire TRF structure).

12.2 System Condition Statement, Degradation and Remaining Life

12.2.1 Roofs

The roof of the Heavy Water Management Building (El. 115 m) is adjacent to the roof of the TRF Building (El. 112 m). Heavy rainfall collects on the roof of the Heavy Water Management Building and drains onto the roof of the TRF Building; the apparent precipitation load on the TRF roof is therefore heavier than suggested by simple measurement. Three roof leaks have been observed—one in the CRS Compressor Room (near the gravity ventilators), one in the HWMB room containing the Stack Monitors, and the last in the Exhaust Fan (F3 & F4) Room in the HWMB.

12.2.2 Blow-out Panels

Some areas of the TRF Building contain gaseous hydrogen isotopes. Blow-out panels are provided in the TRF Building for explosion venting as part of hydrogen safety protection. These blow-out panels are installed on exterior walls and roof and are designed to relieve at a maximum pressure of about 1.2 kPa(differential). Each blow-out panel is attached to the steel frame of the building by a 16 mm diameter pivot hinge rod (on the top of the panel) and a magnet (near the bottom of the panel). However, a few years ago, several blow-out panels on the East side of the TRF Building (near the LTC and HTC Room) were blown away by high velocity winds. Further investigation also revealed that the tie back clips from the blowout panels had not been secured properly to the panel frames during initial installation. The screws used to attach the clips to the panel frames had either sheared, become dislodged, or were never installed. Plywood panels were temporarily used to cover the opening. Later, the tie back clips for the blowout panels were repaired, and the plywood panels replaced by standard blow-out panels. Seals on the blowout panels have become separated at the corners and some of the caulking has deteriorated with age; both are possible source of water migration into the building. A building inspection in 2002 also uncovered damage to the single panel on the north side of room TR-203. The damage does not affect the panel's ability to perform its design function, but it requires repair.

13 ASSESSMENT OF TRF AND SUP (HWM) COMPUTER SYSTEM, (SCI 69791/69891)

13.1 System Description

The TRF and SUP Computer System consists of the following components:

Hardware:

- **SCI 69791: Man-Machine Interface (MMIF)** complete with Monitors, XP-400 DCT Logic Boxes, Keyboards, Mice
- **SCI 69791: Universal File Servers AP6400**
- **SCI 69791: Dual Ethernet Data Highway** complete with transceivers, fan-out boxes and repeater.
- **SCI 69791: Distributed Control Units DCU3200** complete with: DCU Power Supplies, Frames (Chassis), I/O Boards, Interface Terminal Boards and their Power Supplies.
- **SCI 69791: External Lambda Power Supplies**
- **SCI 69791: Printers** complete with Printer Server

Software:

- **SCI 69891: Symphony SR 3.0 System Software**
- **SCI 69891: Conductor UX dcu-sup Software, 7.1.16**
- **SCI 69891: Configured Control Software.**
- **SCI 69891: Configured Display Software.**

13.2 System Condition Statement Summary

All system components are relatively new (acquired by ABB in late 1996 and installed at Darlington in November 1998). However, not all components are equally reliable. Since 2001, the system has been monitored according to Performance Monitoring Procedure SPMP 69791 and Health Reports have been filed (See Section 20 for details).

Summary of system components:

1. Man-Machine Interface. Performance has been satisfactory and failures can be handled with some replacements. This system is expected to last the design life of the TRF.

2. Universal file servers. Performance has been fair. No major problems are anticipated in the near to medium term. There are sufficient spares and redundant equipment to last the design life of the TRF.

3. Dual Ethernet Data Highway. Performance has been satisfactory. With replacement of some components these units are expected to last the design life of the TRF. However, there are problems obtaining spares due to obsolescence.

4. Distributed Control Units. Performance has been satisfactory. Spare parts exist for this system. At the time the system was purchased, it was expected that suppliers would continue marketing this system. However, this has not been the case. To ensure support, a further inventory of spare parts should be collected.

5. External Lambda Power Supplies and Intrinsic Safety Relays and Barriers. Performance has been satisfactory. Spare parts for the power supplies are limited. However, they are expected to last the lifetime of the TRF.

6. Printers. Performance has been satisfactory. Replacement will be required before the end of the plant lifetime but this is not difficult.

7. Operating System. Performance has been satisfactory. Standard software maintenance is considered adequate to maintain the system for the design lifetime of the plant.

14 ASSESSMENT OF TRF AND SUP INSTRUMENTATION AND CONTROL, AND ELECTRICAL EQUIPMENT

14.1 System Description

This section assesses both field instrumentation and control equipment (other than the computer control system) and electrical systems for the TRF and SUP. Input has been primarily obtained from Control Maintenance staff.

14.2 System Condition Statement, Degradation and Remaining Life

Rosemount Gould transmitters throughout the plant have been mounted sideways rather than vertically, and this results in bubbles in the transmitters. In the incorrect orientation, they are difficult to flush or calibrate. An SCR has been raised.

Hard-wired shutdown relays were recently repaired because the springs on the relays had failed. They had been closed for 15 years. While they were checked periodically to ensure that the relay opened, they were only checked to ensure that the contact lifted, and they were never checked to determine that the contact went to the fully open position. Springs on the relays in the hard-wired shutdown system are aging, which is a safety concern. The majority of these shutdown relays have been replaced and more will be replaced in the next TRF outage.

No PM tasks have been identified for gauges in the plant, and therefore reliability of readings may be questionable.

Heavy electrical equipment appears to be fine; however, there is little guidance on equipment maintenance. Cabling in the plant is not a problem except for the Class 1 Division 1 connectors, which may be damaged but have not been inspected.

Hydrogen detector electronics do not fit the housing and the maintainers break the boards every time they remove them for calibration.

14.2.1 Analytical Equipment

The analyzers are obsolete; spare parts are not available and analyzers need frequent maintenance. For example an oxygen analyzer has been out of commission for 2 years. Capacitors on circuit boards of analyzers are failing and no longer protect IC chips from voltage spikes. The IC chips are obsolete and cannot be replaced. Moisture analyzers on the Air Clean Up System were obsolete when they were installed, 15 years ago. Today, they can no longer be maintained.

Area and process tritium monitors have obsolete IC circuits. If they fail, the complete unit will have to be replaced. Replacement monitors are still available.

14.2.2 DMS

Oxygen analyzers on the DMS system can fail if left exposed to oxygen, generally the system is left purged with helium. In addition they were not designed to operate with backpressure. The upstream rupture disk (set at 100 kPag) bursts easily (SCR D-2002-04342).

14.2.3 Auxiliary Equipment

Gauges and elastomers on the gas supplies need replacement. The gauges do not read correctly in many cases but they are still used for control purposes.

Annunciators on beetles are obsolete.

Control room mimic panel annunciators and lights are failing due to age.

Intrinsically safe relays and barriers on Sulzer equipment were replaced at the time the control computer upgrade was made. However, intrinsically safe barrier systems on auxiliary equipment and on non-Sulzer equipment were not replaced. These barriers are important for the hydrogen safety within the plant and an assessment should be made on the necessity of replacing more units.

14.2.4 Recombiner System

There are flow transmitter problems on the Recombiner. The control valves are oversized for the lines on which they are installed, resulting in a slow response. Operators run these valves manually. Controllers and flow orifices were obtained from two different suppliers and may be incompatible.

Leakage from RV2401 caused surface contamination in room TR207 (SCR D-2000-00897). This leakage was resolved successfully. This serves to highlight the critical nature of this relief valve.

14.2.5 Feed Treatment System

The weigh scales run hotter than their normally expected temperature; there is no PM program for flow switches on this system and instrumentation is obsolete.

14.2.6 VPCE

Rosemount Gould transmitters are mounted sideways (see above) and Control Technicians cannot guarantee calibration of level transmitters. They should be replaced by level switches.

14.2.7 DU

The Panametrics dew point meters are obsolete; the sensors are available but the electronic boards are obsolete.

14.2.8 Cryogenic distillation system

The controllers for the heaters are poorly designed. Many IC's are obsolete. One of the gas thermometers has failed and the gas has leaked from it. Diffusion pumps have failed but repairs were possible. Diffusion pump valves are obsolete.

14.2.9 Cryogenic Refrigeration System

Ashcroft pressure switches do not operate reliably because their set points change whenever the cover on the switch is replaced. The CRS shows corrosion in the cooling water system, and flow indicators, blocked by debris, do not reliably confirm flow. Temperature measurements on cooling water lines could be used instead for flow indication. European DN fittings on the CRS are not readily available in Canada.

14.2.10 Tritium Immobilization System

Failing capacitors have been found on ion gauge controllers, pressure transmitters, turbo pump controllers and the mass spectrometers. Valve FCV405, used for draw-off of tritium from the HTC, does not operate reliably. Several instruments have required repair to ensure continued operation (e.g. W.O. #D-83174, D-83238, D-96286, D-1142181 and D-1153486). Instrument controllers, readouts and relays have been installed in the confined spaces of the control panels and racks without adequate ventilation. As a result the units are exposed to higher operating temperatures than recommended which may affect instrument reliability (WO #D-613664).

The mass spectrometer used to analyze the quality of tritium gas has experienced several computer component-related failures (e.g. W.O. #D-83174 and D-1153486). Although still functional, the mass spectrometer is obsolete and replacement parts are difficult to obtain. The mass spectrometer CRT is difficult to read. There are plans to replace the mass spectrometers (W.O. #D-1117289). Instrument cables and elastomer instrument seals exposed to the dry glovebox atmosphere have not been inspected or replaced.

15 SUMMARY

The findings of this investigation indicate that the TRF after 15 years of operation has experienced significant degradation in key systems:

- The Air Cleanup System (ACS) has been inadequately maintained and design deficiencies have been found. It is an essential system, required during accidents. A periodic test has been developed for the ACS to ensure critical equipment is available for service and that the dryer bed regeneration cycle is operational.

- Electrical and instrumentation systems are considered potential problems due to the age of the systems, and limited availability of spare parts.

- The Low Tritium Cold box and High Tritium Cold box systems have not seen a full PM program. Engineering staff have noted that the cold box should be inspected.

- The cryogenic adsorber system operates with only one functional adsorber bed, and this carries a certain risk. Resources have not been assigned to design and build replacement adsorbers.

- The Drain and Purge System (DPS) pumps have experienced repeated failures.

- The Recombiner is run manually because the control loops do not operate satisfactorily. The loop seal on the Recombiner vents frequently and could emit activity.

- The Deuterium Make-up System is unreliable when required for start up and consequently slows the process. Electrolyte level control is inadequate

- The Cryogenic Refrigeration System (CRS) contributes to downtime because oil migrates to cryogenic areas; this appears to be an operational issue and is not primarily a result of equipment degradation.

The Heavy Water Management and Upgrader systems perform well but are showing signs of deterioration. Successful control of the chemistry of the feed water to the Upgrader resulted in continuous operation since 1988 without distributor plugging. However, an inspection in 2004, observed distributor plugging; remedial work is required.

The TRF Chilled Water, Steam and Low Pressure Service Water (LPSW) supply systems show signs of wear and corrosion. The LPSW system has biological growth and zebra mussels. However, no significant problems are anticipated for continuing service although refurbishment of corroding pipes is required. Replacement of carbon steel bolts in the system is recommended.

The TRF and HWM Building has experienced some roof leaks and blowout panel damage.

The performance of the TRF and HWM Building Ventilation System has generally been satisfactory. No problems are anticipated.

The TRF and SUP Computer System components are relatively new (acquired by ABB in late 1996 and installed at Darlington in November 1998). However, reliability of components varies. Since Q2, 2001 the System has been monitored by Performance Monitoring Procedure SPMP 69791and Health Reports have been filed. The performance of the system has been satisfactory.

Short-term steps to improve TRF reliability are procedural. It is recommended that the following steps be taken to reduce the probability of repeated forced outages:

- Eliminate oil ingress to the CRS by revising operating procedures to stop pumping oil around the circuit when the CRS is warming or when the turbine has no load (not extracting energy); brief all operators on the revised procedures and have them acknowledge their understanding

- Change turbine oil only after analysis shows that it is warranted, rather than changing the oil on a schedule. Use dry oil and revise the oil specification to include this requirement.

- Evaluate extension of H_2 compressor scheduled maintenance intervals and if accepted, increase the intervals between maintenance cautiously from 8,000 h to 20,000 h. This should be done in increments of no more than 2000 hours over a 4-year period with increased monitoring.

- Perform root cause analysis for the DPS metal bellows pump failures and eliminate cause of the failures.

In the medium to longer term, the plant can only be improved by replacement of components such as the Adsorber Unit. The majority of the components in the plant will not be replaceable on a "like for like" basis because they are obsolete; replacement requires design engineering and the ECC process.

Replacement parts for some of the specialized equipment at the DTRF have been eliminated from stores at OPG. With an increasingly rigorous procurement process getting suppliers approved and parts on order is now a significant piece of work for the station.

Another improvement to operation is a project to install double block-and-bleed isolation valves on the front-end systems to isolate the LTC Expansion Tank. A significant time saving (several weeks) will be realized by avoiding burn down of large quantities of D_2 gas and subsequent generation of this gas for start-up and inventory build-up. The project has been scheduled since 1991 but has not had sufficient resources and priority to be completed.

In parallel to the Life Cycle Management project, it is important to pursue the Maintenance Improvement Initiative project, which is aimed at asset preservation. The

scope of this project is to improve configuration management, prepare maintenance procedures where they are missing, and build Bills of Material (BOM).

16 ACKNOWLEDGEMENTS

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17 REFERENCES

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2 Gas Purification, Arthur Kohl, Richard Neilson, 5th Edition, 1997, Gulf Publishing Company.

3. Metallurgical Analysis of Cracks in Spool Piece From HX1206, DND-TRF, Kinectrics Report: 3790-030-RA-0001-R00, August 2003.

18 APPENDIX: CONTROL MAINTENANCE – LIST OF INSTRUMENTATION PROBLEMS AT THE DTRF

(Given to the authors during the interview stage)

1. Tritium Monitors 0-63945-AN2451, 2501,2551,2571,2701 – Overhoff – obsolete and failing capacitors, IC's are obsolete
2. Tritium analyzer Transmitter 5 in 1 0-63945-AT2701, 2451, 2501, 2551, 2571 – Overhoff – obsolete and failing capacitors
3. Hydrogen Analyzers 0-63945-AN2702, 2752 – Teledyne 227 AMB-20X – obsolete IC's
4. O2 Analyzer 0-63945-AN2401 – Teledyne 307WAM-020X – obsolete IC's
5. O2 Analyzer-0-63945-AT2601, 2652 – Teledyne 317A201X – obsolete IC's
6. DMS Electrolyser 0-39330-EM1800 – Teledyne – needs to be replace – entire unit
7. Mass Spectrometers 0-39720-AIS110, 0-39720-AIS210 – Spectromass Dataquad – obsolete equipment, failing capacitors, obsolete IC's
8. Ion Gauge controller 0-39720-PIS210 – MKS Type 290 – failing capacitors, obsolete IC's
9. Vacuum Pump controller 0-39720-JC139, 0-39720-JC239 – Leybold-Heraeus NT150/360 – failing capacitors, obsolete IC's
10. Pressure indicator 0-39720-PIT107#1, PIT117#2 – MKS 270B-failing capacitors. Obsolete IC's
11. Heater controller SCR 0-67369-HTR101, ITC Oven 0-63979-TC1, Partlow, 0-39790-OV1 – obsolete controller, failing capacitors, obsolete IC's – Dispatch Controller – obsolete – Barber Coleman Controller – obsolete
12. Weigh Scales – Tank Type 0-63934-WI1101, 1102, 1201, 1202 – Masstron, have to operate with doors open due to heat build up, obsolete IC's
13. Auto valve vacuum pump/valve controller – 0-62941-XC1501, 0-62942-XC1601, 0-63944-XC3301 – CVC Products – obsolete, obsolete IC's
14. Control Room CRT's – 0-69791-CRT1, 2,3,4,5 – failures due to heat
15. Elkon Panel SCR Heater controllers – 0-63900-PL1862-21 – obsolete IC's on firing boards
16. Ashcroft Pressure switches – poor design – setpoint changes when cover is put back on
17. Vacuum pump – solenoid valves (Shuttle type) – obsolete, not able to obtain equipment, seals not able to be obtained
18. PRV 0-63933-PRV1807, elastomers, Fisher 98H, an example of many PRV's that require elastomer replacement
19. Hydrogen detectors 0-62344-AE1 to 13, Bacharach 234012 – transmitter boards
20. FAATM's – 0-62341-RM101 to 123, Overhoff T-321-OH, failing capacitors, obsolete IC's

19 APPENDIX: INTERVIEW NOTES

Interviews with DTRF Staff – Held December 8th and 9th, 2004
(Note there are comments from the report's authors, placed in these notes in square brackets and italics. These comments are intended to indicate key areas where the opinion of the interviewed staff member can or cannot be substantiated directly with evidence.)

19.1 Operations Staff

General Impressions of Plant Health
Over the last 10 years the plant has become less reliable. Long-term problems are lack of bills of materials, procedural problems, and the need for capital improvements. They need a supplier's list and a clear idea of where to get parts. It is their belief that achieving a 60% capacity factor would be sufficient for the plant. Actions that would help

- Reduce the waiting time for spare parts. Getting parts takes too long, even though the parts may be in stock.
- Increase the priority the DTRF has at getting spare parts out of the system
- Need the compressors in separate rooms to allow for maintenance; ideally would like to see 3 compressors
- Consistent procedure for DTRF start-up
- Dedicated maintenance crews for DTRF

Very low history of major investment at the plant except for the new control computer. The TRF has not been given adequate priority within the Darlington Station.

New valves that have been installed have improved operations.

Operating experience/outage experience
As far as the procedures to run the plant, they have never started up or shut down the plant in exactly the same way twice. They do not have a clear shut down/start up manual. There are often no contingency plans and each start up is inconsistent in terms of the procedures used.

If there is an unplanned outage, there is often no list of other jobs to address during the outage (a lack of an outage plan). Lack of availability of station services such as steam or power will cause shut down of the DTRF. They have no control over this but it can have a major effect on their capacity factor. Often the DTRF staff is used in the Nuclear station during outages, as a result they build up banked time which they take off when they return to the DTRF resulting in problems there.

It takes time to get the plant properly set up during a start up; frequently now they find they are forced to start up rapidly.

Cryogenic Adsorber
Five years ago they were meeting about the problems with the adsorber bed 1401, as yet nothing has been done to completely solve this problem. They only use 1401 during start

up since they can't get any normal flow through it. Bed 1402 is virtually un-pluggable. They believe that one of the beds has cemented closed and the other has cemented up with a hole through it. The adsorber bed 1402 runs up to 6 months without regeneration. Seems to act as a cryo trap, temperature is 80-90K for the operating point. As long as the dryer dew point is good there is no problems with the cryo adsorber. Since they don't remove all of the gas during a shut down the gas system stays clean and nitrogen is not a problem. They wonder if it is really necessary.

Dryer

The molecular sieves are probably near the end of life. Flooding problems in past operation have been stopped and the operating experience is better. There has been leaking of drain valves and they are known to pass gas. They have reworked the seats on valves in the dryer to prevent cross leakage. However the dryers are not achieving the same dew point they used to. They used to achieve, off scale low, now they struggle to get to –80°C dewpoint. It takes a long time of operation to go the last little bit of the dewpoint, they have waited up to a month to get below a certain level of dewpoint. Pressure drops across the beds have stayed consistent over the years. They wonder if the dewpoint they are seeing now is the correct number and previously measured lower values were a calibration problem with the dewpoint meters. The dryer is not user friendly to maintain. Some of the drain lines are plugged with desiccant fines.

DPS

They can't properly purge this unit. There is a reliability issue with the Metal Bellows pumps. The unit is not reliable; they cannot always rely on it being available to remove gas. For example at present the last metal bellows pump, which acts as a compressor, now shows a bit of excessive noise. There are chronic problems with the MB pumps and this needs a full investigation

DMS

They have had fires and rapid flame propagations in unit. It now requires a C/M tech to be present to start it up. This unit is not reliable and is not always available when they need gas.

This is a critical system for start-ups, but the operation of the unit is "hit & miss". The DMS is tested monthly on call-ups, but the tests may not be adequate. Some PCVs in the DMS are obsolete. Newer models of electrolysers are available on the market.

TIS

Have had a number of major equipment failures (pumps, pressure transducers and the mass spectrometers), and spare parts have been raided from the TAP. They have just about used up all available spare parts. At one point in the discussions it was noted that the parts that are broken and removed from the TIS, have been put back into the TAP in place of the spare parts being raided. When they come along later to look at parts in the TAP they discover they are looking at an old TIS part not a new one. The mass spectrometers are at end of life.

The Operators find the mixture of units (i.e. kPa, torr, atmospheres) on instruments within the TIS a problem when operating. Operators have also noted complications between

absolute and gauge pressure measurements and it was noted that certain operators might not understand "millibar" and instead rely on knowledge of "where the needle should be". The turbo pumps have been often replaced. The oil-lubricated vacuum pumps are not maintained but are completely changed out due to handling concerns of tritiated oil.

The Storage Vault is running out of space and there is a requirement by CNSC for access to the ITCs. A revised layout that gives more storage space has been approved by not yet implemented.

The main problems experienced with the TIS are availability of spare parts, dose hazard associated with tritiated pump oil, failure of turbo pumps, rotary vane pumps, mass spectrometers and operational problems of FCV405. The TIS could potentially be a real problem in the future due to the large number of components.

Some equipment, which is installed in the gloveboxes, tends to overheat due to the argon atmosphere. It is necessary to heat about 10% of the ITCs to enable tritium immobilization. The type of flexible hose connection used in the TSC airlock is preferred over the bellows connection used to couple ITCs in the ITC airlock. Glovebox 2 is used for tritium immobilization about 60% of the time due to its additional installed equipment. The gloveboxes are clean of tritium contamination.

FTS/VPCE

The operators do not have many problems with this area. The VPCE sight glasses seem very unnecessary; they question why they were ever installed especially in this area of high curie water. No real problems since there are few moving parts. The main problems have been steam leaks in the superheaters.

The VPCE sight glass gaskets have been replaced and are leak tight now, but could be a potential source of problems in the future.

Cryogenic Distillation Columns

The main Cold boxes are not a problem. Cryogenic valves were refurbished at the same time that they worked on all of the valves. Sometimes they get liquid hydrogen where they don't want it during start up.

CRS

Oil problems have plagued the CRS. Linde has come in to help with the current outage and they have learned a number of new things about the turbine oil lube system they did not know before. They should not be changing the oil every year only when testing it indicates it needs it. They do get support from Linde but only at a high cost. There is a manual valve on the outlet of the turbine that the Operators feel should be an automatic valve.

The top 3 problems with the CRS are

- They have problems now during start up getting the plant to reach setpoint of 31K that would automatically shift them from startup into operating mode. They have

to intervene every time now to get the plant into normal operations. They are not getting the full cooling on the refrigeration unit now and often need to get permission to shift set point to get into normal operating mode which kicks in extra cooling.

- Finding the cause and source of oil in the CRS and resolving it for the long term
- They have seen nitrogen concentration that is too high sometimes in the CRS after warm up.

The oil pump motor for the turbine brake is obsolete and is no longer replaceable.

The planned maintenance for the H2 Compressors causes planned downtime, but they have wondered if the intervals between maintenance could be extended.

Operators have expressed a request for a second roughing pump on the cold box ("a nice to have").

General Comments

The DPS, DMS and CRS are the top 3 problem areas. A lot of work seems to be fire-fighting type of activity.

Operating crew is fairly stable but maintenance staff change frequently. The current trend is to use temporary staff and this results in no ownership of equipment.

Design changes are considered to be too much work to do. As a result people have a tendency not do design changes. Even previous changes are being returned to the original design because of configuration control and no detailed documentation has been created on the changes made. It is easier to return to the design basis than it is to do a design change. Procedures to implement design changes are onerous and resourcing is not adequate to cover the work.

The operators would like more feedback on the results of maintenance work.

The operations have daily/weekly Internal Investigation Limits (IIL)set on oxide and elemental tritium. They have occasionally hit the daily IIL. Never have they hit a regulatory limit.

The 13-week maintenance schedule used at the station is a poor fit for the DTRF due to the lack of redundancy, the number of breakdowns and the aging of the plant.
The minimum time required for equipment changeout is between 1/2 and 1 day.

The TRF does not run anything to failure by deliberate choice they maintain everything.

Operators have commented on the lack of day-to-day communication.

Control Maintenance staff

General Impressions of Plant Health
The overall process is finicky – but once operating, operates reasonably. The new control computers have helped to improve reliability and avoid upsets. It is often difficult to get through start up to steady state operation. Obsolescence of parts a major concern. Steam, power outages at the Station have impacted TRF reliability and caused downtime.

They need a clear definition of critical components. Documentation throughout the plant is not as good as they would like. OMs, BOMs have to be made up to date. There are few maintenance procedures. The availability of spare parts is a problem. They would also like to see improvements in documentation such as drawings, procedures, maintenance manuals, operating manuals, etc.

A lot of changes have been made in the past with less than the required documentation. In many cases they are now reversing these even though the change worked better due to the lack of documentation.

They keep getting told that engineering changes are too difficult and thus they have stopped doing them. Any design changes are too expensive to make – i.e the ECC process is cumbersome.

There are problems like the operation of the turbine on the CRS system with the discharge valve closed, which should not happen.

General Comments
Many of the analysers are out of date and obsolete. Spare parts are not available. For example they have had an oxygen analyzer out of commission for 2 years. Other analysers are either out of commission or unreliable.

Equipment has often been installed in poorly ventilated, hot environments. They often run equipment with the doors open to keep cool.

Transmitters throughout the plant have been mounted sideways when they should have been mounted vertically (Rosemount Gould transmitters). This results in bubbles in the transmitters and they have had trouble properly flushing or calibrating these. There has been an SCR issued on this.

Hard-wired shut down relays were recently repaired. The springs had failed. They had been closed for 15 years, people would check that the relay opened but only as far as the contact lifting, they never went to the relays to determine that the contact actually went to the fully open position with the spring. Springs on the relays in the Hard-wired shutdown system may be aging – a potential safety concern.

In many valves they have started changing the elastomers but the progress may not be fully documented. They are concerned about the regulators upstream of the valve actuators. These have not been checked but if they fail they will destroy the valve actuators diaphragms. A lot of diaphragms on PRVs have not been replaced (e.g.

PRV1807 – diaphragm has failed). Elastomers have been changed in many valves, but apparently there was no tracking system put in place to determine which elastomers should be changed again.

They are concerned about an apparent lack of a PM program on all of the gauges throughout the plant; you cannot rely on what the gauge reads.

There is no apparent procedure for stroking valves, which are installed on seldom, used systems. As a result, many of these valves may have seized and required replacement.

Most of the heavy electrical equipment is fine. Cabling in the plant is not a problem except for some of the Class 1 Div 1 connectors that may have been damaged due to people standing on them and they have not been inspected.

Hydrogen detector electronics do not fit the housing and they are breaking apart the boards every time they remove them for calibration.

Run-to-failure would be a good idea on some of the equipment in the TRF. This is only if the parts can be obtained quickly and easily and the operators can run without the piece of equipment easily.

A comment was made: "the documentation is brutal". TAP parts have already been used for TIS, but there is no tracking of which parts have been used.

The Upgrader runs well, but they believe that as a result there may not be as much attention put to long term preventative maintenance on this system.

Analytical Equipment

Most of this equipment is obsolete. On the boards in the equipment they are concerned about the capacitors because if they fail they will destroy the IC chips that cannot be replaced. The electrolytic capacitors in many cases are old and no longer working to protect circuits from spikes. Certain IC chips in old analytical equipment are no longer made. As soon as stocks are depleted, they will not be able to repair the instruments.

On the air clean up system the moisture analyzers were old when they were installed, now 15 years later they cannot be maintained.

Area and process tritium monitors have obsolete IC circuits. If they fail they would have to replace the complete unit. These units however, are still available.

DMS

This unit is difficult to maintain. Recently the representative of the company came in and limited the current by using a potentiometer on the board. The technical representative also suggested a new way of starting up the DMS. This may not captured anywhere in procedures. The unit gets left for much of its life shut down with caustic in the system. The technicians believe it should be drained when it is not in use.

They have problems with the oxygen analyzers on the system. The cells have a life span problem due to the long time they are left without the unit being used. The Teledyne O2 analyser cell needs to be changed regularly. The backpressure on the cell is an issue – since these cells are designed to operate with no backpressure.

There have been occasions where KOD has been pushed into the vents. Some of this is due to the level control on the DMS tank. The level control system can allow you to overfill the tank because the level switches can reset after the level passes them. This eventually pushes electrolyte into the piping. This could be simply solved by having lights on the level sensors indicating which sensor the level is up to.

The combustion sensor on the cells can only be reset 5 times. This is stated on the package for the unit but there is no counter or other device to be sure that no more than 5 resets have been done (other than a label that is not always updated).

The operation of this equipment is based on a lot of tribal knowledge rather than written procedures.

Auxiliary Equipment

Low-pressure service water (LPSW) system exhibits corrosion. They think the corrosion is caused by high humidity in the room. External corrosion is evident beneath pipe lagging.

In the ACS the valves have been in one position for a long time, they are not stroked regularly and could fail.

Chilled Water System: RFU1 Refrigeration unit has been replaced with one that is too large a system for its use – so that it is under utilized. RFU2 has not been replaced – it uses Freon and therefore cannot be repaired but will have to be replaced, i.e. it's obsolete.

Steam supply to the TRF causes problems with the high-pressure steam when the TRF trips off – need positive isolation when the TRF shuts down to stop the RV from lifting.

On all of the gas supplies the gauges and elastomers need replacement. The gauges do not read correctly in many cases but they are still used for control purposes.

Annunciators on beetles are obsolete

Control room mimic panel annunciators and lights are failing due to age (presently the lights can be replaced).

The intrinsically safe relays and barriers on the Sulzer equipment were replaced at the time the control computer upgrade was done; however the intrinsically safe barrier systems on the auxiliary equipment and non-Sulzer equipment were not done at that time.

The cabling in the plant may be OK, but the Class 1, Div2 connections should be inspected.

DPS
Vacuum pump failures are a major problem. These pumps have failed 6 or 7 times. The bellows and the bearings have failed, over 7 modifications have been made to these pumps. The C/M techs are not satisfied with the logic used to start them; they have observed that the motors do a double start when turned on.

Recombiner
There are flow transmitter problems on the recombiner and the control valves seem to be oversized for the size of line they are installed on resulting in slow control. They are now running all of these valves manually.

FTS
The weigh scales are another piece of equipment that runs hot. Some Instrumentation is obsolete.

VPCE
Another system with the transmitters mounted sideways. They cannot guarantee the calibration of the level transmitters; it would help if there were level switches.

Dryer
There is desiccant in the valves on the dryer. The Panametrics dew point meters are obsolete, the sensors are the same as those available today but the electronic boards are obsolete.

The critical flow and pressure transmitters on this system are only checked if the operators think there is a problem, no regular maintenance program.

Cryogenic Distillation system
The controllers for the heaters are very poorly designed. Many of the IC's are obsolete. One of the gas thermometers has failed, the gas has leaked out of it. Diffusion pumps have failures. The diffusion pump valves are obsolete.

CRS
Ashcroft pressure switches are a real problem throughout the plant; they reset their set point when they put the cover back on the switch. The CRS has some observable corrosion in the cooling water system. It was perhaps not flushed properly when they changed from lake water to the closed loop system. Flow indicators on the system are stuck due to dirt; they need temperature monitoring on the cooling water because you cannot rely on the flow monitors to tell you if you have flow. They are concerned about all of the European DN fittings on the CRS as they are not readily available in Canada.

TIS
Instrument controllers, readouts and relays have been installed in the confined spaces of the control panels and racks without ensuring adequate ventilation. As a result the units are exposed to higher operating temperatures than recommended. The mass spectrometers are obsolete and potentially a future problem. The mass spectrometer

CRT is now difficult to read due to age. Cables within the glovebox and elastomer seals on instruments and feedthroughs have not been inspected or replaced.

19.2 Mechanical Maintenance staff

General Comments
There has been water flooding in many of the plant systems.

The plant seems to operate very well once it is up and running. It is the start up that causes the main problems.

Right after the installation of the new computer system everything ran very well and then it seemed to just drop off.

Obsolete parts are not so much of an issue for the MM staff. One of their concerns was the liquid ring pumps and how to rebuild them. Apparently recently they have found a supplier of parts.

The DMS and the DPS systems sit too long between operations and this causes maintenance problems.

There does not exist a good training program to transfer the knowledge of the older staff

Often there are no procedures for a task and they have to get it out of the manufacturer's manual. It would be a lot easier if a procedure were written down.

There are often a lack of records of mechanical changes that have been made.

Preventative maintenance system exists but it may not be adequate. They used to do a daily walk down of the plant and look at equipment operating. They would record temperatures, pressures etc. This is not done now.

Spare parts are difficult to obtain, as the BOM's are not verified. Often equipment was purchased as a skid with no breakdown of the parts.

In the Chilled Water System, the replacement RFU1 refrigeration plant is too big for the load that is on it.

They have not pulled tube bundles for inspection on chillers except for the compressors.

Some vent lines are corroded, the carbon steel lines perhaps should have been stainless. In general the ventilation system has some contamination and corrosion.

GBCS valves are seizing up due to lack of use. They are never touched and get frozen in place.

Low-pressure service water system is corroded. The replacement plan for the carbon steel bolts in the plant is still not done. They have all of the materials they just have not had the resources to do it.

Working in a hydrogen environment (Class 1, Div.2) is not considered to be a problem.

Minimum 1 to 2 days required for simple maintenance assuming spare parts are available.

CRS
The existing 8000-hour maintenance was because of the valves. They are not seeing wear anymore and feel that the maintenance interval could be extended (based only on their own experience). The cooling water system on the CRS has a particulate problem.

Dryer
Desiccant residue has been found in the valves. They have sent a camera into the dryers and looked at the bottom screens and the screens appear to be falling apart [*Note: no documented evidence of this inspection has been found*].

DPS/DMS
Pumps on the DPS are an ongoing problem. They have experienced several bellows and shaft failures.

TIS
A difficult system to work on due to the tritiated oil contamination and the fact that working on it can spread it around. The gloveboxes are dirty, that is, there is some surface contamination within them. Windows are removed for maintenance activities. The turbo pumps have been performing well since replacing the bearing with permanently lubricated ceramic bearings. The ITC airlock heaters have not required replacement. The system has been disassembled to only a minor degree. There has been very little PM performed on the system (no PM on metal bellows pumps, Nupro PVs and Jordan PRVs). Despite the lack of PM, the Nupro PVs have operated reliably. There have been no problems associated with leak tightness of fittings. With the exception of a failure of the bellows used to connect the TIS to an ITC, there have been no problems with the ITC airlocks. There have been no problems experienced with the gloveboxes. [*Note there are a total of 20 PM's existing for system 39720, of these 5 are filter replacements, 4 are RV service, 3 are PSV testing and 8 are oil changes and greasing*]

Vacuum systems
Elastomers O Rings appear to be cracking in the vacuum systems. There is no regular program to inspect or change.[*Note: in reviewing the PM listing for the DTRF there were no jobs identified with inspection of the vacuum system o-rings*] They should be changed as needed. They feel that the cold box vacuum pump capacity may need to be increased. Operators want to evacuate the cold box too fast, which reduces the life of the pump.

SUP
Liquid ring vacuum pumps P14 and P15 are obsolete [*Note: these pumps are not obsolete]*.

Chillers
The LPSW supply to the chillers is causing rusting and corrosion.

Top 5 & other issues

- DPS- MB Pumps, DMS, TIS Vacuum Pumps (Oil problem), ACS damper leakage, Blower work is difficult
- CRS turbine run for days without gas load – so that oil may have got into system.
- GBCS blower F2 was run for days without gas flows.
- Liquid Ring Compressors on VPCE, DU are obsolete.
- Is the VPCE superheater tube plugging indicative of a trend, which is a life issue?
- An RV test bench is available in the TRF but is not used [*Note: installation delayed*].
- Procedures are not available for many tasks. Manufacturer's documentation not available often.
- Ventilation system lines are now contaminated with tritium.
- Communication between groups could use improvement.

19.3 TRF System Engineering staff

General Comments
The TRF has been in the Red category in the plant system health reports for the past two years. The HWP is in the Yellow category. The health reporting system was started in 2001 and the TRF has gradually moved from white to yellow to red mainly due to the poor capacity factor, lack of spare parts and the large number of functional failures.

The worst problems are equipment aging and obsolescence and lack of spare parts.

The plant has little redundancy, lose any system and you have a major problem.

Even though the CRS has had oil contamination problems, it is not considered to be the worst system because the system has such a rigorous PM program.

The TIS has redundancy and it is not felt it is a big issue; however, they have not done a major PM program on the TIS due to the redundancy being available. [*Note; as stated before there is some PM done on the TIS*]

Major problems
The ACS is a problem since there is no PM system in place for this system and it has not been a focus of attention. [*Note: no PM functions have been identified for this system*]

The electrical and instrumentation are a problem due to lack of expertise in the SRE to support this. No focus on these systems and not much of a PM program. Interfacing

equipment such as A/D converters have not been maintained. [*Note: PM's on the instrumentation are primarily calibration*]

The LTC, HTC systems have not been worked on extensively because there are no moving parts and because they have never dropped the bottom of the LTC Cold Box for inspection. There is the ability to have a side stream drawoff and thereby reduce protium in the gas by taking a small overheads stream to the recombiner, but this side-stream appears to have been plugged since it was commissioned and they have never been able to get it running.

DPS/Recombiner systems have problems with the vacuum pumps and compressors. They are pumping on water containing systems, there may be charcoal fines in the system. The original SRTI wobble pumps were replaced by Metal Bellows pumps, which have also not been trouble-free. The recombiner has to be run on manual all of the time, none of the control loops operate. The loop seal system causes problems and creates an emission issue. Need to have the operators fill the loop regularly before start up.

A lot of the problems could be solved by a re-design of the systems but there is no program for design upgrade. Obsolescence is only driver for an upgrade, this is what resulted in the new computer system. Simple improvement is not a good enough reason to do an upgrade. The biggest problem is the design resource issue; they have projects on the books but no budgets and no resources to do them. For example they would like to put double-block-and-bleed valves on the expansion tank. This has been on the books since 1991 and they are still working on that project. The replacement of the adsorber is more of a maintenance project, a like for like replacement. However, they do not have resources assigned to design and build the replacement adsorbers. It is seen as a risk the way they are operating now with only one adsorber. There was a comment that the majority of components, where there will be significant procurement issues, are those for which like-for-like replacement is not possible. This extends even to small items such as oven controllers. Another area of difficulty will be for those components designed by Sulzer, for which there are no detailed design documents.

In 2002 they started a maintenance improvement project, an asset preservation project. They intended to look at all of the Sulzer supplied equipment where there is poor documentation for skid-supplied equipment. They were going to look at the components, categorize them, look at critical items put together the specifications and put together the necessary framework to allow procurement of these parts. They intend to restart this project in January 2005 running for 2 ½ years. The intent is to consider all components, categorize them, put together technical specifications, identify suppliers, prepare Cat IDs and build the BOMs. They would like to use the critical equipment list as a way of focussing this program. The bills of materials are not perfect for this plant. This project is supposed to get this fixed. This project is also supposed to fix up configuration management issues around the plant.

The chronic oil problem in the CRS is a major issue since the root cause is not known. They see high pressure drops indicative of partial plugging of a CRS filter. The CRS was not operating well before the current outage since the turbine flow was reduced. The DF of the plant was not 35 but running more like 18 – 22 due to lack of cooling and thus

reduction of the reflux. They can operate with this low DF as long as they are careful which water they are processing. Darlington water is low enough tritium levels that the DF is adequate, other water they run at a reduced feed rate. They have some flexibility.

The Dryer unit is another problem since the molecular sieve has not been changed since commissioning (approx. 15 years). The trend in the dewpoint has been from –90 to –95 to where it has reduced to –78 to –82 °C. This will eventually lead to a major load on the cryoadsorber. There are no sampling ports on the dryer to check the sieves. There has not been a change in the delta P across the dryer despite the aging. They have inspected the bottom of the dryer bed and see deposits and caking. Fine powder has been found in valve seats.

The DPS pumps have always got one out of service. These metal bellows pumps are specifically built for the DTRF because of the pressure requirements. Failures have occurred on the secondary bellows due to weld failure. Reed valves have been modified but are still a problem. They get failures on both the vacuum pumps and the compressors.

The recombiner only uses a single burner currently and it is run on manual. Mass flow meters have been a problem for the last 15 years. Never have had the resources to fix the problems. Corrosion has been a problem in this system, as have deposits in the pipes. The loop seal is a problem on restart and the operator has to remember to fill the loop, this would be better if it could be re-designed.

When the TRF is operating at steady state, the past operation has been pretty good. However, the start-up procedures used are not always consistent. This is because the system is finicky and also because of the aforementioned CRS problems, which create difficulty in reaching the desired low temperatures. For example, any trace impurities will cause problems in establishing levels in the last column of the HTC. Establishing levels in the HTC can sometime take 2-6 weeks, depending on the levels of residual He3.

After the computer replacement, the start up was good because extra care was taken and the plant was essentially re-commissioned.

The DMS has been a problem, but they do pretty good maintenance now.

A re-write of the procedures for the plant was done 4-5 years ago, but the procedures do need improvement. This will be part of the maintenance improvement project.

Auxiliary Systems

Chilled water system is a closed loop and there is a problem with biological growth in the system. This gets into the flow indicators and can reduce the flow and can shut down the plant. They have flushed the system and have now a biocide addition system that took 2 to 3 years to get approved but has not yet been started up.

Low-pressure service water is just lake water and it also has biological growth and a few zebra mussels. Again the main problem is the instrumentation.

The steam/condensate system has a problem with water hammer due to the 2-phase flow. Differences in temperatures between various condensates that are injected into the system also cause problems. There is a problem regulating the steam from the plant, it has been noted by a couple of groups that the steam system has a PRV and a RV that tend to operate poorly on shut down of the steam. The relief valve goes frequently as it is used as part of the shut down. Steam traps are a problem since Sulzer used European traps and there are no spare parts. They will eventually have to cut out the steam traps and replace them.

In the ventilation system there has been frequent fan motor maintenance and they have trouble balancing the flows especially between the TRF and the HWM. There is lead blanketing required on EV-1101 and TK-2201 due to gamma contamination.

HWM air cleanup charcoal beads are not evenly distributed and they will have to be reloaded. The FTS also has charcoal beds for water clean up that are running at the top end of the allowed delta P. They carefully monitor the water quality.

General Discussion

They agreed that the start-up procedures are not always consistent because the starting conditions of the system are not always the same. Getting the HTC to run properly is a very difficult task and trace impurities such as helium can affect them greatly as they are started up. To establish levels in the last columns operators end up trying a lot of different things to get them running. The operators have been given some flexibility for starting up. Getting the correct operating levels in the final columns can take from 1 week to 6 weeks on start up. Getting the correct dewpoints on the dryer is the same issue; it can take a long time or a short time. They have learned to keep the beds isolated and dry during an outage to help this process.

Right after installing the new computer system they had the best start up ever and ran very well. This was because they completely shut the systems down and removed all of the gas. They eliminated all of the trips from the computer systems, spent a lot of time on the plant (essentially re-commissioned it) and they had a seamless start up and good purity results from it. Right after this good year they were hit with human performance problems as well as unplanned issues due to oil and equipment obsolescence. The good start up after the new computer they started the LTC first and then evacuated the HTC thoroughly and filled it with clean pure D_2 from the sump of the operating LTC. They tried this again on the next start up when there was tritium in the system and it did not work. They had problems with tritium releases and valves passing.

The DMS system can delay a start up. They have had a number of module failures for which they don't know the root cause. This is not an obsolescence problem with this unit, because it is the same as ones run by other plants; however because the TRF runs it intermittently they have problems. They have had KOD carry over from the tank into valves to cause problems. They have considered replacing or re-designing the system.

The FEG matrix is a grouping of equipment into areas for maintenance so that you know all of the equipment in an area to maintain. The PM schedule comes from Passport as

"pre-defines" work requests automatically created in Passport from the information put in to it. The criticality matrix has not been integrated into the work request system.

The PM program covers all rotating machinery, hydrogen monitors, tritium monitors and relief valves (by regulation). There are gaps. For example the WEKA cryogenic valves have no PM because there is very little information available on these valves. Not everything is covered with a PM program. They have to balance what they do with the available resources. It was felt that the current PM plans are adequate.

An inspection program has been developed for components in the plant but they have a great deal of difficulty completing this program due to production pressures. They would like the inspection program brought to a much higher level of attention.

The planned work and the FIN (Fix It Now) work is all done by the same people. This is not a good arrangement

The TRF does not have an outage management group; the same people do everything. As a result they end up with problems planning outages due to lack of resources. No planning is done ahead of time for major outages since the same group is planning the day-to-day activities and running the current outage.

The plant SCR system does not capture potential equipment problems. They have their own in house list of things to do in the future. Currently there are 116 items on that list. Not all are equipment. The top 20 items are usually the focus of engineering support.

The HWM system works well so they have not spent a lot of work on it. They are feel that it is heading for problems because of this. They take a lot of care with the chemistry of the water to prevent problems.

There are serious problems with configuration management as many changes have been made to systems without being documented. The TRF status is RED due to unavailability of parts, low capacity factor and backlog of work.

Major Parts Problem

Obtaining spare parts is a very long process. Due to a streamlining of the parts system within OPG they have greatly reduced the number of approved suppliers and sole source suppliers have been taken off the list when the system was changed from Darwin to Passport. This is a real problem for the TRF where many of its parts are from sole source suppliers. It is a great burden to get a supplier back on the approved supplier list. For example, Teledyne, the supplier of the modules within the DMS system, fell off the approved suppliers list. When the TRF needed a new module it took an additional 6 weeks to get the supplier back on the list.

In addition, parts that no one has accessed for a long time have been scrapped. For the TRF this means that unique parts for equipment that is now aging do not exist. Valve seats for the WEKA valves were in stores but are not there now. There are now much more stringent requirements for pressure boundary parts and the approved supplier must be registered with the TSSA. This has also resulted in a purge of older parts.

This is going to become a very severe problem at the TRF as it goes forward. As it ages getting parts and suppliers will become more and more difficult.

Building Problems
Most of the problems in the building are the blow out panels and the aging of the hinges on these panels. The seals and the hinges require inspection and maintenance. There have been problems with loss of panels during windstorms.

There is also a problem with roof leaks. This is a problem for the whole site and apparently the responsibility for civil structures has changed and they are trying to hand it off from the architectural design group to the station and to the SRE group. This group has not experience or expertise in civil work.

19.4 Interview with System Engineering Staff -December 17, 2004

The top issues which are seen as impediments to improving TRF performance are rated as:

Lack of Spare Parts and uncertainty of availability from OPG stores
Lack of BOM
ECC Process complexity
Too many procedures which are too constraining; the system responsible engineer does not need to approve all procedures for his system.

[Note: It is interesting that none of these issues are equipment related.]

The top 5 systems contributing to lack of reliability are:

CRS
DU
LTC (Vacuum leaks)
Vacuum Systems (Roughing pump maintenance requirements)
DMS

CRS
The turbine running with no load for an extended period may be troublesome. This mode of operation is also not recommended by the supplier. The avoidance of this mode is now being formalized in the Operating Procedures so that it is prevented form occurring in the future. There is a need to avoid running the oil skid during warm up of the CRS when the turbine is not running.

The scheduled maintenance interval for the H2 Compressors may be able to be extended from 8,000 h to 20,000 h in a stepwise manner This would significantly increase the capacity factor for the TRF. This will greatly help in reducing down time. Better temperature monitors for the inter-stage temperatures are required.

The heater in the J-T loop is being replaced. Temperature control in this area used to be a problem. The TCV now controls better since the air pressure to the operator has been reduced from 320 kPa to 180 kPa.

During the current forced outage of the TRF, 700 mL of oil and 150 mL of water were found in the CRS. It is not clear how water could have got downstream of the turbine in the CRS unless it originated form the turbine oil system. It is possible that the small molecular sieve bed in the oil system may have been saturated by now.

The current oil contamination may have resulted form running the oil skid when the turbine is not running (e.g. during warming up)

It would be nice to have more monitoring capability on the oil skid – e.g. ultrasonic flowmeter on oil line, to monitor performance of the oil pump, also to monitor performance of the swash pump (H2 gas).

The evacuation/backfilling procedure for the CRS needs to be simplified – it is too complicated to follow. During evacuation, there exists the possibility of sucking in air if there is any leak. Perhaps the procedure should be changed to one evacuation followed by a pressure purge (minimization of leak paths not practical?)CRS vacuum header rupture disc blows often, e.g, resulting from a small leak from a valve. A design change is suggested.

DU

The past flooding of the dryers is much better now – although it has not been completely eliminated. Changes have been implemented to slow down the closing of some MVs, which has helped. However, after the last power blackout, some water was found in the DU outlet filter. A reposition of the return liquid line to the top of the seal tank rather than the bottom was suggested.

Under certain conditions, the vibration level in the DU compressors appears to be high. This is being investigated.

The dew point generated by the dryers has slowly deteriorated over the past few years, although it is still acceptable at -80C. However, it takes quite a bit of time to go from -76 C to -80C and they commence feeding after a delay without achieving –8-degC. The Dew Pt. meter is calibrated regularly – thus eliminating this source of error…unsure it can be calibrated; just an on-line function check is done…in any case, operational problems from ice build up from increase pressure drop were not reported. Some mol sieve fines are blocking drain valves in the system. They do not see a change in dew point with flow.

AU

The TRF is essentially operating with one effective adsorber. Sometimes, operation occurs with impaired N2 cooling, in which case the adsorber is at about 100K.

LTC
There is a minor chronic leakage issue at valve flanges, e.g. at MV1415, PSV1408, PSV1409, PSV 1410.

HTC
There is a level control problem during operation, which may be related to calibration problems with the level transmitters (neon vapor pressure PTs). There is probably some oil in one of the condensers due to a legacy issue of carry-over form the CRS.

DPS, RS
The DPS is mostly doing its job. Sometimes, emissions from the RS are high. It would be nice to have an oxygen analyzer at the stack, to ensure that there is excess oxygen being supplied to the RS. A method of self-recovery after a blown seal was seen to be desirable.

Analyzers
Analyzers are mostly obsolete. Parts are difficult to obtain and analyzers need frequent maintenance. The DMS O2 analyzer works against backpressure, therefore, the cell needs frequent replacement, as it is only designed for atmospheric backpressure. The upstream rupture disk is easy to blow (set at 100 kPag).

FTS/VPCE
Decontamination of EV1101, TK2201 is required via water lancing or ultrasonic cleaning. However, water lancing may be difficult to perform, as it will require cutting of the pressure boundary.

The charcoal adsorber has high pressure drop.

The gasket leakage in the VPCE evaporators may have been caused by an acidic environment generated by leaching of chlorides from the catalyst. Hence, the problem may not repeat itself and may have resolved itself.

PM vs Corrective maintenance: The TRF has about the right amount of preventive maintenance. There should be a shift towards predictive maintenance in the future.

The VPCE superheaters have leak-off points, which can be used to check for leaks by using a portable tritium monitor.

A second steam supply is desirable.

DMS

There is a planned project to replace the DMS – the system is difficult to troubleshoot.

OTHER

Transformer maintenance results in reduced TRF capacity factor.

19.5 Interviews With Engineering Services Staff from OPG Head Office - November 24, 2004

Systems: FTS, VPCE, DU, DMS

FTS

1. The issue around the lead blanketing and fields near the FTS Evaporator were reviewed. It was felt that the Co-60 accumulation in the FTS has not contributed to downtime in the past and is more of a nuisance than a potential contributor to loss of capacity.
2. No major issues were identified around the Degassing column or the charcoal beds

DMS

1. The DMS has been a bottleneck in the past. Membrane failure in the electrolysis cells has been a problem and has caused repeated failures with resultant downtime. The DMS system is based on old technology which, however, is still supported by the vendor. The vendor can supply the updated system if required.
2. The DMS is required to be available when required, for example, after an unplanned outage which requires burn down of the inventory in the system. Therefore, although it is an auxiliary system to the main process, it is still judged to be a critical system for the TRF.
3. A project to enable double block-and-bleed isolation of the front-end systems from the LTC Expansion Tank is intended to be completed and is in the next 5 year plan for the TRF. When this is completed, a significant time saving will be realized by avoiding the burn down of approx. 1400 m^3 of D2 gas and subsequent generation of this gas for start-up and inventory build-up.

DU

1. Leakage from the Regenerator Heater gaskets has been reported in SCRs. However, it was felt that this issue has not contributed to TRF downtime.
2. In the past, flooding of the Dryers has occurred due to water carry-over from the DU compressors (Liquid Ring Pumps). In the past, this has contributed to downtime. The flooding problem appears to have been resolved, since it has not recurred since 1997. The previous occurrences were attributed to the deficiencies of the old computer control system which caused the DU system valves to occasional be in the wrong positions. Since the control computer replacement in 1999, the flooding is felt to be no longer an issue.

3. Previously, there were incidents where it was difficult to achieve the required dew points from the DU system. This was caused by leakage across valve seats resulting in moist gas contaminating the dry gas product of the dryers. However, this issue also appears to have been fixed by the replacement of all of the Fisher valves in the DU as part of resolving the bellows cracking problem. The dew points achieved by the system have been acceptable since then. This also indicates that aging of the molecular sieve, which is now about 15 years old, has not caused deterioration in performance. Desiccant fines have also not been a major problem. Since the dryers are in a clean operating environment, the lifetime of the desiccant is expected to be much longer than other typical applications.

VPCE

1. There have been 3 incident is the past of steam leaks from the superheater gaskets. Since there is no radioactive release issue, these are normally handled by maintenance and are not felt to be a major potential contributor to downtime.
2. Stress corrosion cracking has been experienced in the VPCE in the past due to residual chlorides leaching out from the VPCE catalyst. In the past, all of the evaporator tubes were replaced with Inconel tubes. Recently, some nozzles on the superheaters have shown damage due to cracks. At this time all the other nozzles in the system were inspected and shown to have no cracks. It is possible that some damage could still to be occurring in these nozzles, but since the superheaters are covered in insulation, reliance will have to be placed on leak detection as a means of checking on these nozzles in the future.

VPCE, DU Compressors

1. No significant issues have been observed with the performance of these Burkhardt liquid ring compressors.

Systems: LTC/HTC

1. There are very few moving parts in the LTC/HTC system. Thus, this system was not expected to be a major contributor to TRF unavailability. This has been confirmed by operating experience.

2. The cryo-adsorbers ADS 1401/1402 are not operating as per their design parameters. ADS 1402 does not cool down well. It only cools down to 90K. It is suspected that this may possibly be caused by poor thermal contact between the temperature diode and the outside surface of the adsorber vessel on which the diodes are mounted.
   ADS 1401 cools down to 80K as expected but plugs up quickly, indicated by a high pressure drop. It is suspected that the silica gel in ADS 1401 may have deteriorated and may have swelled up. This could have been caused by an event a few years ago when significant amounts of water was carried over into the adsorber area.

3. The system can operate well with the current state of the adsorbers (ADS 1401 on a short cycle), but it is apparent that the design margin has been reduced. If similar damage or deterioration were to be experienced with ADS 1402, then there would be significant problem for the TRF and a long outage would have to be taken to replace the adsorbers, as these are custom design vessels and it is not easy to replace the adsorbent.
   A project was started some time ago to replace the adsorbers, but the present status of this project is not clear.

4. Obsolescence issues: Oil diffusion pumps on the cold boxes are obsolete but work well. The analyzers on the system may be obsolete also, but have not contributed to down time in the past.

5. A small H2 leak is suspected in the HTCB, but has not hindered operation in the past.

6. A list of significant unplanned outages that the TRF has experience in the past was generated during the meeting and discussed. There have been 9 significant outages. These are listed in approximate chronological order as follows:

   - Replacement of the Charcoal Catalyst in CAT 1601 with Pt/Alumina
   - Changes to the piping configuration in the HTCB (this involved cutting and welding of tritium-contaminated equipment)
   - Replacement of the tube bundles in all 8 VPCE evaporators due to stress corrosion cracking of the original bundles. Stainless steel tubes were replaced with Inconel-625 tubes.
   - Replacement of the filter FR-3116 in the CRS with a filter having a more coarse mesh
   - Replacement of about 96 Fisher valves in the VPCE/DU due to cracking of the bellows in these bellows-sealed valves.
   - Replacement of the obsolete and trouble-prone control computer system in 1999 with a Fischer and Porter System 6 computer system.
   - Flushing of the CRS system piping to remove oil which had carried over. The piping was flushed with a solvent to remove oil.
   - Repair and inspection of the cracks in VPCE superheater nozzles (suspected to be caused by stress corrosion)
   - The present unplanned outage which is caused by plugging in the CRS (by oil carryover?). The root cause of this has not yet been determined.

<u>Systems: CRS</u>

1. Most of the problems with the CRS occur during startup of the system after a planned or unplanned shutdown. During some past startups, plugging of filters or lines has occurred causing an inability to startup. This can be caused by either inadequate purging of the system, resulting in blockage by frozen residual nitrogen or due to plugging by oil carry-over from the CRS turbine. Currently, the TRF is in an unplanned outage due to a very high pressure drop and suspected

plugging in the CRS. One possibility is of oil carryover into the heat exchangers. At this time, this has not been confirmed and will require an inspection. Unlike in the LTC/HTC system, the relief valves for the CRS are not preceded by a rupture disk. Therefore, it is suspected that air can sometimes be sucked into the CRS during maintenance, etc. if the relief valves don't make a tight seal.
Turbine oil has been found on the process side in the past and has caused an unplanned outage. The oil was removed by flushing with isopropanol as a solvent. The CRS turbine has an oil brake and the turbine has a manual valve on the discharge side and a control valve on the inlet. This has sometimes been a problem area and presents a potential for operator error. Solenoid valves on the oil side may also be a problem. The turbine and its brake system is a critical area for TRF reliability and also an area for potential improvement in the future. Any improvement which will prevent oil carryover will improve TRF reliability.

2. Maintenance of the CRS is focused on the moving parts. Spare turbines are kept in stock and the turbine can be replaced in case of failure. Similarly, the oil pump (swash pump) is replaced rather than repaired. The H2 compressors have operated quite reliably and are on regular scheduled maintenance. A manufacturer's rep is usually on site for service of the compressors.

3. A question was raised on the lifetime of the heat exchangers in the CRS. External OPEX should be searched to see what experience exists on the lifetime of these exchangers in hydrogen service. Currently it is not certain whether oil has been carried over into the HXs during this unplanned outage.

4. There is no formal maintenance program on the cryogenic WEKA valves. Is lifetime of the stem tips of these valves an issue?

5. The heaters on the J-T loop in the CRS are being replaced in this outage. These have caused some minor problems in the past.

6. Some further discussion with Art Reid and the CRS operations staff will be required to determine their view of the condition of the CRS.

20 APPENDIX: ASSESSMENT OF THE TRF AND SUP (HWM) COMPUTER SYSTEM, SCI 69791 AND 69891

20.1 System Condition Statement, Degradation and Remaining Life

All system components are relatively new (acquired by ABB in late 1996 and installed at Darlington in November 1998). However, components are not equally reliable. Since Q2 2001, the System has been monitored according to Performance Monitoring Procedure SPMP 69791and Health Reports have been filed.

20.1.1 Man-Machine Interface

Operation of the interface is satisfactory; screen freezing is infrequent and easily reset by the logic box. With five, fully redundant smart terminals (DCT's), this is unlikely to create problems in the near to medium future. Degradation is most likely due to aging components, DCT Logic Box failure (EPROM), DCT Logic Box recoverable Memory Corruption, CRT failure, Keyboard failure, Mouse failure, Connector and cable failure, Power supply failure, or noise. The man-machine interface, with some replacement, will last for the design life of the TRF.

- There has been one DCT Logic Box failure (December 2004) and 8 second-hand pre-tested Spare DCT's exist.
- There are no spare CRT's: the second-hand CRT's have all been used. EDE Tech Unit will need to order contemporary replacement analogue CRT's. Some digital CRT's might be compatible. Testing can be done on the Training & Testing System.

20.1.2 Universal File Servers AP6400

Performance has been fair. Due to full redundancy at least one of the servers is available at all times ensuring MMIF availability.

- It is anticipated that satisfactory performance of Universal File Servers CON1 and CON2 can continue with the current Performance Monitoring procedures, walkdowns and standard maintenance.

- The performance of CON1 is marginally better than that of CON2. Failures occurred due to Event Historian/Historical Database corruption or Memory Module failures.

- The third server, DMC3 does not contribute to MMIF reliability but is now connected to Station LAN via the Router. Its performance has improved since 2002.

- There are two Spare Servers (one in Stores and one Hot Spare on Hardware Maintenance System, HMS). With licenses for spares now supplied by ABB, no major problems are anticipated. Degradation may occur because of aging components (e.g. CPU), interface controller failure (e.g. Mother Board), Memory card errors (e.g. SIMM modules), Hard Disk#1 failure (in CPU box), DAT Tape Drive Failure (in Exp. Bx#1), Power supply failure, or noise. Universal File Servers AP6400 may need to be

replaced after 2008 (ten years from installation at site) due to wear and unavailability of parts or technical support. However, there are five servers at site and only one is required to support TRF/SUP MMIF without redundancy.

- Two hard drives have been purchased and Symphony and Conductor UX Software loaded onto one of them. It was used to test replace the hard drive on HMS. The original (good) hard drive with Software was removed from HMS and returned to Stores

- A lifetime supply of SIMM Modules was acquired and the inventory is split between the CSTK Shop in HWMB, the A-15 TRF Software Cabinet, and Stores. SIMM Modules have been lost while in Stores, hence precautions are taken to safeguard the stock.

- Server performance should improve after additional filtered fans were installed (fall 2004).

20.1.3 Dual Ethernet Data Highway

- It has been performing well with no collisions observed during routine walkdowns. Thinnet Ethernet connections and transceivers are prone to wobbling, but with proper seating, verified during walkdowns, no problems are anticipated in the near to medium term. Degradation due to aging components, Fan-out Box failure, Repeater failure, Power Supply failure or noise, Transceiver Failure, ECCS Board Failure, T connector failure, Thin-net Cable failure, Thick-net Cable failure, Terminating Resistor failure, Slip-out of Terminating Resistor Cap. Dual Ethernet Data Highway –with replacement of some components (transceivers, fan-out boxes) would last for the plant life if spares were available.

- There was one failure of a thicknet transceiver in June 2004. No spares can be purchased from the original manufacturer (obsolescence).

- Some Spares exist as they were purchased back in 2000 from ABB.

- EDE will need to acquire more Data Highway "plumbing", probably from Second Hand Computer Equipment Brokers.

20.1.4 Distributed Control Units DCU3200

They have been performing well and no problems are anticipated in the near to medium term. There are spares. Degradation due to: aging components; (DCP is a surface technology board with no component level maintenance intended), mechanical wear or damage, connectors, cables, back plane, Power supply noise. Power on/off cycles, Environmental conditions. (Temperature, humidity, dust), Electromagnetic interference, System overloaded. (e.g. by incorrect software configuration), Memory corruption. Distributed Control Units DCU3200 – with some replacement, DCU's will last for the design life of the TRF.

- EDE recommends that more Spare I/O boards and DCP Processors be purchased from ABB by mid 2006. The product is still active but 1 Board, DCP – Processor DCU, 1 Board, A-Loop DCU, 1 Board, D-Loop DCU and 1 Board, A-Input DCU may likely not be enough to support the System for the life of installation. At the time the System was purchased (1996) it was expected that Bailey would keep marketing System Six, but ABB abandoned this idea. Lifetime supply of DCU Spares (I/O Boards and Power Supplies) should therefore be purchased before 10 years have elapsed from the date the Contract was signed (mid 1996).

20.1.5 External Lambda Power Supplies and Intrinsic Safety Relays/Barriers

They have been performing well. No problems are anticipated in the near to medium term. There are some spare Lambda Power Supplies (one of each type for those that were replaced in 1998). However, as the original, good Lambda Power Supplies, replaced in 1998, were not returned to stores but disposed of the spares are limited. Degradation is due to aging components, mechanical wear or damage (to fans, chassis and wiring), environmental conditions. (temperature, humidity, dust). External Lambda Power Supplies and Intrinsic Safety Relays/Barriers -with some replacement, will last for the lifetime of the plant.

20.1.6 Printers

Printers complete with Printer Server. Laser printer has been performing well, Color Printer worse and Alarm Line Printers barely fair. When routine PM on printers finally begins, no major problems are anticipated in the near future. There are spares. Degradation due to: aging (Microplex Printer Server failure), mechanical wear or damage (print-head, toner cartridge, transfer rolls, paper supply), Paper Feed failure due to excessive fan-fold paper accumulation, connector and cable failure. Printers complete with Printer Server-will need to be replaced at least once before the end of plant life. On-going review and maintenance intensity will determine replacement time (likely before 2006).

- A standard, contemporary Laser Printer replaced the failed Laser Printer on the T&TS and is performing very well.

- EDE suggests testing possible replacement printers on T&TS such as a colour laser printer used on the Business LAN at Darlington.

- EDE recommends that contemporary replacement Print Servers be purchased and tested on T&TS.

20.1.7 Symphony SR 3.0 System Software

The operating system has been performing well except for interfaces with Event Historian and Historical Database, which is prone to corruption. On one such occasion an unacceptable MMIF slowdown occurred. Since no Factory Patch is planned by ABB, satisfactory performance will be maintained with the current Performance Monitoring

procedures, walkdowns and standard maintenance as per Performance Monitoring Procedure SPMP 69791. Software corruption can be caused by

- hardware faults
- software faults
- Improper Vendor Software (Symphony and Conductor UX) performance due to known or unknown design deficiency
- Improperly configured software -changes in a shipment or individual patches.
- IP or Ethernet Addresses incorrectly assigned to Network Nodes.
- Configuration control problems.

Software - the intent is to use ABB's software for the lifetime of the plant unless upgrades are required by hardware replacement (e.g. change of platform from server based Conductor UX to PC based Conductor NT). Software maintenance process as per D-PROC-MP-0014 is adequate to keep software configuration at the level required by the Users for the design lifetime of the plant.

20.1.8 Conductor UX dcu-sup Software, 7.1.16.

The performance has been satisfactory. ABB supplied licenses for spare frames. No problems are anticipated in the near to medium future.

20.1.9 Configured Control Software:

Software Shipment Level 0 was installed in October 2000 and has been operating satisfactorily ever since. Patches to Level 0 are being added as per D-PROC-MP-0014 and will form the basis for Software Shipment Level 1. No problems are anticipated in the near to medium term, although major expansion of DCU2 and DCU3 Software configuration will require faster DCP's. Configured Software is monitored as per Performance Monitoring Procedure SPMP 69791.

20.1.10 Configured Display Software

Software Shipment Level 0 has been installed in October 2000 and has been operating satisfactorily ever since. Patches to Level 0 are being added as per D-PROC-MP-0014 and will form the basis for Software Shipment Level 1. No problems are anticipated in the near to medium term. Display Software is monitored as per Performance Monitoring Procedure SPMP 69791.

20.2 Spares Availability

Due to the aforementioned obsolescence of computer equipment, the spares that Darlington currently has are priceless. EDE recommends that CSTK (TRF Control Maintenance) try to store as many of System Six Spares as possible in the air-conditioned rooms and locked cabinets in HWMB. Also, all spares that are not stored at TRF should be traced in the Warehouse and their location known and recorded by CSTK. PassPort no longer shows Part location. However, Stores Employees who use SAP can still see where a part is stored. HWMS Computer Spares were stored partly in the Air-Conditioned Warehouse in Whitby and partly in East Warehouse. SIMM Modules and Lambda Power Supplies (one of each type) were stored in Upper Stores in the Powerhouse. Part location checks were made between 2000 and 2003. Since then parts could have been moved. It is essential that parts still in stock at Darlington not be lost.

SYSTEM SIX spare parts tested on July 22-23 / 2004 WO 1093227						
	Monitors (CRT's) **No Spares left**					
	IIYAMA Corp.		**Fischer Porter**			
	Model	**Serial**	**Model**	**Serial**		
1	MF-8221	3011798	XP350	27780101	To scrap	
2	MF-8221E	5008012	n/a	n/a	For TRF MCR	
3	MF-5321A	910931	n/a	n/a	For Simulator	
4	MF-5621	2001674	93098007u01	9309B8007/1/B1	For Simulator	
5	MT-9021E	5006879	n/a	n/a	To scrap	
	All interconnecting cables and power cables will be returned to the TRF control maintenance shop for storage.					

		SYSTEM SIX spare parts tested on July 22-23 / 2004								
		WO 1093227								
		XP400 Logic Boxes								
		Model	**Serial**	**Physical Address**						
1		808G074U03	9607150010	08	00	11	05	5C	54	
2		808G074U03	9607260572	08	00	11	05	5C	84	
3		808G074U03	9607260577	08	00	11	05	5F	94	
4		808G074U03	9709020284	08	00	11	07	02	A8	
5		808G074U03	9804170018	08	00	11	07	2C	8B	
6		808G074U03	9809190001	08	00	11	07	14	73	
7		808G074U04	9809220033	08	00	11	07	32	87	
8		808G072U06	9509230012	08	00	11	03	E4	B4	

SYSTEM SIX spare parts tested on July 22-23 / 2004				
		System Six Keyboards		
		WO 1093227		
		Part Number	**Serial**	
1		KBA-F9314A-US 9333 177A135U01	100307	
2		KBA-F9314A-US 9333 177A135U01	100321	
3		KBA-F9314A-US 9408 177A135U01	124442	
4		KBA-F9314B-USEB 9633 177A546U010	233879	
5		KBA-F9314B-USEB 9651 177A546U01	251508	

The original set of Spares as purchased from Bailey/ABB, 2000 update				
(most parts have been tested, some parts have been used)				
TRF/SUP Replacement Spares PO 2802 (OHAS 979897217-70) Updated 00Feb18 / VH				
Cat. ID	**Orig QTY**	**Revised QTY**	**Description**	**Required Part # ABB**
309186	1		CPU, R4400SC 200MHz, 256MB RAM, 2.3GB Hard Drive/Floppy, Redundant ECCS Board.	808G082U06
491901		1	Expansion Box with CD-ROM and DAT Tape Drive	808G076U02

The original set of Spares as purchased from Bailey/ABB, 2000 update				
(most parts have been tested, some parts have been used)				
TRF/SUP Replacement Spares PO 2802 (OHAS 979897217-70) Updated 00Feb18 / VH				
Cat. ID	Orig QTY	Revised QTY	Description	Required Part # ABB
309187	1		Terminal, ADDS Systems Console	4000/160
309188	1		Logic Unit, XP-400	808G074U04
491903		1	Monitor, 21" CRT	MF 8221E
309189	1		Keyboard, US Full Travel, Type DCU	KGA-F9314
309190	1		Chassis, Single Frame Type for Bailey System 6	40AC3200
309191	1		Power Supply, DCU for Bailey System 6	40PS3205A
309192	1		Board, DCP – Processor DCU	40CN3210A
309193	1		Board, A-Loop DCU	40PB3201A
309194	1		Board, D-Loop DCU	40PB3202A
309195	1		Board, A-Input DCU	40PB3206A
309196	1	4	Cable, ITB to Board, 8 foot	40CA3200A-008
491874		4	Cable, ITB to Board, 4 foot	40CA3200A-004
309197	1		Board, ITB/AX DCU	40TE3201A
309198	1		Board, ITB/AX12 DCU	40TE3216A
491905		1	Board, ITB/AM DCU	40TE3202A0
309199	1		Board, ITB/DI DCU	40TE3203A
309200	1		Board, ITB/DOR DCU	40TE3207A0
309201	1		Board, ITB/PS24VDC DCU	40TE3208A0
309202	20		Module, Intrinsic Safety Relay – Stahl	9251-02-40
309203	3		Module, Intrinsic Safety Barrier – Stahl	9001/02-175-100-10
491908		1	Module, Intrinsic Safety Barrier – Stahl	9001/00-086-050-10
491909		1	Module, Intrinsic Safety Barrier – Stahl	9001/00-086-150-10
491910		1	Module, Intrinsic Safety Barrier – Stahl	9001/01-086-050-10
491911		1	Module, Intrinsic Safety Barrier – Stahl	9001/01-086-150-10
309204	1		Printer, Tektronix Phaser 240 including start-up kit	179E106U04
309205	1		Transceiver, Dual Port, configured AT270	AT278
491915		1	Transceiver, Single Port, configured AT200	AT208
309206	1		Transceiver, Micro	AT–MX10

21 APPENDIX – DISPOSITION OF OPG COMMENTS FROM REVISION 0

Disposition of comments (please note in some cases there were overlapping comments; all comments on a section were reviewed and the sections re-worked to reflect the total set of comments received)

1. Darek Kulczynski
    - 3 minor corrections, pg 36, 69 and 72 – implemented

2. Thomas Wong
    - Corrected the wording in the section describing the D_2O storage tank volume(pg 28)
    - Corrected the use of TRILLIUM packages (pg 29)
    - Reviewed the section on the UV oxidizer operation. Discussed it with staff at Kinectrics familiar with the process. Corrected the wording in the section, indicated that recirculation is required due to not meeting spec. Gave some reasons for recirculation with these units, indicated optimization may help.
    - Corrected the statement on the charcoal in the slurrying tanks regarding the level indicators and the amount of charcoal in the tanks
    - Reviewed the section on distributor plugging agreed with the word "several"

3. Francis Tang
    - Changed section on steam gaskets and inserted the use of manageable downtime
    - Added details on inspection of evaporators
    - Added note on UT inspection of catalyst pots
    - Reviewed information on dryer water ingress during power failure, inserted opinion on source
    - Added information on vacuum pump oil problems, leaking in mechanical joints, filters in the CRS and detailed information on 2005 oil examination in the CRS.
    - Reviewed section on CRS compressor maintenance and modified it based on these comments and others received
    - Added information on heaters out of service and further vacuum pump oil problems on the CRS cold box

4. Omar El-Behairy
    - Added information on ACS testing program (issue noted by a variety of reviewers)
    - Added note on lack of replacement of ITC controller
    - Added note on when vault optimization will be done

5. Curt Noel
    - A study was made of available information on the operation of electrolysis units in other areas. All available information indicates that most electolysis systems are operated on a constant load basis. However, no information was found that indicated intermittent use would directly lead to a failure. Based on this modifications were made to description of the possible failure mechanisms

of the DMS. Additional comments from the Engineering Services staff review were also added with respect to potential changes in the operation of this system when on standby.

- Statements from the control technicians used in the report were shown to be from that source and that there was a difference of opinion on the factual nature of some of the statements.
- PRV statements were clarified
- Clarified statement on oxygen analyzers concerning purge with helium
- Added information on recalibration of control systems to spec and the limiting of operating changes to the equipment
- Included a recommendation for further review of this equipment to aid in the anticipated replacement

6. Kaly Kalyanam
   - Corrected OP&P limit from 1.5 to 1.2
   - Added requested section with recommendations for some further investigations and how this report can be used in the Equipment Reliability process.
   - Reviewed the request to include key findings in the Executive Summary, it was felt it would be too long to include all of the findings and they were better left to the body of the report
   - Corrected a number of areas suggested for rewording
   - Noted that use of on-line protium extraction is not critical
   - Added references where appropriate
   - Added some recommendations for lifetime of components, some of this had already been addressed in disposition of comments of the system engineers
   - Added a recommendation on the review that should be done before the replacement of the DMS system to be sure the replacement will resolve problems currently encountered.

7. Harold Vogt
   - Comments reviewed and the noted minor corrections made to the report
   - Design limits on adsorbers added to report
   - Comments on the TIS have been reviewed and comments and changes incorporated. Discussion on tritium release, rewritten following review of SCR and discussions with Harold.
   - Comments on contamination levels in the TIS glovebox reviewed and rewritten
   - Requests for additional information on some systems not in the report were reviewed and added where possible