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CONTAMINATION CONTROL DURING PICKERING

UNITS 1 AND 2 LSFCRP

T.A. ROBBINS
T.A. DERESKI

Ontario Hydro
Pickering NGS-A
Pickering, Ontario

ABSTRACT

Removal and replacement of the fuel channel assemblies in Pickering Units 1 and 2 was hindered by a source of loose and extremely mobile contamination. Neutron irradiation of the nitrogen annulus gas in these units had created a Carbon-14 deposit over the inner surfaces of the annulus gas system.

Various retubing operations; but most notably the rapid induction heating of the east Pressure Tube to End Fitting rolled joints caused the expulsion of Carbon-14 particulate into the fueling machine vaults. To control this contamination spread it was necessary to make some significant changes to the retubing program. Process logic was modified, tooling was redesigned and operating procedures were revised to ensure that adequate control was maintained over the contamination spread. Regular monitoring of Reactor Building contaminaton conditions and pre-set action levels for surface decontamination were instituted to prevent the build up and spread of contamination.

Rehabilitation of the reactor building following completion of fuel channel installation included extensive decontamination of the fuelling machine vaults. Most accessible surfaces were cleaned by wiping with detergent soaked mops and rags. Prior to removal from the reactor building, the shield cabinets were thoroughly decontaminated by a high pressure wash down and rinse. Floors and walls were painted to fix residual contamination.

An exception to this manual approach to decontamination was made in the case of the feeder cabinet internals. During reactor operation the temperature within the feeder insulation cabinets reaches 250 to 300°C. At these temperatures the carbon material oxidizes rapidly to form carbon dioxide gas. This gaseous product was continuously drawn out of the cabinet containment, and vented into the monitored unit exhaust stack.

PICKERING 'A' FUEL CHANNEL DESIGN

Each reactor in Pickering 'A' Nuclear Generating Station (NGS) has 390 horizontal coolant channels which project into the east and west fuelling machine (F/M) vaults. Their primary function is to house the reactor fuel and to direct the coolant flow past it to remove the nuclear heat.

Each fuel channel assembly consists of a zirconium alloy pressure tube (P/T) with a stainless steel end fitting (E/F) at each end. The P/T is attached to the E/F's by means of a three grove rolled joint. The outboard end of each E/F makes a sealed connection with the F/M for fuel insertion or removal. The P/T's are located inside calandria tubes (C/T) and the annulus between the two tubes is maintained by garter spring spacers and is filled with a gas which provides a non-corrosive atmosphere to minimize corrosion of the fuel channel components. The annulus is sealed by an Inconel bellows between each E/F and the end shield tubesheets. Feeder pipes which provide a path for coolant flow into and out of the channel are connected to each E/F via a bolted metal to metal coupling.


Fuel Channel Assembly
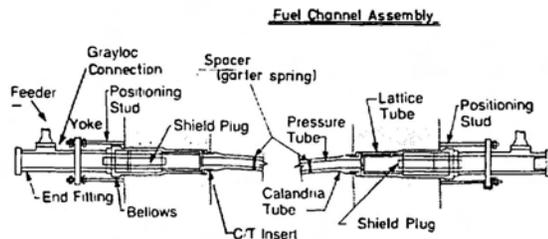
The Retubing Process

A P/T rupture occurred in Unit 2 in August 1983 the cause of which was attributed to a metallurgical problem associated with the Zircalloy 2 material of the tubes. This resulted in a decision to replace all of the P/T's in both Units 1 and 2. These were the oldest of Ontario Hydro's commercial reactors and were the only ones in which this material was used.

The retubing process was a manual operation carried out primarily from shield cabinets built in front of the reactor face in both F/M vaults. These shield cabinets afforded some protection to the workers from the gamma radiation emanating from the reactor core. They also housed support hardware such as the Retubing Tool Carrier (RTC),

Shield Cabinet Hoist, and tool support platform or work table.

Shielding Cabinet Arrangement
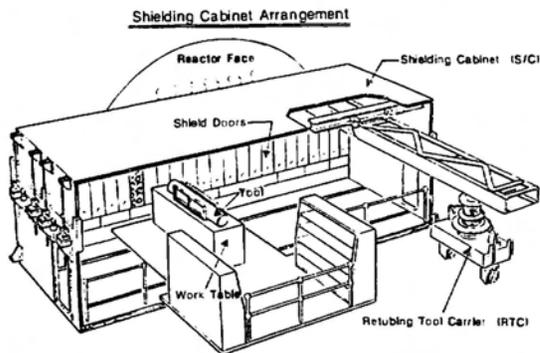
The Large Scale Fuel Channel Replacement (LSFCR) program involved the removal and replacement of the west E/F, P/T, garter spring spacers and both east and west shield plugs. The calandria tubes, east E/F's and the channel annulus bellows were left in place and reused.

The west E/F was removed in two sections. The outboard or relatively inactive end was cut off and sent to the Bruce waste handling facility for disposal. The inboard end combined with a short stub of P/T which had been previously severed was then removed and stored in a Dry Storage Module (DSM) located at the eastern end of the Pickering site. This component was highly radioactive and removal was accomplished by remote operation of the RTC.

Prior to removing the P/T it had to be freed from the rolled joint connection to the east E/F. This was done by a rapid induction (shock) heating technique which caused the P/T to shrink away from the east E/F. Once freed, the P/T, together with the east and west shield plugs which had been previously pushed to the centre of the channel, and the two garter spring spacers could be pushed out of the core. Once again the transfer of the P/T from the lattice site to the shielded flask was, by necessity, a remote operation due to the high gamma fields coming off the P/T and active shield plugs. As was the case for the E/F inboard stubs, the P/T's were stored in the DSM's.

Following P/T removal the east E/F rolled joint bore was refurbished in preparation for receiving the new P/T. An inspection and clean was then performed on the inside diameter of the calandria tubes.

New component installation began with the insertion of the new P/T, which encased within a nylon sleeve and held in an installation can, was positioned at the west end of the channel and pushed into the calandria tube. Once in place the protective sleeve was drawn back into the installation can and returned to the vault floor for reloading. The P/T and east E/F were then

aligned axially and radially and the east end rolled joint was made. The garter spring spacers; four in total, were positioned within the annulus by means of a tool which slid between the P/T and C/T. Once their position had been confirmed via eddy current techniques the replacement west E/F was installed into the lattice site, aligned with the P/T and then rolled into place. The final process was to make the annulus bellows to E/F weld and reconnect the feeder coupling.

CONTAMINATION SOURCE

The original design basis for all the tooling necessary to carry out the retubing process was based on conditions observed during single channel replacements. It was not assumed that large amounts of particulate contamination would be released during the process. Consequently no special precautions were taken for contamination control in the tool design.

It was after the LSFCR program was well underway that the contamination problem was first encountered. Shock heating of the east P/T - E/F rolled joint was in progress, in parallel with the removal of E/F inboard stubs in the west F/M vault. Routine measurements had indicated very high levels of beta/gamma contamination in the vaults and North Accessible Area. During one of these checks an area which appeared clean when monitored using a relatively thick walled detector indicated very high counts when it was surveyed using a thin walled detector. Investigation revealed the presence of a very low energy beta emitting radionuclide, which was subsequently analysed as Carbon-14. Further checks showed extensive C-14 contamination within the vaults and the absence of any gamma emitting contamination had made its detection very difficult. The source was determined to be the annulus gas system, in particular the P/T - C/T interspace.

The existence of high C-14 contamination levels in the annuli and the problems associated with control of this contamination caused the retubing program to be halted. During this time all future and current retubing process were reassessed with regard to their potential for release of contamination into the work environment. Modifications were then made to the procedures and tooling to ensure that adequate contamination control measures were in place. The more significant of these changes have been detailed in sections to follow.

RETUBE PROCESS MODIFICATIONS

Shock Heating East P/T - E/F Rolled Joint

One of the major mechanisms of contamination release was through the shock heating process. The basic principle of operation was that the rolled joint was rapidly heated and cooled a number of times. With each successive cycle some P/T shrinkage occurred. High pressure cooling

air was blown over the east P/T rolled joint at the end of each heating cycle to bring down the P/T temperature as quickly as possible. After the seventh or eighth heating cycle P/T shrinkage was normally sufficient to allow significant air flow through the rolled joint and into the gas annulus space. This flow was the cause of resuspension of C-14 dust within the annulus and the means by which it was expelled into the west vault via the cut bellows or P/T. To keep the shock heating process short enough to be viable for on-reactor use it was essential that the heated rolled joint be cooled rapidly using the high pressure cooling air. Thus contamination control could only be accomplished by sealing off alternative flow paths, thereby directing the airflow back through the heating coil and out into the east F/M vault via a High Efficiency Particulate in Air (HEPA) filter. This was achieved by the following techniques.

The process logic was modified slightly to ensure that prior to shock heating any channel, the west E/F inboard stub had been removed on both the target channel and the channel connected to the target channel via the annulus gas pigtail. This would thus enable the installation of a sealing bung in the west end of the calandria tubes of both of the above channels. This bung was designed to act as an hermetic seal to cut off any air flow into the west F/M vault and also as a restraint to prevent the P/T from being blown out of the channel once sufficient shrinkage had occurred. These bungs were effective and when used correctly were successful in preventing further increases in airborne contamination.

Removal of West E/F Inboard Stub

During removal of the E/F inboard stub large quantities of carbon-14 were observed on the outside of the P/T stub and innermost part of the E/F itself. As the E/F was withdrawn from the channel the contamination would be shaken from it, depositing within the end shield lattice tube, on the work table and shield cabinet floor and also on the vault floor mounted trough. This contamination would then be dispersed throughout the reactor building by movement of the workers. Airborne contaminaton also increased within the local area. This was caused primarily by a system of brushes mounted on the work table over which the E/F was withdrawn. Their purpose was to remove any garter spring spacers which may have been sitting on the P/T stub, such that they would not fall off at random during the E/F removal process. In fact they also acted to sweep the C-14 from the E/F and generate a localized cloud of airborne contamination.

In order to establish control of the contamination spread the following modifications were made to the E/F removal process. A bagging system was employed to completely enclose the E/F. As it was withdrawn from the lattice site the E/F was pulled through a bagging sleeve which automatically deployed a bag covering both the E/F and P/T stub. The E/F would henceforth remain enclosed by the bag at all times. Damage to the bag was guarded against by means of a skid plate positioned on the flask loading trough on the vault floor. The bagged E/F was lowered onto the skid plate and then the whole assembly pushed into the waiting shielded transfer flask. The bag, skid plate and E/F were then taken to the DSM and disposed of. The principal source of airborne contamination, the garter spring spacer removal brushes, were taken off the work table. The garter springs were now adequately controlled by the bagging system. Once the E/F had been removed, the residual contamination which was left in the lattice tube bore was still a possible source of contamination spread as tooling was subsequently inserted into the lattice site. An extensive clean of the lattice tubes and calandria tubes was incorporated into the process logic just prior to the start of component installation.

The use of the bagging system described above did a great deal to reduce the overall spread of C-14 contamination. Its effectiveness was reflected in a gradual decline in the levels of loose contamination which were measured in the reactor building.

P/T Removal

During the P/T removal operation a significant difference in levels of contamination between Units 1 & 2 was highlighted.

Work progress on Unit 1 was not significantly delayed due to work area or tools/equipment decontamination. On Unit 2, however, approximately 2 1/2 weeks of outage time were lost which could be directly attributed to high C-14 contamination levels. This lost time was partially the result of work area/tool decontamination and partially due to down time for tool redesign and procedure modifications to ensure a greater degree of contamination control.

The principal sources of contamination spread were the handling of the C/T flare protective sleeve (Tophat) and the handling of the P/T push tool mandrels. Both of the above two items of equipment became highly contaminated during the removal process.

The tophat was a sleeve which was installed at the west end of the calandria tube. It's function was to protect the C/T from damage as the sagged P/T was pushed out of the core. The original intent was to reuse the tophat until it became unfit for use due to mechanical damage. However, the contamination levels that resulted caused this policy to be rethought. Various techniques for decontamination of the tophats were tried with minimal success. Thus decontamination was ruled out as an option. Instead a procedure was used which minimized the handling of the tophats. Once a channel was complete the tophat was removed from the channel using an RTC held tool and

immediately reinstalled into the next channel. If ever the tophat was to be changed or put down for any reason, it was bagged prior to being disconnected from the tool. This technique was used successfully with minimal contamination control problems.

The contamination of the P/T push tool mandrels was of concern due to cross contamination of the workers' plastic suits during mandrel handling and hence the increased risk of a C-14 uptake during the undressing procedure. In addition this caused the spread of contamination throughout the Reactor Building. The process changes that resulted from this contamination problem were as follows.

A mandrel cleaning box was installed on the east E/F. It contained a cleaning brush which scoured the mandrels as they were withdrawn from the channel. In addition a vacuum was drawn on the box to remove the contamination freed from the mandrels. This technique was successful in maintaining the mandrels in a usable state. However the front end of the lead mandrel was contaminated to a level of approximately 250000 cpm and this was not significantly reduced.

In order to more safely deal with such highly contaminated tools radiological protection procedures were modified. A new item of protective clothing was incorporated. A smock worn over the plastic suit protected the front of the suit and hood from contamination. Upon completion of the work at the face this smock was removed prior to leaving the shield cabinet or disconnecting from an air supply. A mandatory shower was then taken to dampen the protective clothing prior to undressing. This made resuspension of the Carbon-14 less likely.

Calandria Tube (C/T) Cleaning

In view of the increased contamination problems encountered during Unit 2 pressure tube removal it was felt that similar problems and delays would result during the pressure tube installation phase on Unit 2. A number of tools during this process had to, by necessity, come into intimate contact with the calandria tubes and would as a result become highly contaminated. To minimize these potential problems as well as the C-14 uptakes by installation crews, adecontamination of the calandria tubes and lattice tubes was undertaken.

It was initially hoped to clean the calandria tube and lattice tube in one operation. However the contamination checks which were carried out indicated that this merely resulted in C-14 being pulled back from the C/T and redeposited on the lattice tube.

The tooling was then redesigned to clean these two areas seperately using a customised approach. The lattice tube was vacuumed and

swabbed and the shield plug replaced with a decontaminated one. The clean lattice tube was then protected with a sleeve while the calandria tube was swabbed using a sponge bung soaked in demineralized water. This technique was fairly successful and resulted in a decontamination factor of approximately two. This was determined by swipes taken in the lattice tube and calandria tube with a specially designed tool.

Obviously during this series higher than normal levels of contamination were experienced on tooling. The most significant being on the C/T cleaning tool itself, specifically on the plastic sleeve which contained the cleaning bung. This contamination was then spread to the shield cabinet and to the worker when the wet cleaning bung was installed into the sleeve for the next channel.

To overcome this problem the plastic sleeve was made disposable along with the cleaning bungs and a new sleeve was installed on the tool for each channel. This is an example of where 'throwaway' technology can be used successfully to deal with a significant contamination problem. Decontamination of such tools in the vault is difficult and time consuming and can result in high man-rem expenditure.

Fuel Channel Installation

During the entire fuel channel installation phase of Unit 1 and 2 there were no significant contamination control problems. This is indicative of the success of the calandria tube cleaning process mentioned above and also a reflection of the fact that control of contamination spread was a major consideration in the planning and preparation for that stage of the program.

There were however some minor concerns which were dealt with in the following ways.

Bellows Weld Ring Cleaning. During the bellows weld ring I/D cleaning, the airborne levels of C-14 in the immediate vicinity of the channel increased to approximately 1000 MPCa. This was due to a resuspension of the contamination inside the bellows caused by the operation of the weld ring cleaning tool. Two actions of the tool were responsible; the rotation of the flap wheel grinder causing air turbulence and the grinding tool air motor exhaust, which was directed straight at the bellows weld ring. Both problems were resolved by the replacement of this tool with a manually operated cleaning tool.

Garter Spring Installation. During garter spring installation it was routine to experience slightly elevated levels of airborne C-14. The proximity of the garter spring tool to the calandria tube resulted in contamination transfer to the head of the tool and hence increased airborne contamination levels in the

shield cabinet when the tool was withdrawn from the channel.

It was the original plan to bag this tool and keep it bagged during the entire operation in an effort to contain this contamination. However, the concertina action of the bag as the tool was pushed in and out of the channel caused the contamination contained within the bag to be expelled into the vault atmosphere.

A detailed contamination survey was carried out in which it was determined that the airborne and surface contamination, and C-14 uptakes by the workers were not significantly different regardless of whether or not the bag was used. Consequently it was dropped from the procedure as there was an additional man-rem cost associated with its use. In an effort to minimise the contamination brought out of the channel a vacuum collar was placed on the end of the extension sleeve, the purpose of which was to route all the displaced contaminated air through the vacuum system filters and to some extent provide a measure of decontamination of the garter spring installation tool. After the garter springs were installed on each channel, an extensive decontamination of the tool and work area was carried out to maintain general contamination levels as low as possible.

Pressure Tube Installation. During the installation of the pressure tubes, the protective nylon sleeve was in intimate contact with the calandria tube. Thus with each successive channel installation the sleeve would draw back contamination into the installation can. The bore of the can became extremely contaminated and hazardous to reuse, as indicated by increasing C-14 uptakes by workers associated with this job. Contamination control was re-established by replacing the contaminated cans with clean ones and a routine monitoring program was established to keep track of contamination levels within the cans and to trigger decontamination when necessary.

Summary of Source Control

In summary; whenever retubing operations necessitated intrusion into the annulus gas system a C-14 contamination problem resulted. Tooling and procedures had to be developed to ensure adequate contamination control measures were in place.

Routine area decontamination had a fair degree of success using basic techniques of wash down with a decontamination agent such as 'Spotcheck'.

Initial Decontamination Planning

A previous section described the source of the carbon-14 particulate in the vaults. Initially airborne, the fine particulate gradually settled out onto surfaces, horizontal ones receiving the bulk of the load. The once airborne contamination reached as far as the vault air cooling units (ACU), some 15 metres away from the release point at the reactor face. All surfaces in the west vaults were considerably more contaminated than in the east vaults since the west side received most of the exhaust air from the shock heating process. Levels on the order of 50,000 cpm/100 cm^2 were not uncommon on some west vault surfaces. Particularly heavily contaminated were the feeders and headers within the insulation cabinets, as well as the end shields and end fittings.

Prior to the start of fuel channel reinstallation, it was decided that a full scale decontamination of vault surfaces would be required. The process was divided into two phases; reinstallation prerequisite, and reactor building rehabilitation before the units' return to service. Three basic objectives shaped decontamination planning:
(1) Reduce hazard levels of loose surface contamination in the vaults to those typical of a rubber area requiring the wearing of disposable coveralls and a respirator only.
(2) Reduce the potential for contamination transfer out of the R/B during removal of LSFCR equipment.
(3) Ensure low contamination levels are maintained during unit start-up and subsequent return to operation. The target for decontamination was residual loose contamination levels less than 1000 cpm/100 cm^2, and less than 500 cpm on large flat surfaces.

If protective clothing requirements for on-face reinstallation work were to be relaxed, the feeder cabinets, reactor face, shield cabinets, ACU's, and vault surfaces would have to be decontaminated. The potential for loose surface contamination to become an airborne inhalation hazard had to be eliminated. Vault, shield cabinet, and ACU exterior surfaces could simply be cleaned by wiping or mopping with detergent solutions. The face and feeder cabinet interiors present a somewhat more complex surface geometry with difficult access. Review of the options for an effective face and feeder cleaning identified high pressure washdown as the only practical approach. Unfortunately, the lead time was too short for equipment procurement, detergent qualification, and preparations for liquid waste recovery/processing. In the end, decontamination before reinstallation was limited to a labour intensive wipe and mop down of the shield cabinets and high traffic areas of the vaults. Protective clothing restrictions were not lifted, and all reinstallation as well as rehabilitation activities were performed with personnel in air supplied plastic suits (covered with disposable coveralls and booties).

Initial cleaning in both Units 1 and 2 concentrated on easily accessible areas. Vault ACU's were not included as access required extensive scaffold construction. Surfaces

specifically targeted for decontamination by wiping were as follows:

° vault floors
° rolling shields
° vault walls to a height of 8 feet above the floor
° stairways leading to the bridge and feeder cabinets
° shield cabinet roof, interior surfaces, and all equipment mounted within
° vault observation systems (cameras)

Although the decontamination was by wiping and mopping only, technique proved to be critical. Regardless of the starting levels of loose contamination, a systematic cleaning from top to bottom without tracking over areas already cleaned was basic to the technique. Wiping consistently in one direction only, and using a clean rag surface for each wipe prevented recontamination of areas just cleaned. Rags were discarded immediately after they had been used once. Terry cloth rags were found to be most effective, the coarse nap providing absorbency to remove and hold surface contaminants. Overall, the initial decontamination was effective in reducing loose contamination levels to the targets stated earlier. There was no significant recontamination from surface bleed (or sweating) 24 hours later. Throughout the reinstallation phase, routine surveys and decontaminations were aimed at maintaining the general state of cleanliness which had been achieved.

On completion of fuel channel reinstallation, reactor building rehabilitation became the next order of business. Integral to this program was the extensive cleanup of all vault and equipment surfaces. At the time of writing, only Unit 1 had been returned to operation. All discussion to follow is based on the activities which led to the successful cleanup of the Unit 1 vaults. With the exception of minor procedural changes reflecting lessons learned, the techniques for Unit 2 are expected to be similar.

Decontamination Research

To assist decontamination planning, fundamental research into three areas was initiated. Evaluation of detergents, coupled with liquid waste processing studies, were in direct support of a proposed washdown of the reactor faces, feeder cabinets, and vault structural surfaces. Physical and chemical characterization of the carbon 14 particulate was essential to understanding the contaminant behavior under various conditions.

Detergent Qualification. A detergent solution applied to end fitting and feeder surfaces must be of low halogen and sulfur content, as well as being effective in removing insoluble carbon-14 from a variety of surfaces. Ontario Hydro Research conducted a screening of commercially available products. Candidates were chemically analyzed and then tested for their decontamination effectiveness.

Concerns about rusting of carbon steel components on end fitting and feeder assemblies following a water based washdown prompted a search for suitable corrosion inhibitors. This inhibitor had to be water soluble and chemically compatible with reactor materials. An amine based product (CORTEC VCI-309) was found to satisfy both criteria. Applied with the rinse water in a concentration of 0.5% or greater, visible rusting of wetted carbon steel surfaces left to stand in air would be prevented. Preliminary corrosion tests were carried out to assess the impact of residual detergent and inhibitor in carbon steel crevices at operating temperatures. Based on this limited testing, crevice corrosion initiated by residual chemicals was not expected to be a problem.

Waste Processing. Expecting to collect large volumes of highly contaminated waste water during a face and feeder washdown, studies to identify a waste processing strategy were undertaken ([1]). Approval for direct discharge into the station active liquid waste management system could not be assumed. Filtration, ultrafiltration, adsorption, and ion exchange were candidate processes. Mixed bed ion exchange showed the best performance, removing 90% of the carbon-14 from a waste water feed. Resin capacity was estimated at 860 microcuries of carbon-14 per litre of resin. The value of filtration through a range of 0.2 to 2. micron media is still in question. Lab tests report carbon-14 removal of 40 to 70%. Field tests contradict this, as little or no carbon-14 removal across series connected 2 and 0.2 micron filters was observed.

Characterization. Neutron activation of nitrogen to carbon-14 in the Unit 1 and 2 gas annulus systems produced a rather unique product. Analysis of the physical and chemical properties of the carbon-14 bearing material is an on-going process ([2]). It is now believed that the deposit formed within the calandria tubes is a polymeric material containing carbon-14, nitrogen, and hydrogen. Carbon-14 accounts for approximately 50% by weight giving the pure material a specific activity of about 2 curies per gram. In a nitrogen blanketed annulus gas circuit the polymer grew as a crystalline deposit with a dendritic structure (branched or "Christmas tree" like). Retubing operations broke parts of the crystals away from their substrate, freeing particles for release out of the open annulus gas system.

Cleanup of loose particulate was hindered by the materials' insoluble nature. Only a small fraction is soluble in saline or dilute acid solutions. The majority (80%) of the carbon-14 material is unaffected by common solvents and reagents.

On exposure to air the polymer undergoes partial surface oxidation, with a subsequent liberation of gaseous carbon-14 dioxide and a small amount of carbon-14 monoxide. Release is very slow at room temperature, but can be

accelerated at temperatures above 200°C. Over a four day period at 300°C in air, 90% particulate activity is converted to gaseous products. The key here is free reactive oxygen. Under a nitrogen or carbon dioxide cover gas, gasification of the particulate is limited by the extent of surface absorbed or chemically bound oxygen. Once oxidation sites are driven off, the remaining material is inert in the absence of oxygen ([3]). Radiolysis initiated by high gamma doses is not expected to have a significant effect on polymer decomposition beyond that achieved thermally ([4]).

Feeder Cabinet Decontamination

While planning prerequisite activities for the wash down of feeder cabinet internals and reactor faces it became apparent the task was more involved than originally anticipated. It was scheduled to occur after fuel load and removal of the shield cabinets from the bridges. This put the wash down on the critical path just ahead of heat transport system hot commissioning. Without the use of the bridges which were lowered for mounting of the fueling machines, scaffolding or manlifts would be required to prepare for and carry out the spraying. Soffit panels would have to be removed before a waste water catch tray would be hung beneath the upper cabinet overhang. High levels of carbon-14 on the inside surface of the soffits were expected to create a radiological hazard during their removal. Expecting several thousand gallons of contaminated waste water, temporary tankage would be required to hold the volume for processing. Concerns were expressed about the potential damage to feeder insulation panels by direct impact of a high pressure water spray, or wetting of the insulation material itself. Wet insulation that sagged and compacted would lose its insulating properties. The dose penalty to carry out the washdown in both vaults was estimated at 16 Rem. There was no immediate benefit for rehabilitation or recommissioning work to follow the decontamination.

Feeder Insulation Cabinet
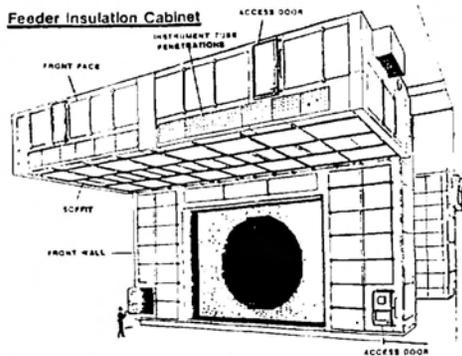
Given the concerns and amount of prerequisite work just described, there grew a reluctance to proceed with a washdown. Results of the carbon-14 oxidation studies at high temperature provided an alternative. After installation of the end fitting jig-saw panels on the reactor faces, end fittings and feeders would be fully contained. Operating temperature within the

enclosure (250°C) is sufficient to gasify (decompose) most of the carbon-14 particulate over a period of a few months. This in effect would decontaminate the face and cabinet interior. Control of carbon dioxide release out of the cabinets was the only issue to be addressed.

Prior to hot commissioning a purge system was tapped into both the east and west cabinets. A small flow is drawn out of the cabinet, routed through an air to air heat exchanger and high efficiency filter, then exhausted into the reactor building ventilation stack. From an emmissions perspective this concept would not pose problems. If the entire carbon-14 inventory, conservatively estimated at 5 curies, was oxidized and vented up the stack in a one week period the release would only be 0.4% of the emission limit. This was confirmed during the hot commissioning (see section: Decontamination Assessment).

With the exception of the soffits, exterior surfaces of the feeder cabinets were decontaminated by simple wiping with detergent soaked rags. Technique was the same as that used for the general vault cleanups preceeding fuel channel reinstallation. The only complication here was panels on both sides of the reactor face which were coated in a film of oil or grease from the bridge drives. This made wipe down to meet the target of less than 1000 cpm loose all the more difficult and time consuming.

ACU Decontamination

Decontamination of the exterior and interior of the 8 vault air cooling units was perhaps the most difficult cleanup carried out. Access to the top and front of the units required considerable scaffold construction spanning the full width of the vaults. At the top of the ACU's are exposed closely packed finned cooling pipes. After years of operation a thick layer of dust had accumulated on the face of these cooling heads. Particulate carbon-14 was believed to be confined and trapped amongst this upper layer of dust. Finned piping surfaces on the inside of the ACU's were generally free of carbon-14. This is not surprising as the ACU's were not running when airborne carbon-14 was introduced into the vault.

Removal of the dust layer and entrained carbon-14 from the cooling heads was achieved by vacuuming. Rapid loading of the vacuum system filters often delayed the job while the filters were being replaced. For Unit 2 a cyclone separator will precede the filters to prolong their useful life. All other exterior and interior surfaces were wiped clean. This was a slow and often repetitive process. Working space inside the ACU cabinets is limited. Most surfaces in the vicinity of the fan shaft and motor bearings were covered with a heavy film of grease. The thoroughness of the ACU cleanup is

credited to a conscientious decontamination crew. Technique again was all important.

Equipment Decontamination and Removal

The greatest potential for contamination transfer out of the reactor buildings was during removal of the bridge mounted LSFCR equipment. Early in the planning stage it had been decided that thorough decontamination of this hardware would be carried out in the vaults and North Accessible Area (NAA). There was no decontamination facility outside of the reactor building large enough to accommodate the shield cabinets and their associated components.

While still in the vaults all equipment underwent some preliminary decontamination. Crevices were vacuumed out. A general wipe down followed. On transfer into the NAA equipment pieces were enclosed within a plastic tent. Detergent solution was applied over the surfaces and then rinsed off with a 14 MPa (2000 psi) water spray. Waste water on equipment surfaces and the floor of the tent was removed and contained using a vacuum system. After wiping to dryness, surfaces were checked for loose contamination. Areas having greater than 1000 $cpm/100\ cm^2$ were further decontaminated by wet wiping. Transfer out of the reactor building was only permitted when contamination levels on all accessible surfaces were less than 1000 $cpm/100\ cm^2$.

Exceptions to the process just described were the two shield cabinet cranes. These cranes contain complex surfaces, drive mechanisms, and an array of electromechanical components all susceptible to water damage. Decontamination was limited to extensive wiping, followed by a plastic wrap and crating. Use of a high pressure liquid Freon spray on the cranes was an option explored in some depth. This concept was rejected when approval for in vault use of the halogen rich Freon could not be secured.

Removable fixatives were another technique evaluated for decontamination of shield cabinet surfaces. If contamination levels could not be reduced to the target levels, a strippable coating could be applied to fix the contaminants. Removal of the coating as a solid waste would be done after the equipment had been transferred out of the reactor building. This notion was shelved upon finding the fixative to have a limited ability to incorporate and bind carbon-14 particulate. The curing time was also found to be too long given our schedule constraints.

Wall and Floor Decontamination

Once the vaults had been cleared of the shield cabinets and the fueling machine bridges were restored, walls and floors were targeted for decontamination.

Vertical surfaces are the least likely to concentrate dust and contaminant deposition. As a result, vault walls wiped down prior to fuel channel reinstallation had remained relatively clean. Except for cleaning top horizontal surfaces of equipment or piping mounted on the walls, no further decontamination of the walls was carried out. It is important to recognize that the initial decontamination of the walls was only to a height of 8 to 10 feet above the floor. This is considered the potential contact zone for personnel working in the vaults. Cleaning wall surfaces above this contact zone provided little or no benefit. As a final measure, residual loose contamination on the wall contact zone was fixed with a coat of paint.

Floors required minimal decontamination effort. Loose contamination levels had been maintained low throughout the face work and vault rehabilitation. Residual contamination was fixed by painting the entire floor area in both vaults and NAA.

Decontamination Assessment

On review of the decontamination achievements it is fair to say we were successful in meeting our objectives. Throughout the process of decontaminating and removing the shield cabinets there was no contamination release outside of the reactor building. Contaminated waste water collected during washdown of the shield cabinets and associated equipment was all directed into the active liquid waste system. The total carbon-14 inventory in this discharge only added about $10^{-4}\%$ to the station monthly emission limit.

Releases of carbon-14 dioxide from the feeder cabinets and gas annulus system were monitored during heat transport system hot commissioning. Even with purges of the annulus gas system the total release of gaseous carbon-14 for the entire station did not exceed the emission target (1% of regulatory limit). There was a definite contribution from the feeder cabinets, indicating some gasification of carbon-14 particulate had taken place. The extent of radiolysis assisted decomposition during unit criticality had not been determined at this point.

After hot commissioning the west vault was checked for recontamination. Recently painted surfaces and the new metal face panels had not been contaminated during the hot test. This effectively dispelled all suspicions that ACU operation would stir up residual loose contamination and spread it around the vaults. There were however localized areas on the exterior of the feeder cabinets with contamination levels well in excess of the 1000 cpm target. Recontamination from other sources is not believed to be responsible. Current thinking is that these were spots not adequately cleaned, or contamination has crept out of crevices and joints after the cleaning.

Regardless of the reason, no further action was taken. Levels will be rechecked during the first planned maintenance outage. At this same time a survey for carbon-14 within the feeder cabinets will assess the effectiveness of high temperature oxidation as a method of decontamination.

Conclusions

The retube of PNGS Units 1 and 2 has provided many valuable lessons. Contamination control requires a constant vigil. Potential pathways for the release and spread of particulate into the work area must be considered in every aspect of tool design and operation. Decontamination should be directed at the source itself before the system containment is breached. Failing complete elimination of the source, capture of the contaminant at the point of release must be the next line of defense. Achieving these objectives would simplify both on-face work and vault decontamination in future LSFCR projects.

References

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