Reference #3

SUMMARY

Inadequate cooling of the irradiated fuel storage bay water lead to the inspection of the Heat Exchangers 0-34411-HX1 and 0-34411-HX2. Severe fouling was observed. This fouling was removed by inhibited 10% formic acid. Approximately 50 kg of deposit was removed from each heat exchanger by acid cleaning.

1.0 BACKGROUND

During the summer months of each year since 1975, there has been a problem providing adequate cooling to the Irradiated Fuel Storage Bay (IFB) water. During the early summer of 1979, the temperature of the IFB water rose to an unacceptably high level. A temporary Heat Exchanger (HX) was installed during which time both HX1 and HX2 were visually inspected confirming severe fouling. Between May and August 1979, much effort and time was expended trying to clean HX1 on line using Zimmite ZM136 solutions and air bumping.

Zimmite ZM136, an anionic polyelectrolyte, is described by the manufacturer as a mud remover. Treatment is usually long term at 10 to 20 mg/kg for 1 hour each day.

Visual inspection of HX1 after the air/zimmite treatment showed some improvement, but the tube bundle remained fouled. No attempt was made to clean HX2 using the zimmite and air treatment. During August, the Decontamination Section of CNS was asked to assist in cleaning the HX's. This report details the cleaning process, results and contracted costs for both HX's.

2.0 DEPOSIT INVESTIGATION

A sample of the deposit fouling the tubes of HX1 was taken on August 3, 1979, and sent to Research Division for investigation. Analysis showed that the deposit was similar to others obtained previously at Pickering NGS. [1][2] The deposit was a mixture of calcium carbonate, iron oxides, silica, and alumino-silicates. Tests were carried out, by Ontario Hydro Research Division, to try to break up and suspend the deposit using proprietory dispersants. After many proprietory dispersants had been tried without success, formic acid was tested. The acid generated copious amounts of carbon dioxide, dissolved about 30% of the deposit and left a finely divided, easily fluidized residue.

Choice of Cleaning Method

Originally both physical and chemical methods were considered for cleaning this HX. Chemical methods were preferred because physical methods would have required "pulling" the tube bundle. As a suitable chemical had been found, the chemical method alone was pursued to completion. The HX would be cleaned using inhibited 10% formic acid. Tanks, pumps, and chemicals would be supplied under contract from a chemical cleaning contractor.

3.0 PLANNING THE JOB

The chemical cleaning contractor was selected by tender. The technical section of the invitation to tender document is appended as Appendix 1. As stated in the contract, the contractor's staff attained ARW status. The blood tests and medical and X-ray examinations were carried out in Sarnia.

At a prejob meeting held at Pickering NGS-A, the contractor detailed the services required of Pickering NGS-A for the job to proceed. These details were incorporated in the plans(3)(4) which were written by Pickering NGS staff with chemical input from CNS.

4.0 CHEMICAL CLEAN - HX1

First Acid Wash, Flush and Neutralization

The cleaning loop (Figure 1) comprised of the HX, temporary pipework, and the contractor's equipment. The temporary pipework extended from the HX to the reactor auxiliary bay door and was comprised of two, 2 inch carbon steel pipes with isolation valves and pressure relief valves.

The cleaning loop was filled with service water, then leak checked by recirculating the water while heating. At about 60°C the inhibitor and formic acid were added. The resultant concentrations were approximately 0.5% and 10% respectively.

The calcium concentration rose rapidly and started to level off about 4 hours after acid injection (Figure 2). After 9 hours of recirculation, an excess of acid still remained, indicating that all the available calcium carbonate had been dissolved. The acid solution was then drained into the contractor's tanker. The HX was then rinsed with service water and sufficient soda ash to neutralize any remaining acid and raise the pH to 9. When the pH was acceptable, the HX was drained for visual inspection.

Both acid and flushing solutions were disposed of into the Water Treatment Plant (WTP) settling basin. Each tank was discharged only after the level of radioactivity had been shown to be $\leq$ 50 nCi/kg.

4.1 Visual Inspection

The cover plate on the shell at the U end of the bundle was removed to allow visual inspection. Inspection confirmed that the majority of the deposit had been removed. In locations where tubes were very nearly or actually touching, deposit still remained. However, the U-bend area was not thought to be representative of the remainder of the tube bundle.

A sample of the deposit remaining in the U-bend region was obtained and examined in the laboratory. The deposits had been transformed from a hard cake to a loose mud. Addition of hot 10% formic acid produced some effervescence. The decision was made to perform a second acid washing using 5% formic acid and regularly reverse the flow to try to dislodge the remaining deposits. A lower acid concentration was used for the second wash as the major removal mechanism for the remaining deposit was to be turbulent flow.

4.2 Second Acid Wash, Flush and Neutralization

The second inhibited acid solution was recirculated for 5-1/2 hours at about 30°C during which time the flow was reversed 3 times. The calcium concentration rose quickly to, and remained at, 300 mg/kg (Figure 3). Although the flow was reversed several times, the suspended solids concentration remained low (20 ppm). After the HX had been flushed and the pH raised to an acceptable level, the HX was drained and reinspected. The waste solutions, as before, were disposed of only after their reactivity was shown to be $\leq$ 50 nCi/L.

4.3 Second Inspection of HX

Very little change was observed in the appearance of the tube bundle U-bend region after the second cleaning cycle. Another view of the tube bundle was obtained, by looking down into the service water outlet stub. The visible area of the tube bundle was extremely clean and deposit free.

5.0 ZIMMITE FLUSH

At the request of Pickering NGS staff, an extra cleaning cycle was performed. A 200 mg/kg solution of Zimmite ZM136 was recirculated to try to remove the stubborn deposits in the U-bend region. The flow was frequently reversed to promote deposit removal, but the suspended solids content remained very low. Unfortunately the Zimmite solution escaped to the lake via storms drains from a line that had previously been frozen solid and subsequently thawed. The activity of the solution was shown to be $\leq$ 50 nCi/kg.

5.1 Third Inspection of HX

Inspection of the HX showed no change in the appearance of the deposits in the U-bend region of the tube bundle. At this stage, the HX was declared clean.

6.0 CHEMICAL CLEAN - HX2

Figures 4 and 5 show how the calcium concentration varied during both acid washes of HX2.

HX2 was acid cleaned in a similar manner to HX1. The HX was declared clean after the second acid wash sequence.

7.0 RESULTS

7.1 HX Cleanliness

Subsequent service has shown that the two heat exchangers are giving satisfactory service. However, the U-bend regions of the HX's were not as clean as they might have been. A modified solvent or process could improve the results. Any solvent or process changes should be compatible with other HX materials at Pickering, eg, copper alloys.

The performance of these HX's should be monitored to show how fast they foul. This would indicate the frequency with which the HX's should be cleaned.

7.2 Chemical Sampling

The plan had called for samples to be taken and analyzed every half hour. During the acid washes, the sample frequency was changed to hourly as more frequent sampling was found to be unnecessary. The acid cleans removed approximately 50 kg of deposit from each HX.

7.3 Corrosion Coupons

To monitor the metal loss from the tubes and shell, corrosion coupons of both 304 L stainless steel and carbon steel were exposed to the acid wash, rinse and neutralization solutions. Investigation[6] of the corrosion coupons show the average metal loss expressed as depth to be:

	HX1	HX2
Carbon Steel	12.1 μm	12.5 μm
304 L Stainless Steel	< 0.1 μm	< 0.1 μm

No pitting observed.

These results were most acceptable.

8.0 COST

The contracted costs for cleaning both HX's were 19.1 k$. The cost can be broken down as below:

Cost Code	Group	Cost (k$)
10	CNS	7.1
61	Research Division and RMEP	3.0
62	Contractor	9.0
		19.1

9.0 LESSONS LEARNED

9.1 Freezing Lines

A lot of time was spent thawing frozen equipment. An extra connection had been installed to facilitate draining HX1. (Figure 1, V3). This line and valve were frozen solid with the valve left open by an operator and subsequently a solution was lost.

This hazard would be eliminated by correct operator action and by taking suitable precautions for HX cleaning during winter.

9.2 Inspection of HX's

The U-bend of HX1, when inspected after cleaning, was found not to be representative of the bundle. It is strongly advised that, when practical, HX's should be thoroughly inspected before and after cleaning.

9.3 Safety Aspects

A difference exists between the safety standards acceptable to Ontario Hydro and chemical cleaning contractors. At the prejob meetings, the safety requirements (handling of chemicals, safety equipment) must be explained to eliminate hold-ups during the cleaning process.

10.0 CONCLUSIONS

(a) Inhibited 10% formic acid cleaned both HX's.
(b) About 50 kg of deposit was removed from both HX's.

11.0 RECOMMENDATIONS

(a) The performance of IFB, HX1, HX2 and HX3 should be monitored to identify fouling before it recurs as a major problem.
(b) Inhibited formic acid should be considered for cleaning other HX's at Pickering NGS that are fouled with silt and cannot easily be physically cleaned.
(c) The solvent should be modified to improve the cleaning effectiveness in the U-bend region.
(d) The compatibility of the solvent and copper alloy tubes should be tested.

12.0 REFERENCES

(1) B.R. Nott, Research Report No. C79-162-H, "Pickering NGS-A Heat Exchanger Deposits."

(2) R. Trimble, Research Report No. C78-10-K, "Pickering NGS-A Heat Exchanger Deposits."

(3) A.H. Green, Work Plan 79-66, December 13, 1979.

(4) A.GH. Green, Work Plan.

(5) P.J. Leinonen, Research Report C80-22-K.

(6) M.G. Van Horne, Research Report C80-62-K.

Figure 1

Layout of Equipment and Pipework

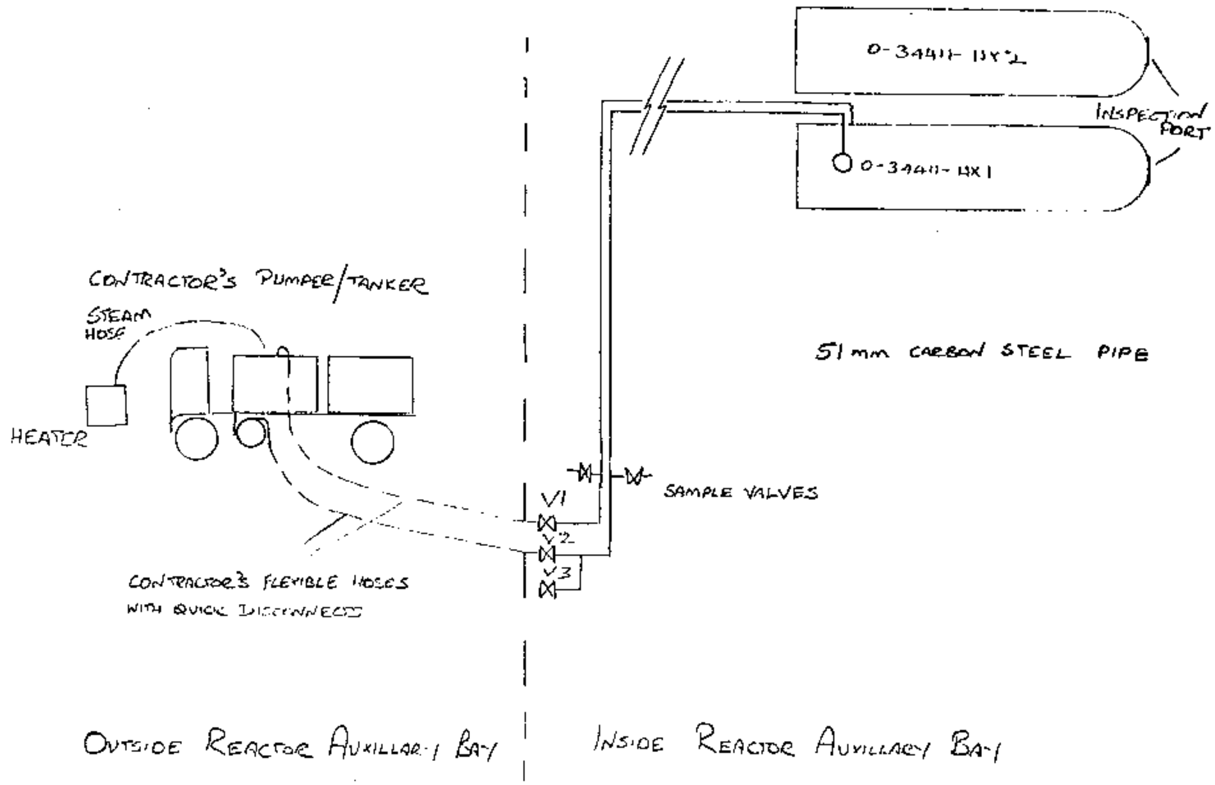
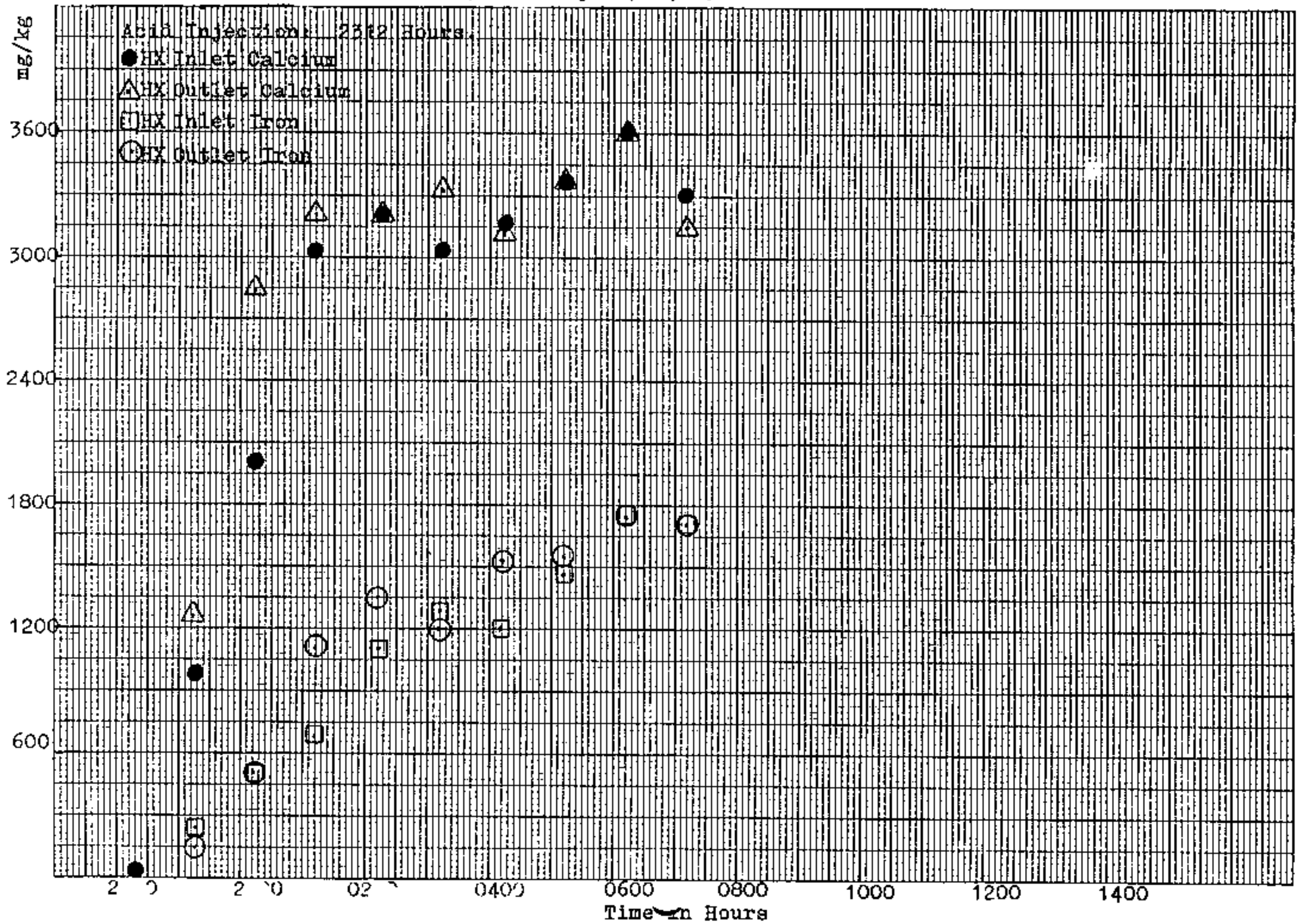


Figure 1

Layout of Equipment and Pipework

46 1320

Fig. 2 Graph showing variations of Calcium & Iron concentrations during 1st acid wash of 1FB-HX1, January 11/12, 1980.



PI 24.61-1 App III

K+E 10 X 10 TO 1/2 INCH KEUFFEL & ESSER CO. 46 1320

Fig. 3 Graph showing variation of Calcium & Iron concentrations during 2nd acid wash of 1FB-HX1, January 12/13, 1980.

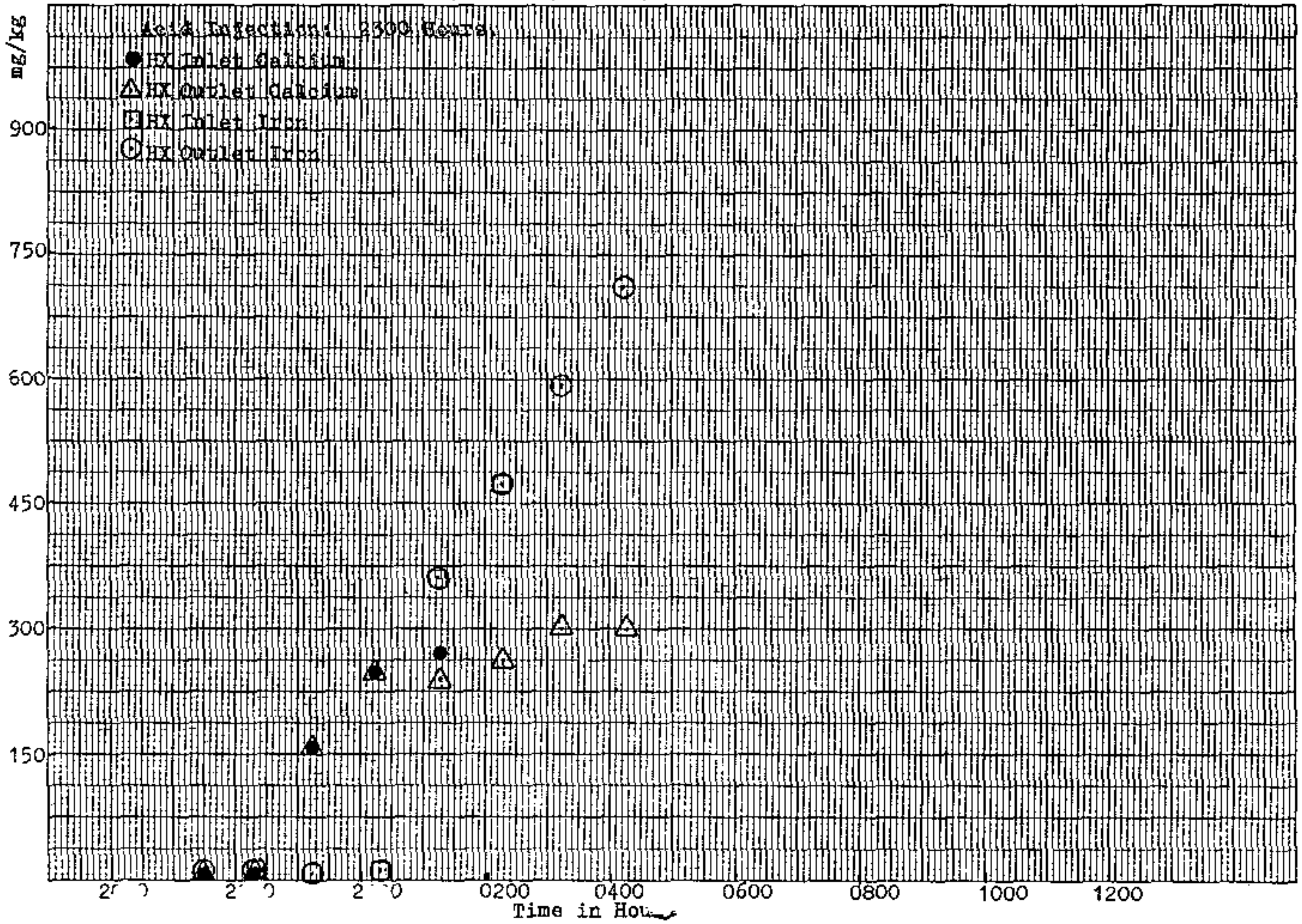


Fig. 4 Graph showing variations of Calcium & Iron concentrations during 1st acid wash of 1FB-HX2, March 6, 1980.

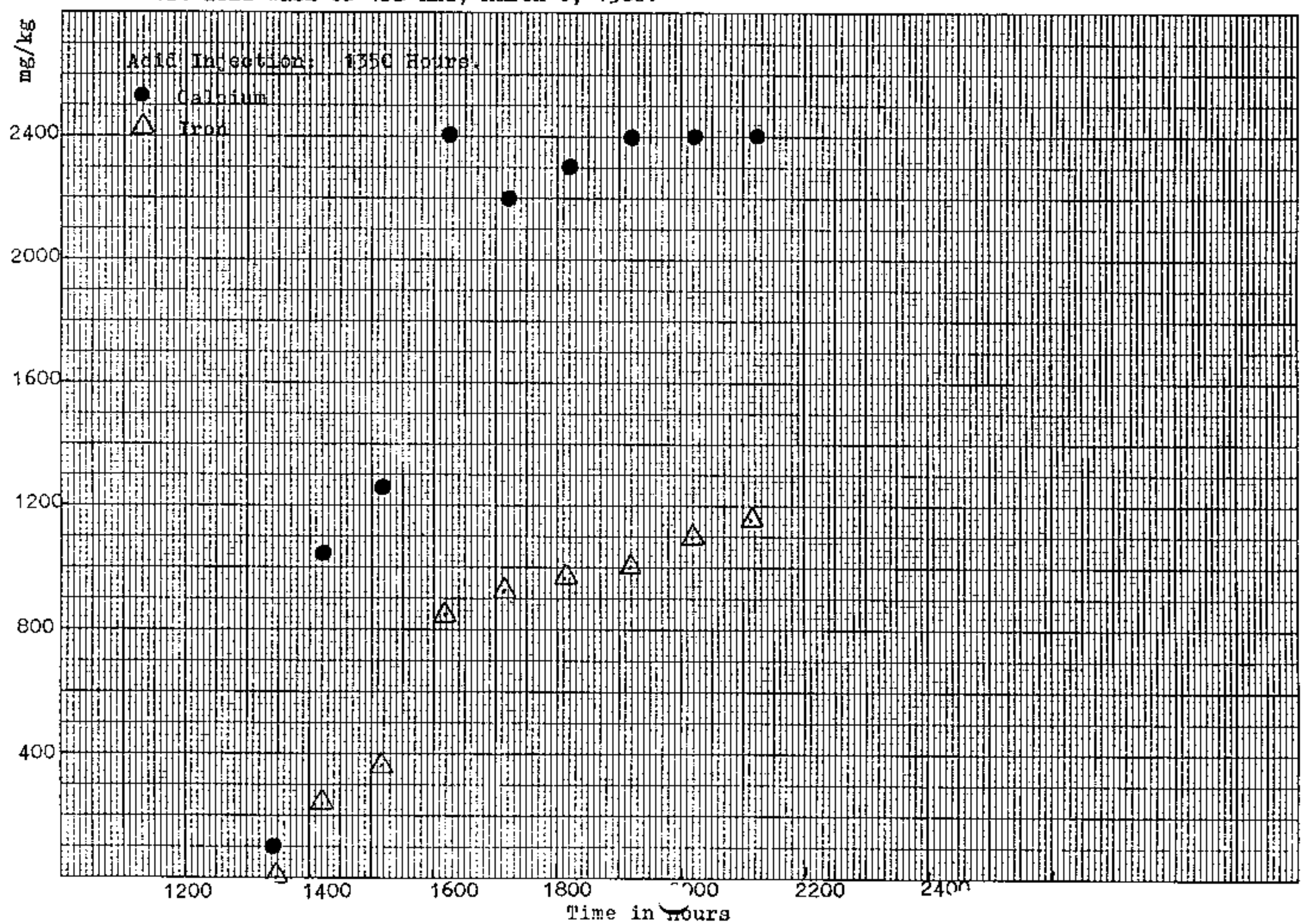
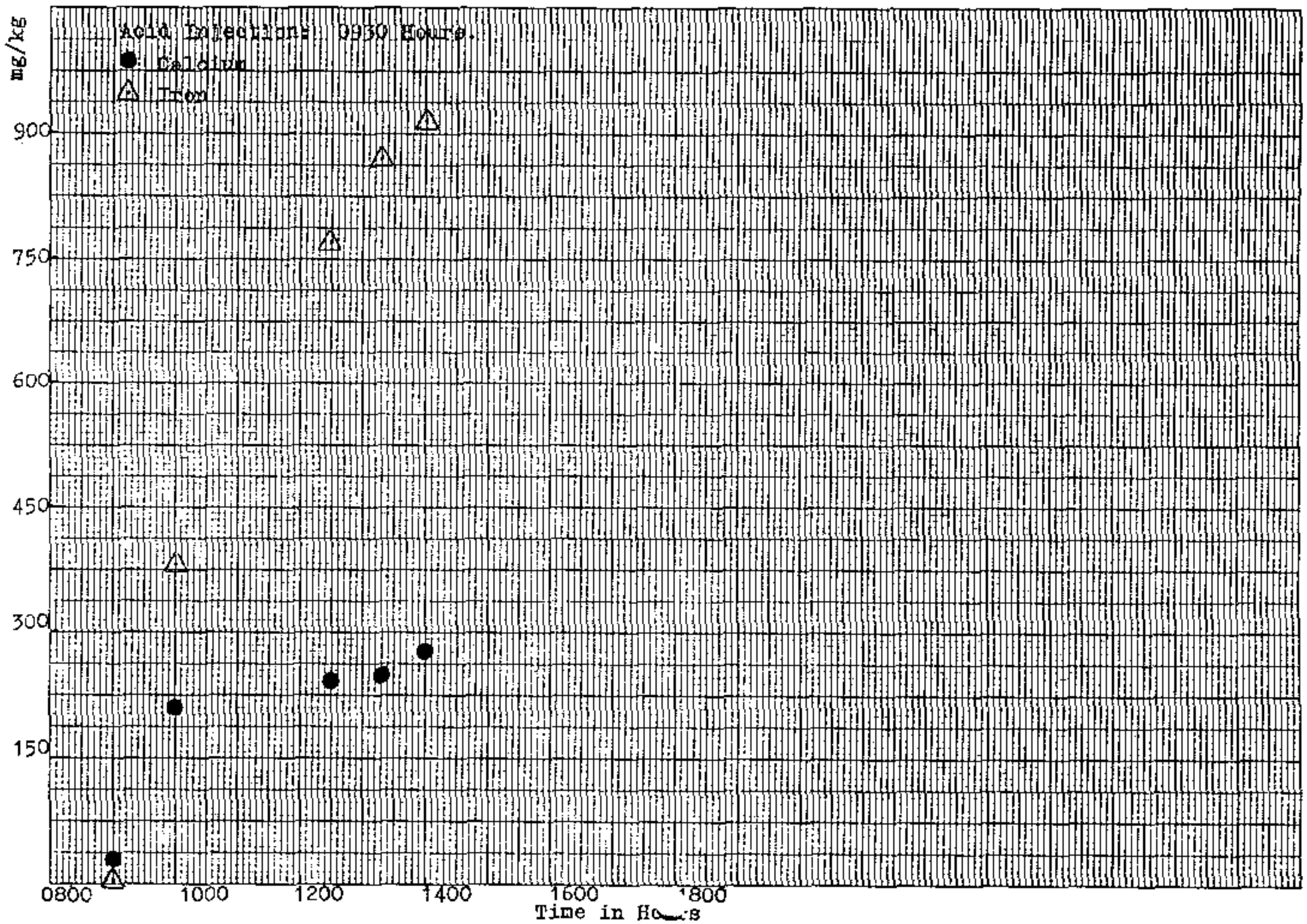


Fig. 5 Graph showing variations of Calcium & Iron concentrations during 2nd acid wash of 1FB-HX2, March 7, 1980.



Cleaning of Heat Exchangers at Pickering NGS-A

PART 2 - DETAILED SERVICE REQUIREMENTS

2.1 Work To Be Done

(a) The work to be done comprises the cleaning, by chemical means, of the shell side water wetted parts of the irradiated fuel storage bay heat exchangers 0-3441-HX1, HX2.

The heat exchangers are horizontal units of the U-tube-in-shell design. Carbon steel and 304 L stainless steel are the materials of construction, the shells alone being carbon steel. The location of the interfaces for recirculation will be at ground level just inside the reactor auxiliary bay door, and the interface for the drain pump will be as near as practicable to the heat exchangers. The contractor's equipment will be located out of doors. The approximate volume required to fill the heat exchanger and pipe work to the interface is 2,500 L.

The heat exchanger will be cleaned by recirculation of chemical solutions through each heat exchanger. HX1 will be cleaned first, followed by HX2 some weeks later.

(b) Proposed Cleaning Method

Examination of the HX deposit has shown it to be a soft silt. Analysis shows the deposit to be a mixture of calcium carbonate, silica, and small quantities of algae and iron oxide. The estimated quantities of calcium carbonate are 530 kg in HX1 and 1,060 kg in HX2.

Each heat exchanger shall be cleaned with solutions of inhibited 10% formic acid to dissolve the $CaCO_3$. The flow of the solution shall be reversed as and when necessary. After each wash, the inhibited formic acid solution will be made alkaline to pH 9 with sodium carbonate and pumped into the contractor's tanker draining the heat exchanger. When the heat exchanger has been drained, after each acid wash, the tube bundle will be inspected.

A high volume flush may be carried out after the final visual inspection to remove remaining insoluble matter from the HX.

In order to expedite the cleaning, the contractor is requested to operate on a shift basis, preferably two 12-hour shifts.

At no time should the pressure in the shell side of the heat exchanger exceed 125 psig.

2.2 Company's Responsibilities

The company shall be responsible for the following matters:

(a) Provide all the labour necessary for the performance of the work.

(b) Provide labour qualified as Atomic Radiation Workers (ARW).

(c) Provide and handle all chemicals and solutions.

(d) Provide the necessary safety apparatus to allow safe handling of chemicals in accordance with Ontario Hydro and other relevant safety rules.

(e) Ensure all personnel are equipped with safety hat, safety glasses, safety boots and comply with all station practices and policies.

(f) Maintain safety and protection to personnel and plant.

(g) Provide and operate all pumps, pressure gauges, and tanks for chemical injection.

(h) Provide an adequate heat supply for raising the temperature of the system being cleaned, if at all necessary.

(i) Allow Ontario Hydro to insert corrosion coupons into the header tank of the recirculation pump.

(j) Provide a pump of suitable size for pumping each neutralized formic acid wash to the tank truck from the heat exchangers.

(k) Provide a tanker truck with sufficient volume to contain an alkaline inhibited formic acid wash and rinse.

(l) Truck the inhibited formic acid washes and rinses to the water treatment plant lagoon and pump the fluid into the lagoon.

(m) For both safety and good housekeeping reasons, identify to Ontario Hydro the number and location of leakages expected and supply collection vessels, and process leakage.

(n) Qualification of the ARW status labour at Pickering NGS-A in radiation protection and conventional safety through attendance at an orientation meeting at site. The contractor's personnel on site shall adhere to the relevant procedures detailed in the orientation meeting.

The tenderer shall include in the tender the following:

- a description of the equipment that is proposed to be used in the performance of the work for each HX,
- a list of the quantities of each chemical to be used for each HX,
- the name, chemical composition, and concentration of the inhibitor to be used,
- a work schedule showing the number of company personnel, number of formic acid washes, and estimate of the number of hours to complete the work for each HX,
- a list of the chemical analyses recommended to be carried out,
- the hourly rate charged for nonproductive work during the time associated with ARW medicals, radiation protection orientation, and delays at site caused by Ontario Hydro, and
- the extra cost, if an adequate heat supply were to be used.

2.3 Ontario Hydro's Responsibilities

Ontario Hdydro shall be responsible for providing the following;

(a) all temporary pipework and connections between the interfaces and the heat exchangers,
(b) water,
(c) service air,
(d) electrical supplies, and
(e) monitoring of the cleaning process.

The overall direction and control of the cleaning operation shall be the responsibility of Ontario Hydro. Ontario Hydro assumes responsibility for all matters relating to radioactivity.