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POINT LEPREAU GENERATING STATION

INFORMATION REPORT

STEAM GENERATORS SECONDARY SIDE CHEMICAL CLEANING AT POINT LEPREAU G.S. USING THE SIEMEN'S HIGH TEMPERATURE PROCESS

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STEAM GENERATORS SECONDARY SIDE CHEMICAL CLEANING AT POINT LEPREAU USING THE SIEMEN'S HIGH TEMPERATURE PROCESS

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ABSTRACT

The secondary sides of all four steam generators at the Point Lepreau Nuclear Generating Station were cleaned during the 1995 annual outage run-down using the Siemens high temperature chemical cleaning process. Traditionally all secondary side chemical cleaning exercises in CANDU as well as the other nuclear power stations in North America have been conducted using a process developed in conjunction with the Electric Power Research Institute (EPRI). The Siemens high temperature process was applied for the first time in North America at the Point Lepreau Nuclear Generating Station (PLGS).

The paper discusses experiences related to the pre and post award chemical cleaning activities, chemical cleaning application, post cleaning inspection results and waste handling activities.

INTRODUCTION

Point Lepreau Generating Station is a seawater cooled 680 MWe Pressurized Heavy Water Reactor located on the Bay of Fundy. The unit went into service in 1982 and has mainly operated as a base load station, operating for 4214 effective full power days at the time of chemical cleaning. After twelve years of operation the inspections of the steam generators (SG) have revealed:

- Accumulation of hard caked sludge in the center of the hot leg side tubesheet covering less than 10% of the tubes in each SG (Max. recorded height 6" - 8" in 1987).
- Blockage (varying degree) of some of the trefoil broached holes of the lower (1st and 2nd) tube support plates (TSP's).
- Onset of blockage of some of the trefoil broached holes of some of the top support plates.
- OD side damage (isolated pitting and phosphate wastage) of some of the tubes in the sludge pile region above the tubesheet as well as at the intersections of some of the first and second support plate broached holes, on less than 1% of the tubes in all four steam generators.
- Observation of fretting of some of the tubes in the U-bend region.

Monitoring of the operational parameters has also confirmed deterioration of the steam generators heat transfer capability which is partially attributed to the deposits on the inside and outside surface of the tubes as well as due to leakage across the primary side divider plates. An increase of the steam generator outlet temperature (Reactor Inlet Header Temperature) of approximately 5.4°C (262°C to 267.4°C) since initial start-up was observed.

To address these problems, NB Power decided to chemically clean the secondary side of the steam generators during the 1995 annual outage along with other maintenance and inspection activities.

The objective of chemical cleaning was to effectively:

- Remove all sludge from the tubesheets.
- Clean all tube support plate trefoil broached holes including crevices at the TSP lands and tube to tube sheet intersections.
- Clean the secondary side heat transfer surface area, including the pre-heaters, of all tubes.

PLANT INFORMATION

Point Lepreau Generating Station employs four recirculating steam generators designed and manufactured by Babcock & Wilcox (Canada) Ltd. with I-800 tubes, stainless steel trefoil broached hole support plates and integral pre-heaters.

The secondary side has an all ferrous copper free feedtrain except for the condenser tubesheets which are of Aluminum Bronze.

The SG chemistry control since start-up has employed the congruent phosphate technique. The feedwater pH control using ammonia was switched to morpholine in 1988, because of damage to some piping systems due to erosion/corrosion. To protect the SG tubes from sea water ingress due to condenser leaks, a full flow condensate polisher consisting of mixed bed ion exchange columns was added in late 1986.

Sludge samples have been obtained from the sludge pile during tube removals and during water lancing in the past. The analysis of the sludge is summarized as follows:

- Main elements were Fe, P, Na.
- Minor elements (< 2 wt%) Ca, Mg, Mn, Cr, Zn, Cl, Cu, Ni, Ti, Si, Pb.
- Compounds of magnetite and metal phosphates were predominant, SiO_2 was present in trace amounts.

PROCESS AND VENDOR SELECTION

NB Power working with AECL and COG, embarked upon a program of evaluating all the current commercially available processes for the chemical cleaning of the secondary side of SG's at Point Lepreau in order to select the most suitable process. The selection criteria were:

- Corrosiveness and effectiveness of different processes.
- A process which has been applied successfully in conditions similar to those at Point Lepreau.
- Use of the least amount of chemicals to meet the cleaning objectives, and as a consequence produce the minimum amount of chemicals in the waste.
- A non-complex process application which can be applied using plant heat.
- Minimum impact on the critical path of the plant annual outage.

The evaluation of factors affecting process selection was achieved by:

- An independent comparative testing using different process parameters (by AECL).
- A review and assessment of the data base of different vendors and their cleaning processes (by AECL).
- Witnessing of chemical cleaning exercises at different sites.
- Holding discussions and visiting sites which had applied chemical cleaning exercises in the past.

Based on the evaluation of all factors, it was concluded that both the Siemens/KWU hot temperature process and the EPRI-SGOG crevice cleaning process fulfill the requirements in terms of effectiveness and minimizing corrosion. However, the Siemens/KWU hot temperature process was selected based on the following factors:

- Overall cost for the cleaning application,
- Time for the implementation,
- Equipment/material required,
- Amount of chemicals in the waste generated, and
- Feedback from other utilities on experiences with the vendors and their cleanup processes.

SIEMENS HIGH TEMPERATURE CHEMICAL CLEANING PROCESS

Since its first application in 1986, Siemens/KWU High Temperature Chemical Cleaning Process has been improved continuously in order to increase its flexibility and to meet all the needs and demands of steam generator chemical cleaning [Ref. 1-4]. Presently, the procedure is applied using ethylenediaminotetraacetic acid (EDTA) under alkaline and strongly reducing conditions. The highlights of the process can be summarized as follows:

- The iron removal step is generally applied at temperatures between 160°C to 200°C lasting up to approximately 5 hours.
- The high temperatures during the iron removal step are achieved by using primary side heat during rundown or startup conditions of the plant.
- The cleaning application is implemented using step wise injection to ensure only the required amount of chemicals are added, thus reducing the amount of chemicals in the waste generated.
- The cleaning effectiveness is further enhanced by periodic venting during application to ensure proper mixing and replenishment of the solvent in the crevice regions.
- No corrosion inhibitors are needed because of the limiting effects of low EDTA concentrations achieved by the step-wise injections and the short exposure times of the SG internals to the free chelate of the cleaning solvents.
- The corrosion control is enhanced by alkaline and reducing conditions of the Siemens/KWU process.
- As the chemicals are added in a stepwise manner, they react immediately and become non-corrosive. (The tests conducted by Siemens/KWU and AECL demonstrated that the spent solvent can be kept inside the SG's for extended periods without any corrosion concerns).

PRE-CHEMICAL CLEANING ACTIVITIES

To complete the process qualification program the following steps were performed in conjunction with the SG vendor (Babcock & Wilcox):

- A comprehensive materials and weldment survey of the SG's was completed.
- A detailed corrosion allowance determination exercise for various components and materials was undertaken. These components were either to be exposed to the cleaning solvents or were determined to be critical by stress analysis.
- Installation of corrosion coupons in one SG two years before the chemical cleaning application.
- Installation of chemical injection, steam and water sampling connections on the SG's during the 1993 outage. (Figure 1)
- Assessment to define the solvent injection temperature.
- In addition, NB Power conducted chemical cleaning dry-run exercises using plant equipment during the 1993 annual outage run-up as well as the 1994 outage run-down conditions to ensure that all steps for the actual chemical cleaning could be completed without any problems.

PROCESS QUALIFICATION PROGRAM

To finalize the application procedures and other cleaning parameters, tests were conducted to cover plant specific aspects of the cleaning sequence, chemical injection, soaking time, steam-off operations, application temperatures, solvent concentration, plant heat-up and cool-down rates, sludge dissolution efficiency, material compatibility of the SG construction materials (weldments and galvanic coupons) and the calibration of the H_2/N_2 corrosion monitoring system.

For these tests, coupons of the actual materials of construction and the sludge removed from the SG's during lancing and other maintenance activities of previous years were used.

CORROSION AND PROCESS MONITORING

During the Process Qualification Program, calibration of the Siemens/KWU corrosion monitoring system (H_2/N_2 monitoring) under the plant specific conditions for process and corrosion control was completed. For the monitoring of the H_2 to N_2 ratio, SG steam sampling was performed. The results of the gas chromatography analysis were also used to determine the amount of chemicals to be injected and to help ascertain when the cleaning process is complete.

The Corrosion Monitoring System measures the amount of the corrosion hydrogen produced as a consequence of base metal corrosion. Hydrogen release provides an extremely sensitive monitoring method even if only a small amount of corrosion takes place. This technique of monitoring/controlling corrosion delivers on-line indication for general corrosion, independent of the location within the SG. It covers the corrosion monitoring aspects of the entire SG. Together with the results of the qualification tests, the gas chromatography measurements provide an indirect measurement of the average corrosion of the exposed materials.

In addition to the on-line corrosion monitoring system measuring H_2/N_2 ratio, a corrosion probe, carrying coupons representing key materials of construction of the SG's , was installed in SG #1 during the 1993 annual outage. Upon completion of the chemical cleaning exercise, the corrosion probe was removed and the coupons were analyzed by an independent laboratory for weight loss and any localized attack in order to validate the corrosion monitoring measurements.

PROCESS ENGINEERING

All of the chemical cleaning equipment consisting of tote tanks, pumps, heat exchangers, valves and sampling/analysis stations were located inside the Reactor Building (Figures 2 and 5). Mixing of chemicals and storage of spare chemicals was done in the Water Treatment Plant. The interim storage tanks supplied by Vectra Technologies to receive the spent solvent and the rinse solution were located inside a lined berm outside the Turbine Building. The chemical injection equipment, pumps, mixing tanks and heat exchanger were placed within a dyke inside the reactor building. Chemical injection hoses were sleeved, the system was hydrotested and inspected prior to and during chemical cleaning.

CHEMICAL CLEANING PROCESS APPLICATION

After the reactor was shutdown, the Primary Heat Transport (PHT) system was cooled down to approx. 170°C by selecting Boiler Pressure Control to the cooldown mode using the Atmospheric Steam Discharge and Condenser Steam Discharge Valves and then by valving in of the Shutdown Cooling Heat Exchangers to 160°C. The PHT system was maintained at this temperature by adjustment of the Shutdown Cooling motorized valves. In concert with the Primary Heat Transport System cooldown, the water level in all four SG's was lowered using a combination of steaming-off and draining via Boiler Blowdown. Only two SG's were cleaned at one time. The SG pair to be cleaned was drained to the lowest possible level. The water level of the other two SG's was maintained at preset levels for heat sink reasons.

Once the PHTS temperature was stable at 160°C the chemical cleaning process was started:

- To clean the Preheater section, the chemical cleaning solvent was injected into the SG via the preheater drain connected to the feedwater inlet lines.
- For cleaning the entire SG, the solvent was injected into the SG through the 2" lines which discharge directly into the downcomer on the hot leg section of the tubesheet below the first tube support plate.
- The chemicals were injected in several steps. During the Injection of the chemicals the Atmospheric Steam Discharge Valves were opened to induce boiling and promote mixing of the chemicals and then reclosed.
- For process control the subsequent chemical injections were initiated only after the on-line corrosion monitoring system in-between injection steps had confirmed that the cleaning process was progressing satisfactorily and further injections were required (Figure 3).
- For the cleaning of the crevices and any residual sludge at the tubesheet the PHTS temperature was finally increased to 175°C, and a final injection of chemicals was made to the SG's.
- After the cleaning of the first SG pair was completed, the temperature was lowered to 160°C and the entire chemical cleaning process was repeated for the other SG pair.

- The cleaned SG pair was kept full with the spent solvent for heat sink reasons.
- After all four SG's were cleaned, the PHTS was cooled down and depressurized in accordance with the plant normal procedures, resulting in the solvent temperature being reduced to ambient temperatures.
- The spent solvent in the SG's was then drained to the interim storage tanks, located in a dyked berm outside the turbine building via the boiler blowdown system, for processing at a later date.
- After the solvent was removed, the SG's were refilled and rinsed to remove any residual spent solvent.
- The rinse solution was also drained via the blowdown system and transferred to separate storage tanks in the same dyked berm.

EVALUATION OF CHEMICAL CLEANING RESULTS

Deposit Removal:

The amount of iron oxides and the impurities removed are given in Table 1: [Ref. 5]

Table 1: The Amount of Oxides and Salt Impurities Removed

Removed Deposits	SG 1 [Kg]	SG 2 [Kg]	SG 3 [Kg]	SG 4 [Kg]	Total [Kg]
Magnetite	259	313	266	274	1112
Salt Impurities	32	33	36	23	124
Total Deposits	291	346	302	297	1236

NOTE: The total salt impurities removed (124 kg), included 70 kg of phosphates.

Corrosion Assessment:

The corrosion assessment of the cleaning exercise was performed based on the results achieved by the H_2/N_2 corrosion monitoring system and by the evaluation of the in-situ corrosion coupons. The results can be summarized as follows:

- **Corrosion Coupons:**

After chemical cleaning the in-situ corrosion coupons were dismantled and evaluated by Babcock & Wilcox for weight loss and for dimensional changes. For the carbon steel base metal, weldment and galvanic coupons a general average corrosion of approximately 24 µm (Maximum corrosion 35 µm) was observed after considering the effect of two years of operation prior to chemical cleaning. The contribution of two years of operation on bare metal coupons can be expected up to approximately 30 µm. [Ref. 6] For the stainless steel and steam generator tubing material no detectable corrosion was measured. No selective type of corrosion was experienced in any of the materials. The carbon steel corrosion was <10% of the allowable corrosion allowance for the steam generator components.

- **H_2/N_2 Corrosion Monitoring System:**

The on-line H_2/N_2 corrosion monitoring system indicated an average carbon steel corrosion of 20 to 25 µm (Figure 4). Considering the corrosion contribution of the two years of operation these results are in good agreement with those achieved by actual in-situ corrosion coupons.

<u>Post Cleaning Inspection Results:</u>

The Primary Side Non Destructive Examination (NDE) of the tubes by Eddy Current Testing (ECT) along with fiber-optic visual inspection of the tubesheets and the tube support plate broached holes of all SG's was performed after chemical cleaning. The achieved results, in comparison to those obtained during previous outages can be summarized as follows:

- Outside surface of tubes were cleaned to shiny metal.
- The majority of the trefoil tube support plate broaches were cleaned. Only in a few broaches could some deposits still be seen.
- In some limited small areas above the tube sheets some deposits were detected, but significantly less than previous years.
- The visual inspection results were consistent with MRPC-ECT results.

<u>RADIATION DOSE EXPOSURE</u>

The total radiation dose exposure related to all aspects of the secondary side chemical cleaning exercise was as follows:

Gamma dose:	22 mSv
Tritium dose	6 mSv
Total dose	28 mSv

WASTE HANDLING ACTIVITIES

After the completion of the chemical cleaning exercise the spent solvent and the rinse water were drained separately to the interim storage tanks for processing at a later time. The amount of waste generated is as follows:

Spent solvent	$170 m^3$
Rinse solution	$143 m^3$

The radio-nuclide analysis of the spent solvent and rinse water confirmed that all waste could be disposed of as non-radioactive waste. As a result of this analysis and assessment:

- The conventional disposal of the spent solvent using an incineration technique was completed by a contract arrangement with Laidlaw Environment Services.
- The rinse water was neutralized at PLGS and was disposed of using normal plant disposal pathways in accordance with the AECB and NBDOE guidelines.

CONCLUSIONS

Based on the results of the chemical cleaning application and the experience gained at Point Lepreau it can be concluded that:

- Objectives of chemical cleaning were achieved:
  - Tube surfaces were cleaned.
  - Broach holes were cleaned with only minor deposits evident.
  - Sludge removed from tubesheet with only minor deposits evident.
- Good agreement between qualification, H_2/N_2 and installed corrosion coupons. Corrosion was measured to be low (approximately 25 µm for carbon steel and zero for stainless steel and I-800 tubes)
- Actual cleaning exercise took approximately 5 hours of critical path time for a total of less than 16 hours for all activities.
- The Siemens high temperature chemical cleaning process can be applied successfully at other CANDU stations with minimum impact on the critical path of the outage.

REFERENCES

1. "Field Experience with KWU Chemical Cleaning Process". S. Odar, Water Chemistry of Nuclear Reactor Systems, 5. BNES, London, 1989.
2. "The KWU Chemical Cleaning Process as a Remedial Measure to Improve Steam Generator Performance". S. Odar, K. Kuhnke, Water Chemistry of Nuclear Reactor Systems, 6 BNES, London, 1992.
3. "Crevice Cleaning Experience with the KWU Chemical Cleaning Process". S. Odar, SFEN International Conference "Chemistry in Water Reactors Operating Experience and New Developments", Nice, April 24-27, 1994.
4. "Material Compatibility and Corrosion Control of the KWU Chemical Cleaning Process". S. Odar, International Symposium FONTERAUD III, 12-16 Sept. 1994.
5. Siemens - "Final Report of Secondary Side Chemical Cleaning", Point Lepreau Nuclear Generating Station
6. AECL letter Allsop/Balakrishnan/Cheluget to MacNeil/Slade/Verma of 1995 September 15.

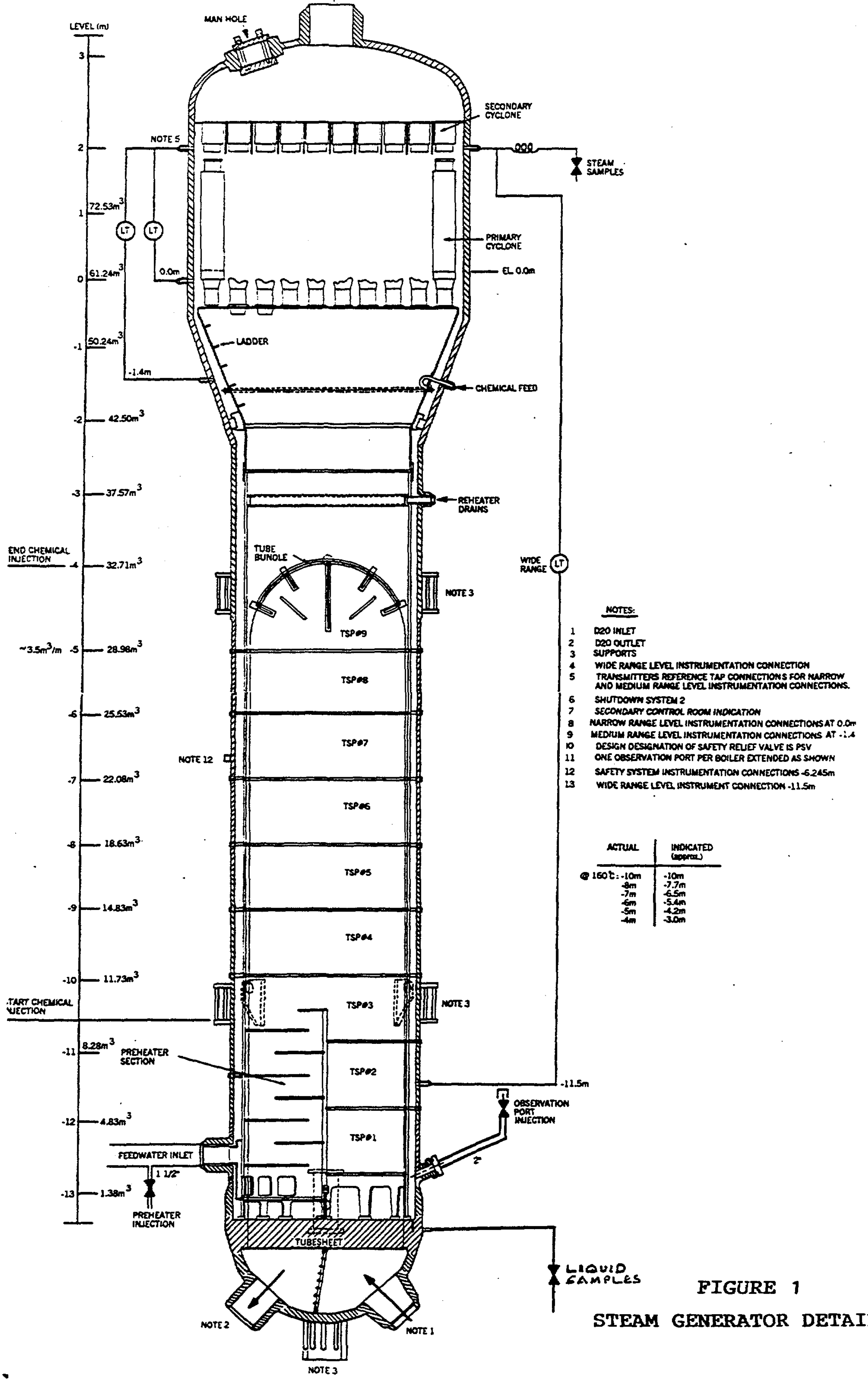


FIGURE 1

STEAM GENERATOR DETAILS

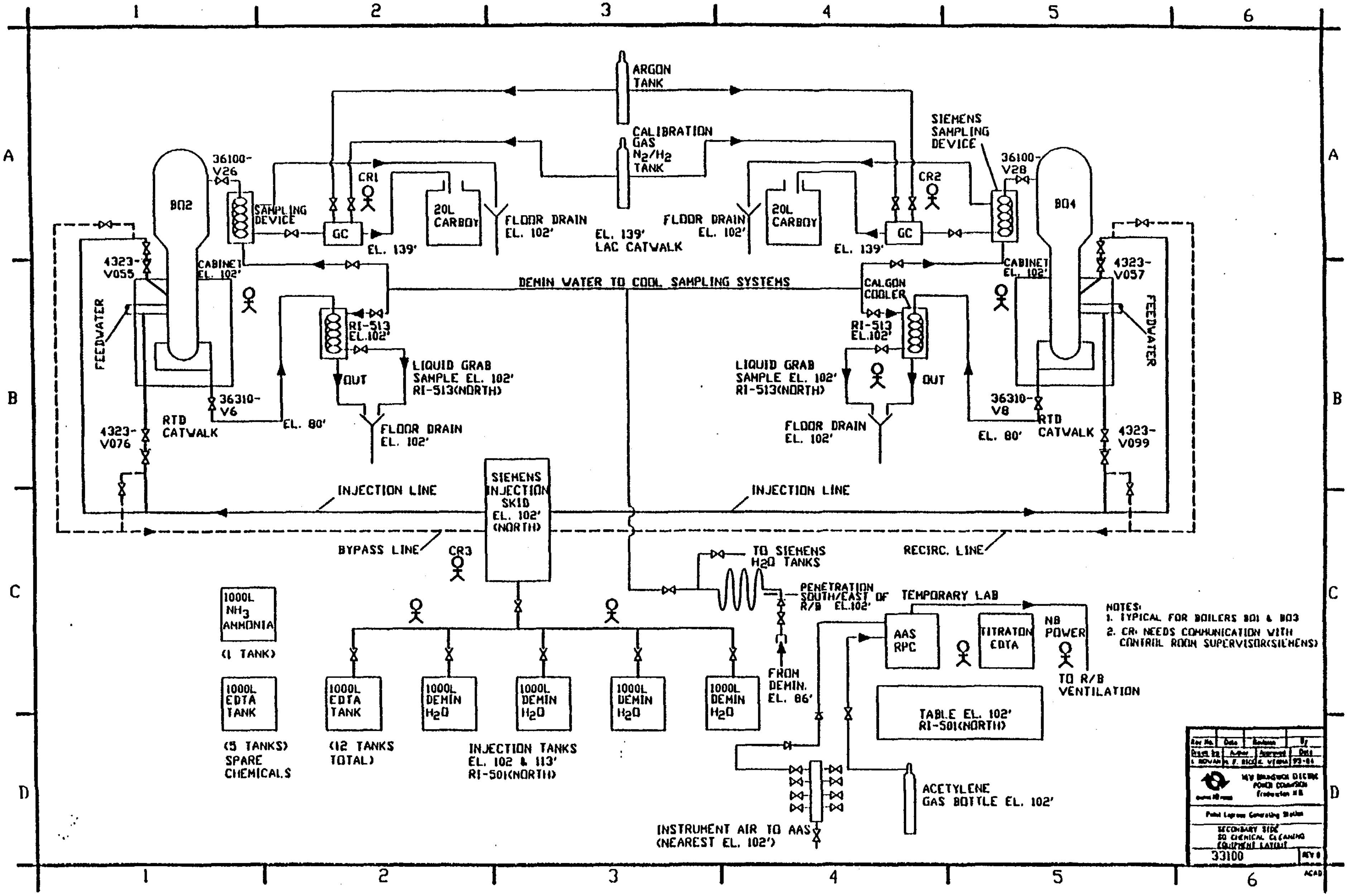
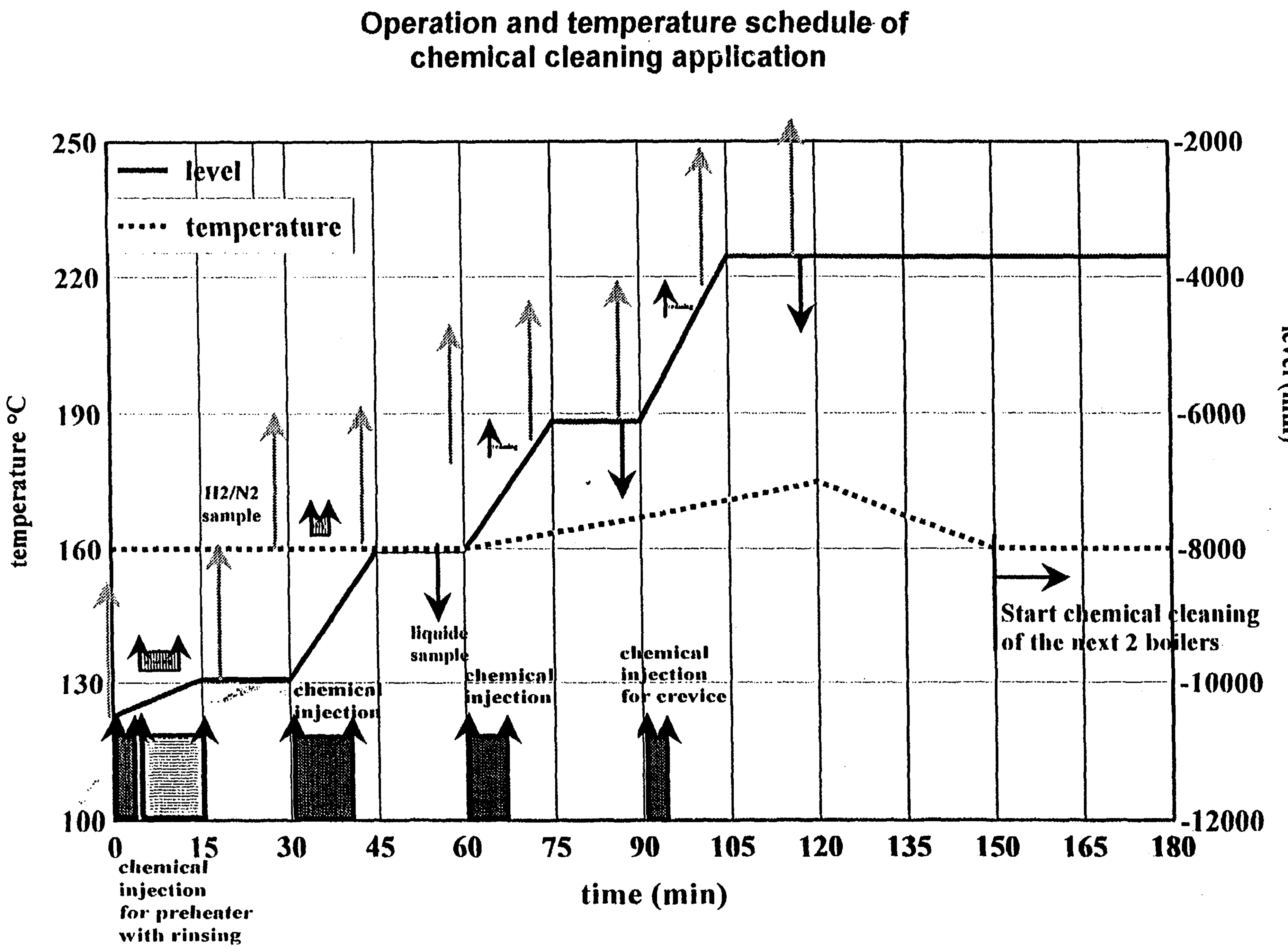

ARGON TANK
CALIBRATION GAS N2/H2 TANK
SIEMENS SAMPLING DEVICE
36100-V26
36100-V28
B02
B04
SAMPLING DEVICE
CR1
CR2
CR3
GC
20L CARBOY
FLOOR DRAIN EL. 102'
EL. 139'
EL. 139' LAC CATWALK
CABINET EL. 102'
4323-V055
4323-V057
DEMIN WATER TO COOL SAMPLING SYSTEMS
CALGON COOLER
FEEDWATER
RI-513 EL.102'
OUT
LIQUID GRAB SAMPLE EL. 102' RI-513(NORTH)
36310-V6
36310-V8
RTD CATWALK
EL. 80'
4323-V076
4323-V099
INJECTION LINE
SIEMENS INJECTION SKID EL. 102' (NORTH)
BYPASS LINE
RECIRC. LINE
TO SIEMENS H2O TANKS
PENETRATION SOUTH/EAST OF R/B EL.102'
TEMPORARY LAB
FROM DEMIN. EL. 86'
1000L NH3 AMMONIA
(1 TANK)
1000L EDTA TANK
(5 TANKS) SPARE CHEMICALS
(12 TANKS TOTAL)
1000L DEMIN H2O
INJECTION TANKS EL. 102 & 113' RI-501(NORTH)
AAS RPC
TITRATON EDTA
NB POWER
TO R/B VENTILATION
TABLE EL. 102' RI-501(NORTH)
NOTES:
1. TYPICAL FOR BOILERS B01 & B03
2. CR: NEEDS COMMUNICATION WITH CONTROL ROOM SUPERVISOR(SIEMENS)
ACETYLENE GAS BOTTLE EL. 102'
INSTRUMENT AIR TO AAS (NEAREST EL. 102')
33100

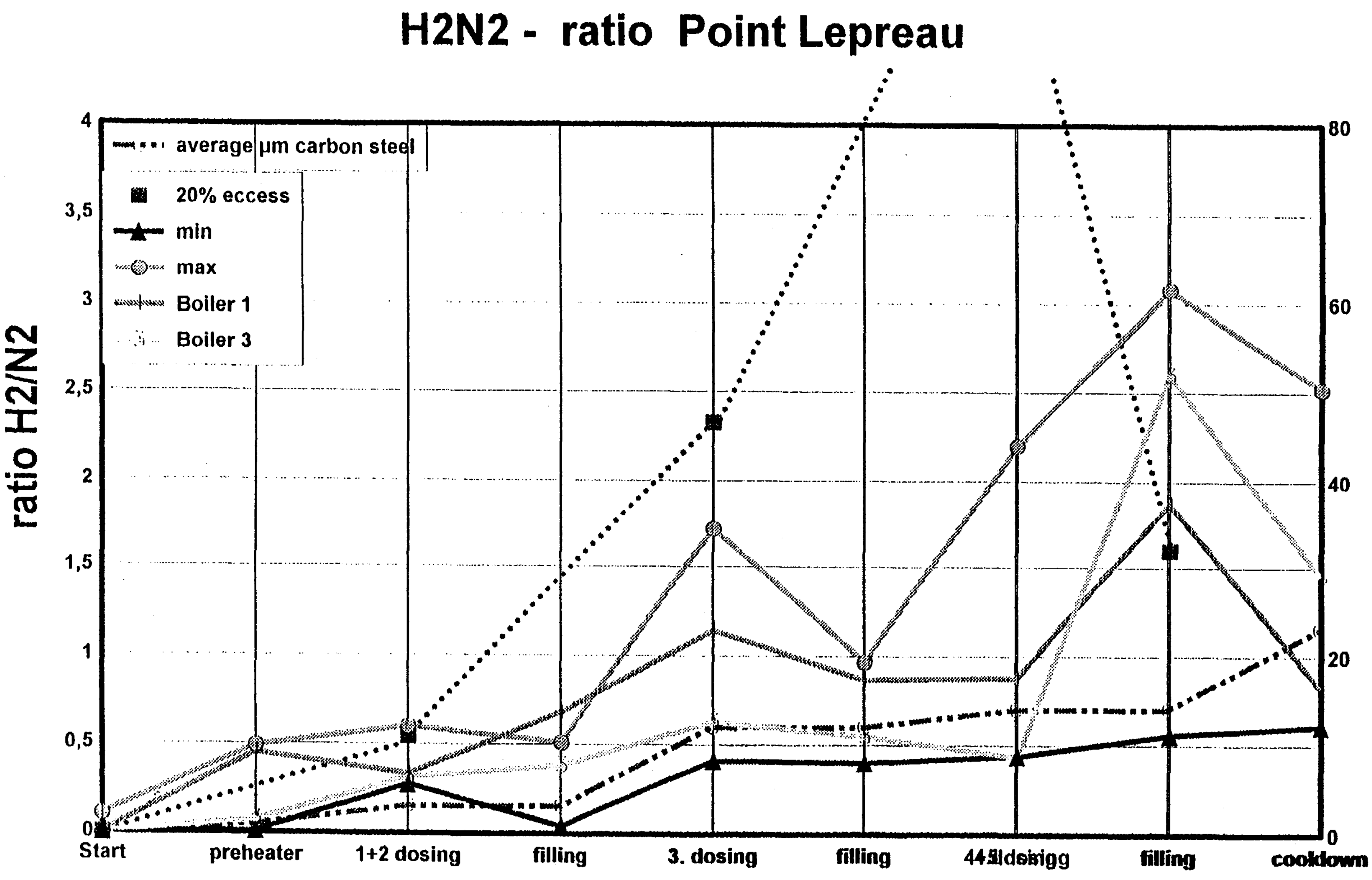
FIGURE 2

FIGURE 3

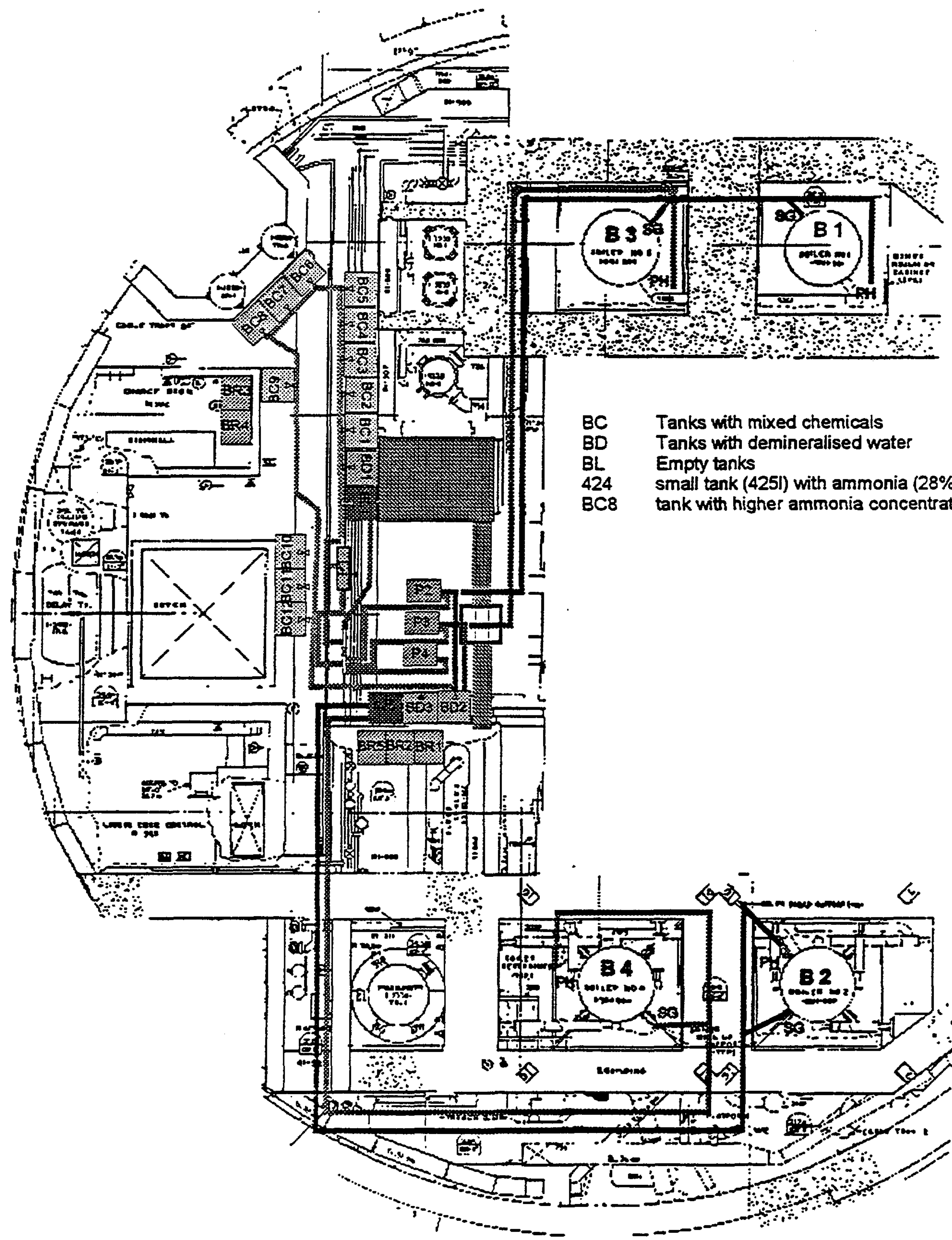


Operation and temperature schedule of chemical cleaning application
level
temperature
250
220
190
160
130
100
-2000
-4000
-6000
-8000
-10000
-12000
temperature °C
level (mm)
H2/N2 sample
liquide sample
chemical injection
chemical injection
chemical injection for crevice
Start chemical cleaning of the next 2 boilers
0
15
30
45
60
75
90
105
120
135
150
165
180
chemical injection for preheater with rinsing
time (min)

FIGURE 4


H2N2 - ratio Point Lepreau
average µm carbon steel
20% eccess
min
max
Boiler 1
Boiler 3
ratio H2/N2
corrosion in µm
0
0,5
1
1,5
2
2,5
3
3,5
4
0
20
40
60
80
Start
preheater
1+2 dosing
filling
3. dosing
filling
filling
cookdown

PLNGS Boiler Cleaning
Equipment- Layout Status:95/04/10



BC	Tanks with mixed chemicals
BD	Tanks with demineralised water
BL	Empty tanks
424	small tank (425l) with ammonia (28%)
BC8	tank with higher ammonia concentration

Figure 5