REPLACEMENT OF THE INPUT/OUTPUT CABLES OF THE DIGITAL CONTROL COMPUTERS AT GENTILLY 2

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1. INTRODUCTION

During the 1990 annual outage at Gentilly 2, the Preventive Maintenance Program inspections on the digital control computers (DCCs) revealed an alarming degradation of cable insulation at several locations. It was found that approximately 20% of the cable connector assemblies inspected showed signs of degradation. These findings raised the concern of an increased risk of random short-circuit faults at the very heart of the station control system.

Given the excellent reliability of the Gentilly 2 DCCs and their inherent design robustness, it was decided to proceed with the replacement of all of the complete cable connector assemblies within a reasonable time frame. It is planed to replace all assemblies of DCCX and DCCY during the 1991 annual outage.

The degradation of the insulation was traced to a material incompatibility problem originating during cable manufacture. A migration of the plastifier contained in the PVC of the transparent sheaths, surrounding many of the cable conductor to terminal block connections, resulted in the chemical attack of the conductor insulation.

This paper summarizes the problem identification and disposition process followed by Gentilly 2 Technical Unit personnel.

2. EVENT CHRONOLOGY

2.1 Problem Discovery

In 1987 the computer maintenance group was requested to diagnose an analog input fault on the station master digital control computer (DCC X). The fault origin was eventually traced to the analog input card connector deficiency. However inspection revealed some cable conductor insulation polypropylene degradation and a short circuit.

2.2 Planned Inspection

Additional inspections performed on the station development computer (DCC Z) in 1989 indicated that a generic problem existed. As a result it was decided to initiate a thorough program of planned inspections to obtain a better understanding of the nature and amplitude of the problem. Inspection is possible only during a Guaranteed Shutdown State outage and the physical access is restricted.

Approximately 10% of all input/output cables (approximately 300 assemblies)of both station computers, DCC X and DCC Y (slave), were inspected by station personnel during the 1990 annual outage. The inspection revealed that about 20% of this sample displayed some indication of conductor insulation degradation immediately adjacent to the terminal blocks connections. It was deemed necessary to proceed immediately with the replacement of 10% of the inspected cables. The condition of the replaced cables was judged to be unacceptable.

2.3 Initial Reaction of Operations

The operating staff reaction during the 1990 outage to the news of widespread cable degradation was immediate. The outage start-up of the station was in jeopardy. A study of the potential impact of computer cable short circuit faults on station safety and production was requested.

A technical report was produced during the outage to investigate the incidence of computer cable degradation upon station safety. The principal conclusions of the report were:

1- The excellent availability of the station computers did not justify immediate cable replacement.
2- The redundant design of the computers and the principal station systems is fault tolerant in many cases.
3- An upgraded computer preventive maintenance program had significantly reduced the number of deficiencies in recent years.
4- Only one case of a "degraded cable conductor" short circuit fault had been identified.

The Atomic Energy Control Board was advised of the situation and HydroQuébec's plan to resolve the problem. Station start-up following the 1990 annual outage, proceeded according to schedule.

2.4 Problem Investigation

The Energy Research Institute of Québec (IREQ), the research wing of Hydro-Québec, was requested by Gentilly 2 staff in October 1990 to perform a materials analysis of several degraded cable conductor samples. The physical-chemical analysis revealed that a combination of temperature and humidity conditions could induce migration of the plastifier contained in the PVC sleeves surrounding the connections. The liberated chlorine (HCl) was able to chemically attack the polypropylene of the conductor insulation. IREQ considers that PVC instability, not uncommon with the available technology of the early 1970's, initiated the chlorine migration.

An independant investigation initiated by CAE Electronics, the computer vendor, reached the same conclusion. However, CAE believes that trapped trichloroethylene under the transparent PVC sleeves initiated the migration of chlorine. In accordance with the cable assembly technique in use at that time, a solution of trichloroethylene was used to soften the PVC sleeves and facilitate connection assembly.

2.5 Inter-Utility Communication

The other Canadian nuclear utilities were contacted to investigate the existence of computer cable degradation phenomenon at their stations. No evidence of advanced degradation comparable to the replaced Gentilly 2 cables has been reported to this date. However, there is evidence to the effect that a chemical reaction has been initiated at several stations. The evidence includes some signs of greenish colouring of the transparent PVC sleeves, an accumulation of white salts and a discoloration of the conductor insulation. It appears that these stations only exhibit phenomenon characteristic of the initial stages of the degradation process. All of these phenomenon are clearly visible on roughly 20% of the Gentilly 2 computer cables.

It is pointed out that only the Gentilly 2 computers were subjected to high temperature endurance testing prior to site delivery. The ambient temperature was maintained at 35°C in the test area for two days. It is also noteworthy that in the early years of Gentilly 2 operation, the computer room ambiant temperature was not adequately controlled. Air conditioning was upgraded in 1985 to maintain an ambient temperature of 20°C.

2.6 Replacement Decision

The decision to replace all computer cables was taken in December 1990 prior to release of the investigation reports. It is now known that the potential of a repeat of the identified problem is nil since the cable assembly techniques have evolued to eliminate the PVC sleeves. However it was recognized that a strict quality control program is necessary to minimize the risk of defects in the material and manufacturing process.

The idea of removing only the affected end of the cable was also considered. This would cause the resulting cable length to be insufficient in many cases. However the greater risk of assembly error and the potential for prolonged down-time eliminated cable amputation as a viable option Hydro-Québec decided to remplace all of the computer cable connector assemblies including the associated terminal blocks.

3. PROBLEM DISPOSITION

3.1 Emergency Spare Cables

Immediately following the 1990 annual outage, emergency spare cables of each type were ordered from the vendor. This approach would reduce the risk of prolonged station unavailability in the event of a degraded cable fault.

3.2 Interim Maintenance Instructions

The computer maintenance group was instructed to curtail preventive maintenance activities involving cable disturbance. However all relevant corrective maintenance activities would be utilized to perform a systematic inspection of the cables.

3.3 Procurement of Replacement Cable Assemblies

The procurement program was initiated by a thorough review of all cable drawings and documentation by Technical Unit personnel. It was critical that all site "as-builts" and modifications be integrated prior to the order of material by the vendor. Numerous deficiencies in the design documentation were identified and corrected.

Several meetings with the "sole-source" vendor, CAE Electronics, were held to define the scope and content of the cable assembly replacement contract. The contract scope included material procurement, engineering review, manufacture of the cable assemblies (including terminal blocks), factory testing, site installation and verification and quality assurance. The contract was prepared in view of minimizing the risk of the old and new problems. Particular attention was paid to material selection and testing. Ageing tests of the new cable assembly were initiated at an early stage of procurement.

The contract was placed early in 1991 to permit DCC X and DCC Y cable replacement at the 1991 annual outage beginning on August 4, 1991. The "20 week" manufacturing schedule is tight and did not allow for pre-contract award testing.

The cable assembly manufacture and replacement program is to be executed to the CSA Z 299.3 quality assurance standard. Several Hydro-Québec inspection points have been defined to verify compliance. The contract also requires an update of the engineering documentation and a complete set of new drawings to be produced. The drawings are to prepared using CAD technology.

3.4 Cable Replacement Work Plan

The 1991 annual outage duration is 73 days. However the SLAR program requires the availability of DCC Y for the major portion of the outage. In any case computer unavailability must be minimized.

CAE Electronics will provide (4) teams of (4) people under Hydro-Québec supervision to enable the site replacement work to proceed around the clock. This allows cable replacement on one computer in a 15 day period (note that extensive system dismantlement is necessary). Commissioning, followed by the computer preventive maintenance program require 6 additionnel days. The total unavailability for one computer is estimated at (21) days.

The commissioning plan will ensure that all cable connection assemblies are tested with the fields signals. The complete computer control system integrity will be demonstrated prior to station start-up. Note that all computer input/output signal cables must be disconnected and reconnected.

4. CONCLUSION

Given the vital nature of the station control computers, the cable assembly manufacture, testing, inspection and replacement program must be conducted in accordance with stringent quality assurance standards. An extensive commissioning program is needed to confirm the computer control system integrity prior to station start-up.

The original cost of the Gentilly 2 digital control computers was $1.5 million in 1975. The total replacement program cost (including overhead and interest) will reach $1.0 million (1991 dollars). It was not possible to predict the latent defect during manufacture of the Gentilly 2 DCCs. This is however, a moot point. One can argue that the Gentilly 2 problem constitutes a good example where the original quality assurance effort was not "enough".

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