MILLSTONE #1 RECIRCULATION PIPING AND RWCU PIPING DECONTAMINATION

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ABSTRACT

In February, 1987, Northeast Utilities Service Company (NUSCO) contracted LN Technologies (LN) to decontaminate the recirculation piping and reactor water cleanup piping systems for Millstone Unit 1. The decontamination and waste processing operations were completed in June, 1987.

The decision to perform the decontamination was based upon the expected man-rem expenditure in the drywell during in-service inspections, seismic hanger work, and general maintenance supporting the outage. The expected man-rem savings were compared with the cost to perform the work which included vendor costs, NUSCO support costs, and waste transport and disposal costs. Based upon the technical evaluation of the process and review of past decontamination experiences, NUSCO decided to proceed with the project.

This paper discusses the results of the decontamination including activity removed, dose rate reductions, and waste produced. Three key factors which influenced the success of this project are:

<u>ALARA Review</u> - A complete ALARA review was conducted before the decision was made to proceed with this project. Major factors in this analysis were the effectiveness of the decontamination process selected, the cost to apply the process, the quantity of dose intensive work to be performed, and the value of a man-rem assigned by NUSCO.

<u>Project Pre-Planning</u> - Specific steps were taken in the pre-planning phase to ensure that the project achieved the desired technical result without impacting the overall project schedule.

<u>Waste Generation</u> - Decontamination reagents are removed from the piping systems using ion exchange resins which result in the generation of solid radwaste. Therefore, adequate plans were made for processing and disposal of resin containing chelants.

The consideration of these factors contributed to the success of the decontamination. The project was completed ahead of its critical path schedule and resulted in significant reduction in man-rem exposures.

INTRODUCTION

Millstone Unit 1 is a 650 MWe Boiling Water Reactor (BWR). The primary piping was previously decontaminated by LN Technologies (formerly London Nuclear Services) in April 1984 with excellent results.

A cracking problem in older BWR piping systems has caused several outages for in-service inspections (ISI), weld overlays, and even piping replacements. In this particular outage, ISI plus seismic hanger work was performed. Both of these tasks required significant amounts of work in the reactor drywell near the recirculation pumps and piping. This time spent in the drywell translated into significant accumulated dose due to the high radiation levels. In addition, Millstone had made the decision to apply the GEZIP Process (zinc injection during power operation) which would passivate the reactor coolant system (RCS) and inhibit radiation field growth. Implementing GEZIP after a chemical decontamination would allow RCS passivation on piping that was relatively clean. Therefore, decontamination prior to application of GEZIP would give additional dose reduction benefit in future outages.

Due to the significant projected man-rem expenditures, the lack of sufficient numbers of qualified ISI inspectors and the projected benefits of the GEZIP Process, Millstone decided to investigate the feasibility of performing a decontamination to the reactor recirculation piping and reactor water cleanup (RWCU) piping. A chemical decontamination is a complex project which utilizes significant amounts of contractor and client resources. Therefore, an adequate ALARA review had to be performed to determine if the projected radiation dose savings were sufficient to merit performing the decontamination.

ALARA REVIEW

NUSCO reviewed the expected work load, previous decontamination results, and the expected project cost. This ALARA review yielded the following data:

Man-Rem Without Decontamination	420
Man-Rem With Decontamination	103
Net Man-Rem Savings	317
Man-Rem Cost ($/Man-Rem)	$20,000
Man-Rem $ Savings	$6.34OM

NUSCO assigns a large cost to an expended man-rem ($20,000/man-rem) and does not consider critical path in ALARA cost/benefit analysis. This demonstrates NUSCO's aggressive commitment to radiation exposure reduction. Total cost to perform the decontamination was estimated to be $1.30M. Thus, net benefit = Man-Rem $ Savings - Total Cost = $5.04M. It is noted that the above estimates were based upon the expected work scope. Actual man-rem savings were not available at the time of this printing.

Based upon the results of the ALARA review and NUSCO's commitment to reduce exposure, LN Technologies was contracted to provide decontamination services to the recirculation piping and RWCU piping systems.

APPROACH TO THE DECONTAMINATION

When a BWR operates, the reactor coolant flows from the vessel annulus through the suction piping to the recirculation pumps. The pumps send the coolant to the discharge piping, through the ring manifold where coolant is distributed by the jet pumps into the reactor vessel. The jet pumps create efficient mixing as the coolant is distributed over the reactor core and flows back to the annulus to complete the flow loop.

The only section of the flow path desirable to be decontaminated was the piping in the drywell where work would be performed. Therefore, an adequate method was required to generate sufficient flow rates in the required piping areas while preventing the reagents from entering the reactor vessel.

Engineering Pre-Planning

The reactor recirculation system consists of two separate loops that are interconnected at two points, the vessel annulus on the suction side and the ring manifold on the discharge side. The interconnections allowed the decontamination to be performed in two phases, a discharge phase and a suction phase. Each phase is described below.

The discharge piping was decontaminated by incorporating the two ring manifold cross tie lines into the flow path (see Fig. 1A). The suction side isolation valves were closed and the discharge isolation valves opened. The two pumps, the discharge piping, the ring manifold, and the jet pump risers were incorporated into the flow path. The recirculation system was tied into the portable decontamination equipment at existing flanges located at the suction piping near each pump. One of the ring manifold cross-tie valves was throttled to create enough differential pressure to force liquid up the recirculation risers on the high pressure side while the liquid level in the low pressure side dropped into the ring header. The decontamination equipment had flow reversal capability to allow liquid to be forced up the opposite set of jet pump risers. Control of the levels was maintained at 2 - 3 feet above the riser safe end. This allowed the riser elbows to be adequately decontaminated while also maintaining safe distance (approximately 10 feet) from the top of the jet pump risers. With regular reversal of flow direction, fluid movement up and down the risers was accomplished.

Decontamination of the suction piping was a much simpler task because both suction loops were interconnected through the vessel annulus. The discharge isolation valves were closed and the suction isolation valves opened. The liquid level was adjusted to approximately 6 inches above the top of the suction nozzles to ensure adequate coverage of the elbows. This was approximately 5 feet below the slip joint. (See Fig. 1B.)

The Reactor Water Cleanup System Piping (RWCU) decontamination utilized the flowpath shown in Fig. 2. Connections to the RWCU were made by removing the internals of valves 1-CU-6 and 1-CU-10 and fabricating a flange adapter which connected to each valve bonnet. Flow passed through valve 1-CU-6, both sets of regenerative and non-regenerative heat exchangers, and back out through valve 1-CU-10. Flow was periodically reversed to aid in oxide film dissolution.

Auxiliary equipment was required to perform the decontamination. The equipment was supplied by LN and utilized the following components:

- A circulation pump
- Two electric heaters
- A corrosion coupon holder
- A chemical make-up system
- Six ion exchange columns
- A sampling system
- Ancillary piping, hoses, and controls

By connecting the decontamination equipment to the reactor piping system, a flow loop was established. This

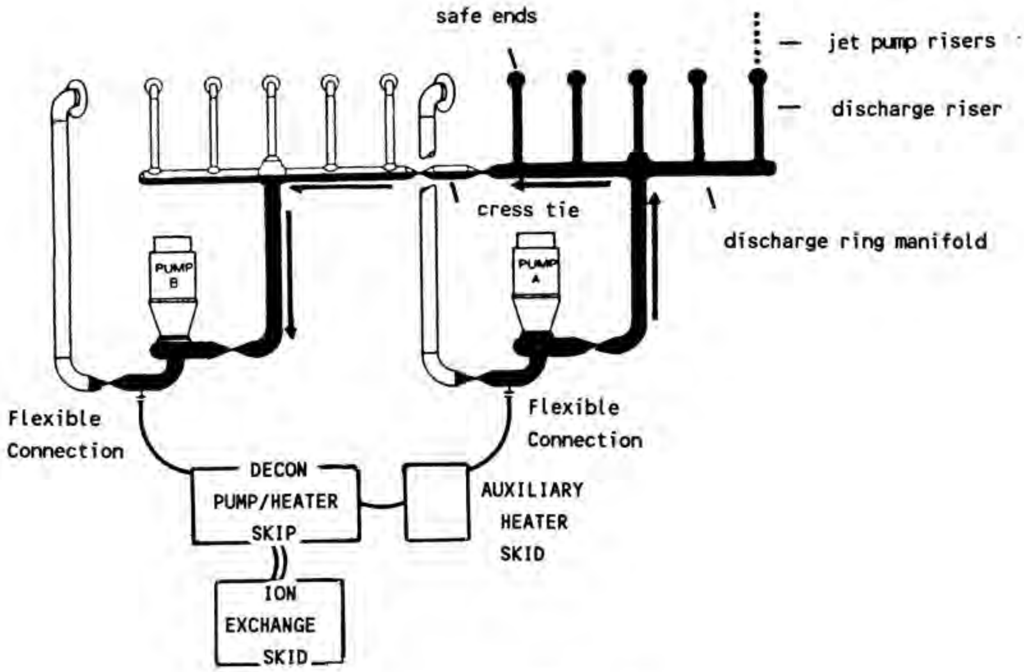

Fig. 1A. Flow Path

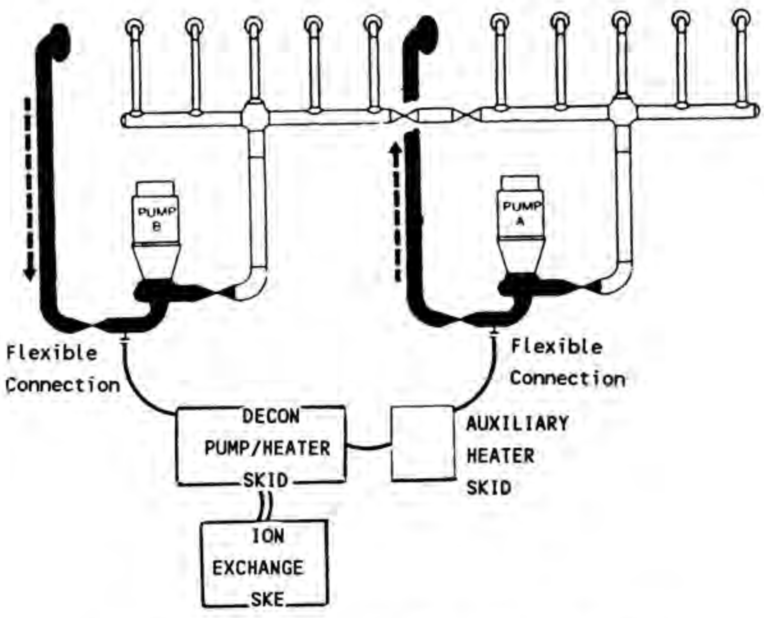

Fig. 1B. Flow Path Suction Piping Decontamination.

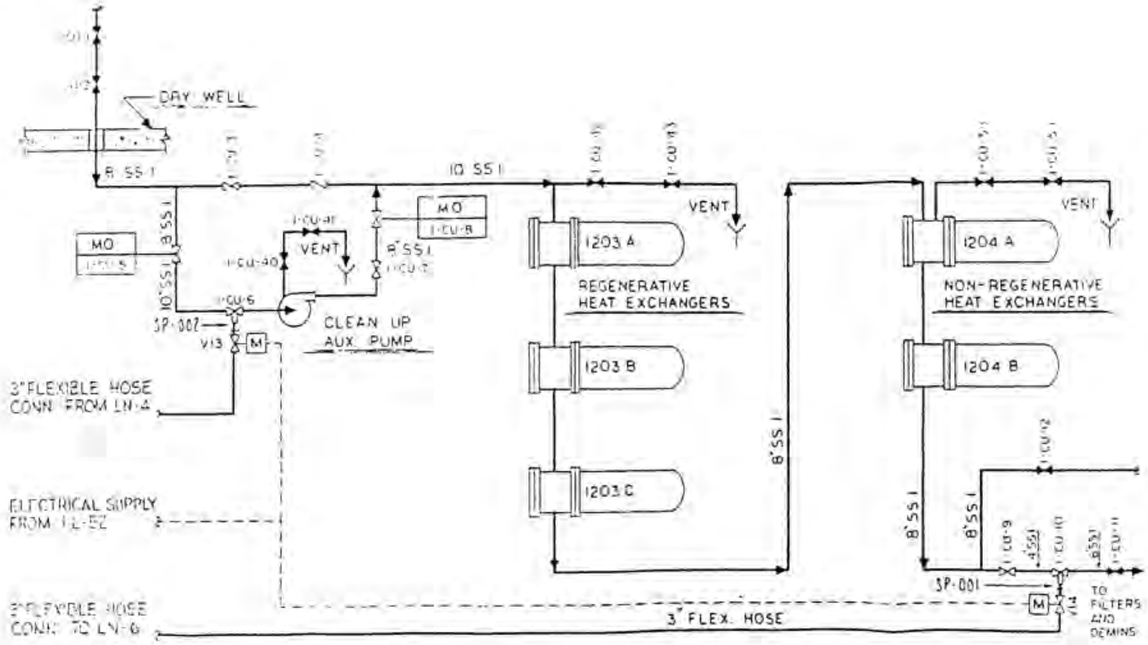

Fig. 2. Flow Diagram Decontamination of Reactor Water Cleanup System.

allowed the equipment to circulate the reagents throughout the reactor piping system. In addition the equipment had the capabilities to monitor and control process temperature, inject reagents, monitor and control fluid levels, provide sampling capabilities, and remove reagents on ion exchange.

The equipment was skid mounted for ease of transport and installation. The various skids were located near the reactor drywell entrance to minimize flexible hose runs. The exact equipment location was coordinated with outage support groups to meet the following criteria:

- Minimize interference with other outage tasks
- Ensure sufficient floor strength to support the skid mounted equipment
- Locate at a low enough elevation to prevent circulation pump cavitation
- Locate close to the solid radwaste building where resin transfer hose was routed

Chemistry Pre-Planning

Chemical decontamination involves the dissolution of metal oxides. The reagents circulate through the system dissolving the deposits and releasing contaminants from the walls. Once the contaminants are in solution, they can be removed from the system by ion exchange purification. Dissolved metals, such as iron and cobalt, are removed by cation resin. The decontamination chemicals are removed by mixed bed enriched with anion resin.

TABLE I

Main Features of the CAN-DEREM and the LOMI

Feature	CAN-DEREM	LOMI
Dissolution Rate	24 - 48 hours for complete oxide film	6 - 8 hours for complete oxide film dissolution
Operating Temperature	95°C - 120°C requires 2 Atm. overpressure to maintain good flow at higher operating temperature	75°C - 90°C therefore requires no pressurization to meet chemistry requirements
Chemical & Quantities	0.1 wt.% chemicals typically requires 1.4 - 1.7 cubic meters of ion exchange resin for a typical RCS	0.7 wt.% chemicals typically requires 3.5 - 5.2 cubic meters of ion exchange resin for a typical RCS. Chemicals are very expensive
Operating	Regenerative; uses minimal man-rem	Non-regenerative; man-rem generally higher than CAN-DEREM

Two chemical decontamination processes were considered for use by NUSCO; CAN-DEREM and LOMI. CAN-DEREM is an acidic dissolution method which uses organic acids in a 0.1 wt.% concentration. The CAN-DEREM process is regenerative; that is; as it dissolves metal oxides, the solution passes over a cation bed which exchanges a metal ion for a hydrogen ion. This allows radionuclides to be constantly removed on the resin beds while regenerating the organic acids to continue the dissolution process. A major ALARA benefit of this process is the reduction in radiation exposure to operating personnel due to continuous removal of dissolved radionuclides in solution.

LOMI is a reductive dissolution method which uses vanadous formate and picolinic acid in a 0.7 wt.% concentration. LOMI is a non-regenerative process which dissolves all oxide film and is subsequently removed by ion exchange. A major advantage of LOMI is that its reaction rate is significantly faster than CAN-DEREM which results in reduced critical path time Table I.

Based upon the fact that this project was on the outage critical path, NUSCO decided that the critical path time saved in applying LOMI outweighed the costs of additional chemicals, resin, and waste processing.

With the process chemistry established, chemical and resin quantities were calculated based upon several different possible decontamination options. Chemical decontaminations have not always proceeded based upon artifact testing or even previous work on the same reactor.
Therefore, three possible decontamination options were planned for:

- LOMI
- LOMI-LOMI
- LOMI-NP-LOMI

The single LOMI was the most likely approach to occur. The LOMI reagent would be injected, circulated for 6 - 8 hours and cleaned up using ion exchange resin. Since the LOMI reaction time is relatively short, it may all react before completing a full circulation through the piping system. This is particularly true in the jet pump risers where it is difficult to generate good turbulent fluid flow, and where significant work (and therefore man-rem) is expended. Therefore a second LOMI step may be required to dissolve the remaining oxide film.

Occasionally an oxide film occurs which is not characteristic of BWR's. Due to differences in operating conditions, the film can contain 5% to 10% chromium oxides with the usual iron oxides. The chromium oxides do not readily dissolve in LOMI or CAN-DEREM, therefore a modification to the chemistry is required. The NP, or Nitric Permanganate, is an oxidizing step which oxidizes the chromium to a higher valence state. In this state, it is more soluble and is removed from the film. This NP step is then followed by a second LOMI or CAN-DEREM which then dissolves the remaining film.

Since the decision to proceed could not be made prior to completion of the first LOMI step, adequate pre-planning was performed to:

- Ensure sufficient chemical and resin quantities were on site for supplemental steps.
- Ensure acceptable decision making criteria were established and reviewed.
- Ensure waste processing equipment with a sufficient number of properly sized liners were available.

A detailed decision making criteria was formulated for each option. Since the project was on the outage critical path, it was essential to establish a clear decision making process in advance.

To assess the effects of the decontamination on process piping, a technical safety evaluation was prepared. Included in this evaluation were the following:

- Review of all test data for galvanic corrosion, stress corrosion cracking, crevice corrosion, intergranular corrosion, and pitting corrosion with LOMI and NP reagents.
- Evaluation of long-term affects of trace residual reagents.
- Review of the vendors proposed operational control program to ensure that all foreseeable problems had been addressed.

This review concluded that the proposed decontamination would not significantly degrade any components and therefore would not involve an unreviewed safety question as defined in 10 CFR 50.59 and that the required margin of safety would not be degraded. To monitor the effects of the decontamination on the reactor components, small coupons of key representative material were placed in the decontamination equipment coupon holder and exposed to the process conditions.

Waste Processing Pre-Planning

The waste generated from a chemical decontamination consists of spent ion exchange resins containing chemicals, metals, and radionuclides. Between 5.8 and 7.6 cubic meters of waste resin would be generated depending upon the number of steps required to complete the decontamination. The two major chemicals used in the LOMI process, formic acid and picolinic acid were considered to be chelants. It was desired to ship to the Barnwell site which has the following chelant restrictions:

Chelant Concentration	Restrictions
<0.1%	None
0.1%&<8%	Must be solidified in accordance with 10 CFR 61 criteria
8%	
ot accepted	

Chelant concentration was calculated to be in the 4% to 6% range; therefore waste solidification was required. Since more than one waste liner was required, the anticipated operating steps and resultant resin transfers were reviewed to ensure that one liner did not become overloaded with chelants.

Another factor which was considered was curie loading of the liners. Based upon results of the 1984 Millstone Unit 1 decontamination, and the fact that radiation fields on the recirculation piping had risen to the 1984 pre-job levels, approximately 34 curies of Cobalt-60 were expected to be removed from the reactor system. Cobalt-60 would be the main contributor to shipping cask dose rates. The worst case predicted was the concentration of all the curies into an LN-182 liner and its shipment in an LN-14-170 cask. Under this condition, up to 44 curies of Cobalt-60 could be transported. In previous decontaminations, liners with greater than 50 curies of Cobalt-60 had been transported without exceeding shipping limits.

Therefore it was felt that both curie and chelant loading on the waste resins could be handled with existing equipment and processes. The equipment used for the solidification process consisted of the following components:

- A mixing fillhead
- A hydraulic power unit
- A self contained ventilation system
- Remote controls and indicators for system operation and control
- A bulk cement storage trailer
- A pneumatic cement transfer system

The solidification system used a batch mixing process where the resin waste was preconditioned with additives and mixed with dry cement in a disposable liner. Spent ion exchange resin was transferred from the ion exchange vessels to the liner through a flexible hose which penetrated the truck bay containment wall and continued to the Solid Radwaste Building. Prior to waste transfer the liners were placed in a (station supplied) mobile shield. The transfer hose was hydrotested to double the maximum expected operating pressure. In addition, a dike was constructed around the transfer hose in the unlikely event that a leak would occur. Upon completion of the resin transfer and solidification, the liners were transferred to on site storage containers (OSSC's) to await isotopic analysis prior to shipment.

With the equipment and flow paths chosen, the site specific decontamination procedures were prepared and presented to NUSCO for review and approval. The procedures addressed the following key areas:

- Project Organization and Responsibilities
- Equipment Installation and Set-Up
- Equipment Testing and Operations
- Chemistry Monitoring and Decision Making Criteria
- Equipment Tear-Down and Shipment From Site
- Abnormal Operations Response

OPERATIONS SUMMARY

The decontamination of the recirculation piping and RWCU piping took 8 days to complete. The table below lists the key activities which took place. On the discharge piping and the RWCU piping a LOMI-LOMI was performed. On the suction piping, a single LOMI was performed.

TABLE II

Summary of Key Activities

Date	Activity
5/28/87	Decontamination equipment arrived on site
6/15/87	Waste processing equipment arrived on site
6/17/87	Decontamination equipment set-up completed
6/18/87	System functional testing completed
6/19/87	Discharge 1st LOMI completed Discharge 2nd LOMI completed
6/20/87	Transferred spent resin (80 cu.ft.) to 1st liner
6/21/87	Suction LOMI completed
6/23/87	Pre-operational testing for RWCU completed RWCU 1st LOMI completed
6/24/87	Transferred spent resin (40 cu.ft.) to 1st liner RWCU 2nd LOMI completed

TABLE II

Initial and Final Radiation Readings

Recirculation Piping	Initial (Mr/hr)	Final (Mr/hr)	DF (WHM)
Main Piping	219	24	9.3
Ring Header	282	141	2.0
Riser Elbows	386	101	3.8
Pump Bowl	120	5	24.0
Recirc Piping Average	285	77	3.7
RWCU Piping	155	57	2.7

TABLE III

Detailed Examination of Data from the Ring Manifold

*Point #	Initial (mR/hr)	Final (mR/hr)	Final 18" From Pipe (mR/hr)
7	210	100	90
8	420	160	70
20	200	70	70
21	500	200	75
27	65	40	20
28	300	240	90
29	280	180	60
Average	282	141	68

*Note: Point numbers refer to specific data points taken by the station health physics technicians.

6/25/87	Transferred spent resin (120 cu.ft.) to 2nd liner
7/04/87	All decontamination equipment packaged for shipment
7/09/87	All decontamination equipment shipped from site

The day to day operations proceeded quite smoothly and the project was completed approximately 13 hours ahead of the critical path schedule. This was due mainly to close coordination between LN and NUSCO. Meetings were held at each shift change (every 12 hours) to evaluate the previous shifts progress and plan work and support requirements for the next shift. All support groups such as health physics, radwaste, chemistry, plant engineering, and mechanical support attended as required.

RESULTS

Initial and final radiation readings on the process piping were obtained by the station health physics technicians. The results, summarized below, Table II, are average contact readings which most accurately reflect the effect of the decontamination on the piping. Refer to Figs. 1B, and 2 for general location of the areas listed below.

In the recirculation piping, all of the decontamination factors (DF's) were very high except for the ring manifold where only a DF of 2 was achieved. The higher DF's in the main piping, riser elbows, and pump bowl indicates good chemistry and flow conditions were present. Typically, the riser elbows exhibit lower DF's because a given riser will only see reagent flow 50% of the time. The DF's are usually high in the ring manifold due to good flow characteristics.

A detailed examination of data from the ring manifold yields the following: (Table III)

One possible explanation for the low DF in the ring manifold is the circumstances under which this section of piping was surveyed. All piping was initially surveyed with the shielding plugs in place. A post decon survey was performed with the shield plugs removed and yielded low DF's in the riser elbows and ring manifold. At a later date the shield plugs were re-installed and another survey was performed on the riser elbows. This new survey gave much higher DF's due to the reduction of background radiation. However, this survey did not include the ring manifold. As shown above, the average background level was 68 mR/hr in this area. The survey results may not realistically reflect the radiation reading on the piping and could be artificially high due to a high background field.

A similar hypothesis is postulated for the RWCU piping where many survey points were located in areas of high background fields. These fields could be due to piping

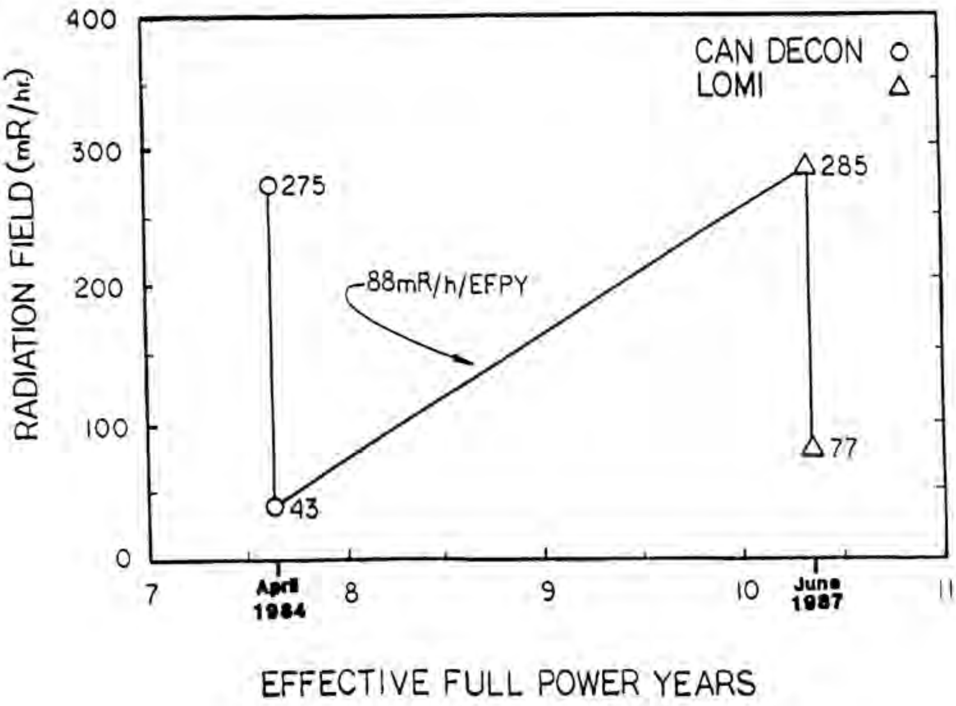

Fig. 3. Millstone-1 Recontamination History.

not in the decontamination flow path or other background radiation sources.

Overall, the radiation readings were reduced back to near the post decontamination readings of 1984. Figure 3 illustrates the recontamination of the recirculation piping after the 1984 decontamination and the subsequent reduction from the 1987 decontamination.

A total of 7.1 cubic meters of waste resin was generated. The waste resin was solidified in two LN-182CD liners. A summary of the liner loadings is shown below. Both liners were well below the 8% chelant limit. The first liner contained the majority of the activity. However this liner was well within shipping limitations.

The table below compares the actual metal penetration with the allowable penetration based upon the 10 CFR 50.59 safety review. In addition to simple weight loss analysis, all of the coupons were sent to Ontario Research Foundation (ORF) for a 30X and 250X visual examinations and 250X photographs. Also the sensitized 304 stainless steel and the 420 stainless steel were cross sectioned and photographed at 400X. Neither the 304 or the 420 stainless steel showed any evidence of intergrannular attack. As expected, the 420 stainless steel did show evidence of general corrosion but was well below the allowables.

CONCLUSIONS

The reactor recirculation piping and RWCU piping was successfully decontaminated using the LOMI dilute chemical decontamination process. A total of 69.3 curies of activity was removed from the reactor system. The waste resin generated was processed in two LN-182CD liners. Corrosion rates were well below the limits dictated by the safety review.

Average radiation readings on the recirculation piping dropped from 285 mR/hr to 77 mR/hr. This resulted in a savings of hundreds of man-rem with additional future savings due to the application of the GEZIP process. By adequately pre-planning all phases of this project, the decontamination of Millstone Unit 1 Recirculation Piping and RWCU Piping resulted in a) good decontamination factors, and b) adherence to the stations critical path schedule.

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