TECHNICAL REPORT

No. 3/87

LESSONS FROM THE

SSPS - CRS

SODIUM FIRE INCIDENT

by

Motor Columbus
Consulting Engineers Inc.
CH-5401 Baden, Switzerland

DEUTSCHE FORSCHUNGS- UND VERSUCHSANSTALT
FÜR LUFT- UND RAUMFAHRT e.V.

DFVLR - DEUTSCHE FORSCHUNGS- UND VERSUCHSANSTALT FÜR LUFT- UND RAUMFAHRT E.V.

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June 1987

D F V L R

Secretariat of the Executive Committee

SSPS Small Solar Power Systems

FOREWORD

The Executive Committee of the SSPS Project requested, at its 32nd meeting, a report elaborating on the lessons to be learned for future solar power plants using liquid sodium as a coolant with reference to the sodium fire which occurred on the SSPS-CRS plant in Almeria/Spain and having caused severe damages to the sodium installation, the plant control room and the building itself.

Via the company Motor Columbus, two British experts with many years of experience in operating sodium plants were contracted.

Their report contains valuable recommendations for potential benefit to designers and operators of future projects.

Additionally, the manufacturers of valves for sodium installations may consider design changes ensuring lower probability of bellow failures and/or make repairs less elaborate and dangerous.

This report is submitted to all Contracting Parties, and if required for its further distribution beyond the printed distribution list on the back cover, for dissemination of the lessons learned from the sodium fire in Almeria.

Köln, June 1987.

Wilfried Grasse
DFVLR
Secretariate of the
SSPS Executive Committee

DEUTSCHE FORSCHUNGS- UND VERSUCHSANSTALT

FÜR LUFT- UND RAUMFAHRT

DFVLR

LESSONS FROM THE SSPS - CRS SODIUM FIRE INCIDENT

March 1987

MOTOR COLUMBUS
CONSULTING ENGINEERS INC.
CH-5401 BADEN/SWITZERLAND

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1 INTRODUCTION

Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR) have entrusted Motor-Columbus Inc. (MC ING) with a remit to examine the circumstances of the sodium fire that occurred at the SSPS-CRS Solar Plant at Almeria on August 18, 1986, and to identify lessons that could be learned for potential benefit to future projects.

The fire occurred due to outleakage of sodium, while cutting a metal seal on a sodium valve from which the internals were being removed to repair a faulty bellows. The plant was at pressure and the intention to prevent outleakage of sodium by freezing sodium in pipework and the valve was not achieved. An estimated release of more than 10 tons of sodium occurred before the plant was sufficiently depressurized to prevent further outleakage.

Our examination has sought:

- first to determine all factors contributing to the cause and progress of the incident

- second to identify how the incident could have been avoided and reduced in size and consequences

- finally to use this information to identify lessons that can be learned from the incident

We were not required to establish the detailed sequence of events related to the incident or in any way to criticize or to allocate responsibility for circumstances of design, operation and maintenance that contributed to it. We understand that the report written by the plant operators and attached as Appendix 1 to this report has been accepted by the Project Executive Committee as the formal record of the incident.

The study has been made by Mr. J. Moore and Dr. K. Eickhoff, who have both had many years experience of projects using sodium. Mr. Moore was Director of the Fast Reactor Project in the UK for 7 years before joining MC ING in 1980. Dr. Eickhoff was responsible for fast reactor engineering development with more than 25 years experience of sodium technology before retiring to become a consultant in 1986.

During the study, visits have been made to the following organizations for discussions with the personnel concerned:

- CIEMAT, Instituto de Energias Renovables, Madrid

. Mr. Luis Crespo	Director
. Mr. Fernando Sanchez	

- Plataforma Solar de Almeria

. Mr. Alfonso Sevilla	Director Plataforma Solar, CIEMAT-IER
. Mr. Jose Manuel Molina	Head of Operations and Maintenance, Mompresa
. Mr. Angel Navarro Martinez	Chief of CRS Operations, Mompresa
. Mr. Bernabe Calatrava	Safety Engineer
. Dr. Michael Geyer	Site Representative, DFVLR

- DFVLR, Köln

  . Mr. Wilfried Grasse
  . Dr. A.C. Kalt

- INTERATOM, Bensberg, FRD

  . Mr. Bruno Floss

2 THE SSPS-CRS PLANT

The SSPS-CRS (Small Solar Power Systems - Central Receiver System) is a 500 kW(e) prototype solar power plant. 93 Individual Heliostats concentrate the solar radiation into a receiver installed 43 m above the ground. The thermal energy is transferred by liquid sodium to a steam generator which in turn drives a steam motor. This mechanical energy is converted by a generator into electrical power.

The flow diagram of the Liquid Sodium Heat Transfer System is shown in Figures 1 and 2. Briefly, it comprises a hot loop (hot storage tank and hot pump) taking heat from the receiver at 530 °C, and a cold loop (cold storage tank and cold pump) running at 270 °C.

Due to the large difference in height between the receiver and the main part of the sodium plant, the pressure of the Argon Cover Gas in the storage tanks is 8 bars. In general, the sodium loops are controlled by electrically driven valves operated from a control room, whose location is shown in Figure 3.

3 DESCRIPTION OF THE INCIDENT

The following is a brief description of the incident; a more detailed account will be found in the Report "SSPS-CRS Sodium Fire Incident", attached as Appendix 1 to this report. Reference is made to Appendix 2 on page 13 of Appendix 1.

During the routine daily inspection of the sodium plant on August 11, 1987, solid sodium or sodium hydroxide was observed on the spindle of valve LK01-AA06 between the valve body and the motor. A drawing of the valve is shown in Figure 4. This valve is in the line between the receiver and the hot storage tank, and is located 18 m from the latter. This observation implied that sodium was leaking past the spindle packing seal which in the past had meant that the bellows' seal was leaking. It was, therefore, decided to repair the valve. This would necessitate removing the bolts between the upper and lower clamps, machining-off the hermetic seal weld, and replacing the spindle, bellows and connecting disc with a new prefabricated subassembly.

The operators decided to isolate the valve LK01-AA06 by freezing the sodium in the line LK01-BR03 between valve LK01-AA06 and the hot storage tank. To achieve this, all the sodium piping except line LK01-BR03 was drained by opening all the relevant valves except LK01-AA06. To ensure that pipe LK01-BR03 would not drain if valve LK01-AA06 was not well seated, an argon pressure of 4.5 bar was maintained in the receiver, and 5.1 bar in both storage tanks. This pressure difference of 0.6 bar between the receiver and the storage tanks should have ensured that the sodium level in line LK01-BR03 remained 6.7 m above the level in the tanks. Valve LK01-AA06 is located 3.3 m above the sodium level in the tanks.

After this operation, both storage tanks were partly full. The electric trace heating in piping sectors LK01-BR03, LK01-BR07 and the receiver were disconnected and some pipe insulation removed to allow the sodium remaining in the piping to freeze.

On August 18 at 08.30 hours, the temperature near valve LK01-AA06 was 35 °C and on the pipework, 3 m from the valve, 43 °C. Attempts to open and close the valve were unsuccessful, indicating that the sodium in the valve was frozen. The temperature of the hot storage tank was 270 °C, and that of the piping near the hot tank was 170 °C.

The valve repair started at 10.00 hrs. The ten clamping bolts were removed, permitting the motor and upper clamp to be dismantled and giving access to the seal weld. The seal weld was removed slowly using a drill. About 15 minutes after cutting of the seal weld had commenced and 2/3 of its circumference had been removed, the two halves of the valve were suddenly forced apart and pieces of frozen sodium were ejected, followed immediately by a gush of liquid sodium. This implies that the frozen sodium seal between the valve and the hot storage tank had failed; not immediately but due to some form of progressive failure, as outlined in Appendix 3.

This happened at 11.00 hrs. The liquid sodium reacted immediately with the air filling the hall with dense smoke. The maintenance personnel evacuated through the fire door into the computer room, fortunately without suffering any serious injury.

One of the operators immediately pressed the button to depressurize the hot storage tank by opening valves OG01-BR28, OG01-AA32, and OG01-AA35, allowing the Argon Cover Gas to vent to the atmosphere. Venting would be relatively slow, over a period of many minutes, because of the large volume of argon to be released. A few seconds after these valves were opened, the electric grid supply failed and there was some delay before the emergency diesel generators were started. However, according to the INTERATOM designers, the vent valves are connected to the guaranteed electrical supply and in addition are designed to open if the supply fails, so that the interruption in the electrical supply should not have affected the depressurization of the hot tank.

Indications are that the sodium leakage continued for at least 15 minutes, during which time about 12 m^3 of liquid sodium was ejected. Because the jet of sodium was directed upwards, probably in the form of a spray, it covered a wide area and the resulting fire was very extensive. After the fire, about 3 m^3 of metallic sodium was recovered from the catchment trays, showing that most of the sodium ejected was burned.

Early during the fire, the control room was filled with smoke which entered through the air conditioning system. Additionally the fire entered the computer room through the fire door, which had been left open after the personnel had evacuated through it. This fire soon spread to the control room.

An early attempt to transfer sodium from the hot storage tank to the cold storage tank was unsuccessful because the essential electrical cables to the valves and pump had been destroyed by the fire.

The fire soon destroyed parts of the roof of the hall, and the windows between the hall and the control room were broken. This allowed more air to reach the fire, which burned with great intensity. From the damage caused to parts of the building structure, some observers have estimated that temperatures in the region of 1,000 to 1,200 °C were reached. Temperatures of sodium fires are generally understood to be about 800 to 850 °C but that is for liquid "pools" and the higher temperature must be attributed to the finely divided sodium spray plus good ventilation available for the Almeria fire.

By 12.15 hrs, 1 hr 15 min after the fire had started, it appeared to be reducing, and a man was able to enter the hall and observe that the sodium leakage had stopped. The remaining burning sodium, mostly in the catchment trays, was extinguished using "Graphex" powder.

Much of the sodium pipework had been damaged in the fire, but the two storage tanks were undamaged. It is surmised that the large heat capacity of the sodium in the tanks (30 m^3 in the cold storage tank, which was immediately underneath the leak, and about 18 m^3 in the hot storage tank) was an important factor in preventing damage to them.

4 PROCEDURES THAT WOULD HAVE AVOIDED THE ACCIDENT

4.1 WHOLE SODIUM SYSTEM DRAINED, DEPRESSURIZED AND ALL PIPES AND COMPONENTS COOLED TO AMBIENT TEMPERATURE

This is the procedure recommended in the Operating Manual, Section 7670, Subsection 5.2.5. However, the time taken to cool down and heat up the plant is very long, and it was to be expected that the operators would search for a maintenance procedure which reduced the plant outage time. It would have been reasonable to maintain temperatures at about 200 °C, except for pipework and components in the part of the system to be repaired.

4.2 WHOLE SODIUM SYSTEM DEPRESSURIZED BUT NOT COMPLETELY DRAINED OR COOLED

The operators were unwilling to depressurize the system because of a history of oil leakage into the plant through the pump oil seals. However, the INTERATOM designers confirm that it would have been quite feasible to reduce both the argon gas pressure and the pump oil seal pressure simultaneously, so as to keep the differential pressure between the two within acceptable limits. If the system had been depressurized before the valve was dismantled, the incident would not have happened. However, it would still have been necessary to ensure the integrity of the frozen sodium seal (as outlined in Appendix 3 of this report) in order to prevent air ingress into the hot storage tank.

4.3 ENSURE INTEGRITY OF THE FROZEN SODIUM SEAL WITH THE SYSTEM HOT AND PRESSURIZED

The report of the accident, attached as Appendix 1 to this report, gives one explanation (Section 9) of the failure of the frozen sodium seal, due to inaccurate pressure measurements. Errors in pressure gauge measurement are deduced to have caused the sodium level to be lower than the valve under repair. There may be other explanations.

Appendix 3 of this report explains how frozen sodium seals can be formed and their integrity ensured. If some of the additional precautions outlined in Appendix 3 had been carried out, it is possible that a satisfactory frozen sodium seal could have been formed. However, since failure of the seal would lead inevitably to a massive sodium fire and loss of the sodium plant, the risk of adopting this procedure with the plant at pressure would remain unacceptably high, and it cannot be recommended. It is essential to depressurize.

5 ACTIONS OR DESIGN CHANGES THAT WOULD HAVE PREVENTED OR ALLEVIATED DAMAGE

5.1 ABILITY TO DEPRESSURIZE THE STORAGE TANKS MORE QUICKLY

If the argon vent valves and lines had been substantially larger so that the storage tanks could have been depressurized in seconds rather than minutes, the quantity of sodium ejected from the leak would have been significantly reduced and the resulting damage decreased. Since the emergency operating procedures (Operating Manual, Section 7670) do not mention storage tank depressurization, it appears that the plant designers did not envisage this type of incident that could result from the repair procedure adopted.

It should be noted that the designers provided facilities for rapid dumping of sodium from the plant into the storage tanks. This is achieved without having to depressurize the system and, therefore, does not require outflow of a large volume of argon gas from the sodium storage tanks. However, this rapid dumping cannot be effective for the plant condition during the incident.

5.2 FIRE DOORS/FIRE WALLS MORE EFFECTIVE

The fire walls between the sodium hall and the steam generator room and PCS hall were in general effective in preventing the fire from spreading. If the fire door between the sodium hall and the computer room had automatically closed after the personnel had evacuated through it, the spread of the fire to the control room would have been delayed, although it might eventually have spread when the control room windows were broken.

5.3 BETTER CONTROL ROOM ISOLATION

If the control room ventilation system had been separate from the sodium hall ventilation system, the ingress of smoke into the control room would have been delayed. Similarly, if the cable ducts into the control room had been better sealed, smoke would not have entered the control room via that route.

5.4 IMPROVED DESIGN OF CATCHMENT TRAYS

If the trays which caught the unburned metallic sodium had been provided with covers to restrict the access of air to the sodium in them, less sodium would have burned and the residual fire would have been easier to extinguish. One such design is sometimes known as the "Karlsruhe Tray", presumably since it was initially used at the Karlsruhe Research Center in W. Germany. It incorporates a ridged cover with holes in the valleys to allow the sodium to be drawn into the trays while restricting the access of oxygen.

6 PROCEDURES THAT WOULD HAVE ASSISTED DECISION MAKING

6.1 ELEMENTARY HAZARDS' ANALYSIS

In the UK, the regulation of safety in industrial plants is the responsibility of the Health and Safety Executive. In the light of experience gained in the design and operation of nuclear plants, the Health and Safety Executive requires that any new potentially hazardous industrial plant is subjected to an elementary hazards' analysis.

The main requirement is that every type of accident shall be examined, the likely accident sequence determined, and the extent of the likely damage assessed.

If such an elementary hazards' analysis had been carried out on the SSPS-CRS, it is likely that the consequences of the long depressurization time for certain type of failures would have been appreciated, and possibly design changes to permit faster depressurization would have been made.

6.2 WRITTEN MAINTENANCE PROCEDURES

A major contribution to the improvement of safety during plant maintenance is the insistence that the maintenance procedures to be adopted are written down and approved in advance of starting the work. This ensures that the whole sequence of operations is clearly thought through and any difficulties highlighted.

A convenient way of achieving this objective is to start by producing standard written procedures for the more common maintenance operations. For any particular job, the instructions would then be either:

(i) this operation is routine and will be carried out in accordance with Routine Maintenance Instructions .....

(ii) this operation if not routine. Parts 1 and 2 .... will be carried out in accordance with Routine Maintenance Instructions. Parts 10 and 11 ..... will be carried out in accordance with the following instructions .... The additional hazards arising from the nonroutine part of the work are ....

The maintenance instructions should include details of the protective clothing to be worn, any special equipment required, and a note of any particular precautions necessary, such as additional firefighting equipment.

7 LESSONS LEARNED

Although the initiating event was the failure of the frozen sodium seal, the major cause of the incident and the large-scale of the incident was the decision by the operators to carry out maintenance work on the plant with the storage tanks pressurized. The reason for the large-scale of the incident was the plant design feature, pressure release valve plus associated pipework, that prevented quick depressurization of the storage tanks. Hence the main lesson learned is that, for any future plant, new procedures should be adopted that will greatly reduce the likelihood of similar errors of judgement being made. Two main changes in procedure are recommended:

(a) an elementary hazards' analysis should be carried out on any new plant as part of the design process

(b) for any maintenance work on the plant, written maintenance instructions should be prepared and authorized before the work is started.

7.1 ELEMENTARY HAZARDS' ANALYSIS

The elementary hazards' analysis that should be undertaken as part of the design process, should cover the following points:

- An analysis of every type of accident that could arise during plant operation, with an assessment of the likely consequences, and consideration of whether any design changes would be justified to reduce the severity of the consequences.

- An analysis of every type of accident that could occur during plant maintenance, with an assessment of the likely consequences, and consideration of whether any design changes would be justified to make plant maintenance easier.

- An analysis of accidents that could occur due to external causes (e.g., storm or aircraft crash) and an assessment of the likely consequences.

For a large chemical or nuclear plant, it would be customary in the UK to assign probabilities to the various accidents and the consequent damage. This is not considered to be necessary in the case of the type of plant under consideration here, and is not recommended as part of this Elementary Hazards' Analysis. The main purpose of the proposed analysis is twofold.

(i) To encourage the designers to consider possible accident sequences in detail. Experience has shown that this can lead to design changes to improve the safety of the plant.

(ii) To provide the operators with detailed information on the possible consequences of operations which they may consider undertaking. Again experience has shown that this leads to improvements in operator judgements.

A further benefit of the hazards' analysis is that it provides a logical basis for decisions on plant safety features (emergency escape routes, fire barriers, etc.) and also for decision related to emergency equipment (location and quantity of fire extinguishers, etc.).

7.2 WRITTEN MAINTENANCE INSTRUCTIONS

It is strongly recommended that, before any maintenance operation is undertaken on any future plant, detailed written maintenance instructions are provided. These instructions should cover:

- the objective of the maintenance operation

- detailed instructions on how to carry out the work

- details of protective clothing to be worn, and any special equipment necessary

- details of any special precautions to be taken

It is envisaged that these written maintenance instructions would be of two types:

(i) Routine instructions: these would cover all normal maintenance operations and would be written well in advance as part of the plant documentation.

(ii) Special instructions: these would be written at the time to cover nonstandard maintenance operations. They should include an assessment of any particular hazards arising from the nonstandard work.

It is expected that the maintenance instructions would be written by the person directly supervising the maintenance work and would be authorized by his immediate superior. The main purpose of insisting on written instructions for all maintenance work is to ensure that the sequence of operations and their consequences are properly thought through in advance of starting the work.

The foregoing are the two major lessons to be learned from the accident to the SSPS-CRS plant, but there are a number of smaller, but none the less important, lessons that can also be drawn.

7.3 COMMUNICATIONS

In any international project, such as the SSPS-CRS, there are inevitably problems of communication. In this particular case, while the plant was designed in W. Germany, but built and operated in Spain, all the documentation is in English and is studied by persons whose mother tongue is not English. Furthermore, the operating manual (Volume 37 of the Final Documentation) is 6 cm thick. It is a formidable task for an operator to tackle a document of this size in a foreign language.

It is recommended that for any future plant a simple set of operating instructions is prepared in the native language of the operators, setting out the main principles of operation of the plant, the main safety precautions to be taken, and in particular setting clear guidelines for circumstances when reference to the full operating manual must be made.

Also consideration should be given to placing simple notices with important safety-related instructions at entrances to the plant area. For example "wear goggles" is usually displayed at the entrance to a sodium plant. Another could be "depressurize before maintenance".

7.4 PLANT DESIGN

Attention should be paid to the following details relevant to the design of any future plant.

The escaping sodium immediately produced a dense cloud of smoke, making it impossible to see. It is essential that personnel working in the plant can find their way to the emergency exits under these conditions. Suitable handrails or other aids for evacuation should, therefore, be provided. It is essential that two separate emergency escape routes are available from every location in the plant.

The fire door between the plant and the computer room failed to close. It is essential that the design of fire doors allows quick escape in an emergency, while closing automatically and reliably afterwards.

"Karlsruhe" type catchment trays, as described in Section 5.4 of this report, should be provided whenever practicable. The "Graphex" fire extinguishing powder proved very effective, but careful consideration should be given to the siting of stocks of this powder. While ample supplies should be available inside the sodium hall for immediate use, back-up supplies are needed outside the hall for occasions where the fire and its associated smoke lead to enforced evacuation of the sodium hall.

Consideration should be given to adding additional controls for the main dump valves at a location remote from the control room, so that if the control room has to be evacuated for any reason, the sodium in the plant can still be dumped. If the dump valves are electrically controlled, the electrical cables to them should be designed with some degree of protection from a sodium fire and they should "fail safe" on total loss of all power.

Smoke entered the control room through the ventilation system; similarly the cable ducts allowed the ingress of smoke. These shortcomings should be eliminated in future designs. An elementary hazard analysis would draw the designer's attention to design weaknesses of this type.

The windows between the control room and the sodium hall were broken by the intense heat. A design compromise has to be made here between the ability to observe the plant from the control room and the desirability of isolating the control room from a plant fire.

Part of the roof insulation contained PVC type material which produced toxic fumes. Again, the requirement to produce an elementary hazards analysis would draw the designers' attention to this possibility.

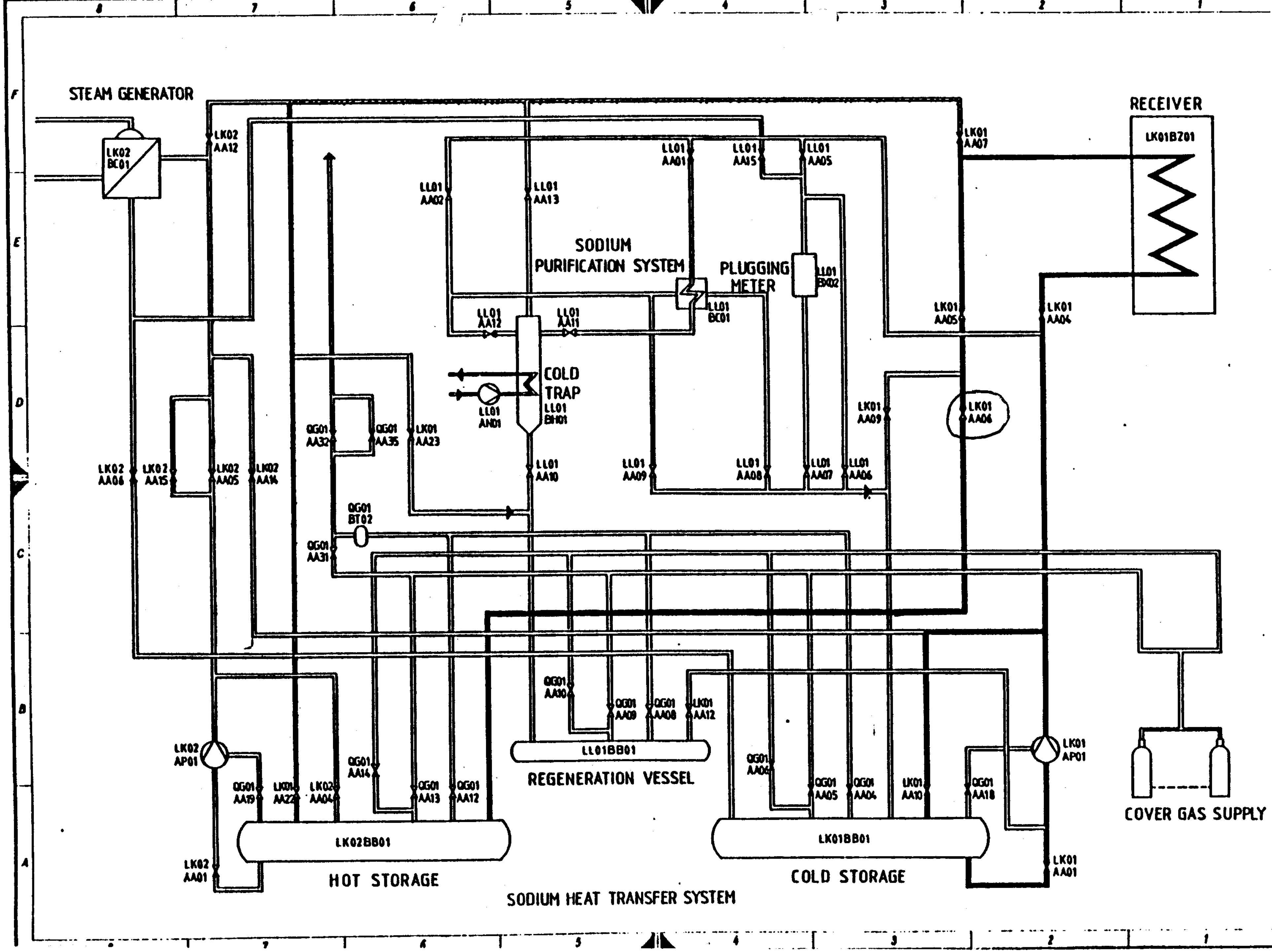
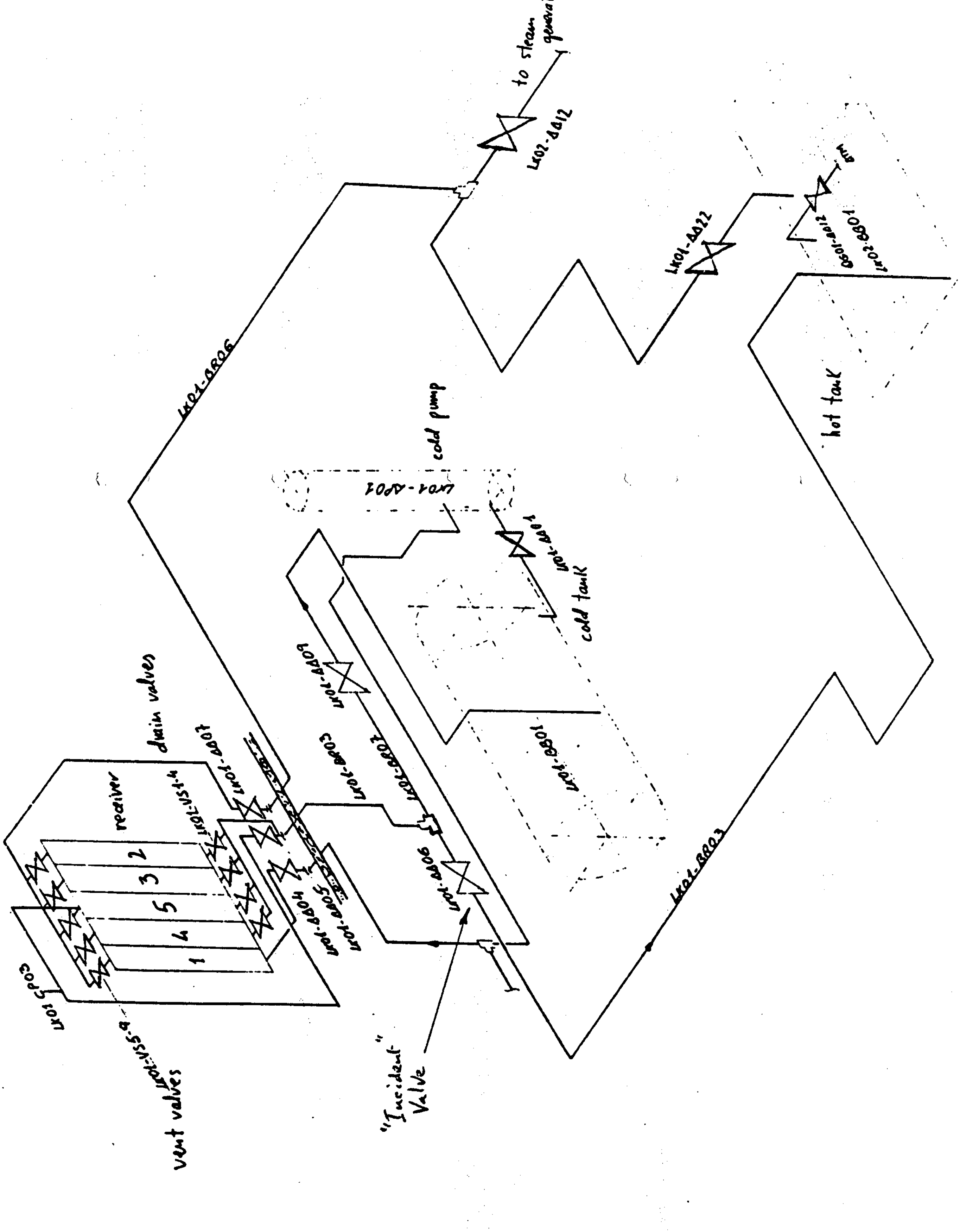

STEAM GENERATOR
LK02 BC01
RECEIVER
LK01BZ01
SODIUM PURIFICATION SYSTEM
PLUGGING METER
LL01 BX02
LL01 BC01
COLD TRAP
LL01 BH01
LL01 AN01
LK02 AA12
LK01 AA07
LL01 AA01
LL01 AA15
LL01 AA05
LL01 AA02
LL01 AA13
LL01 AA12
LL01 AA11
LK01 AA05
LK01 AA04
LK01 AA09
LK01 AA06
QG01 AA32
QG01 AA35
LK01 AA23
LK02 AA06
LK02 AA15
LK02 AA05
LK02 AA14
LL01 AA10
LL01 AA09
LL01 AA08
LL01 AA07
LL01 AA06
QG01 BT02
QG01 AA31
QG01 AA10
QG01 AA09
QG01 AA08
LK01 AA12
LL01BB01
REGENERATION VESSEL
LK02 AP01
QG01 AA19
LK01 AA22
LK02 AA04
QG01 AA14
QG01 AA13
QG01 AA12
LK02BB01
HOT STORAGE
LK02 AA01
QG01 AA06
QG01 AA05
QG01 AA04
LK01 AA10
QG01 AA18
LK01 AP01
LK01BB01
COLD STORAGE
LK01 AA01
COVER GAS SUPPLY
SODIUM HEAT TRANSFER SYSTEM

FIGURE 1

FIGURE 2


to steam generato.
LK02-AA12
LK01-BR06
LK01-AA22
hot tank
cold pump
cold tank
LK01-BB01
LK01-BR03
receiver
drain valves
vent valves
"Incident" Valve
1
4
5
3
2

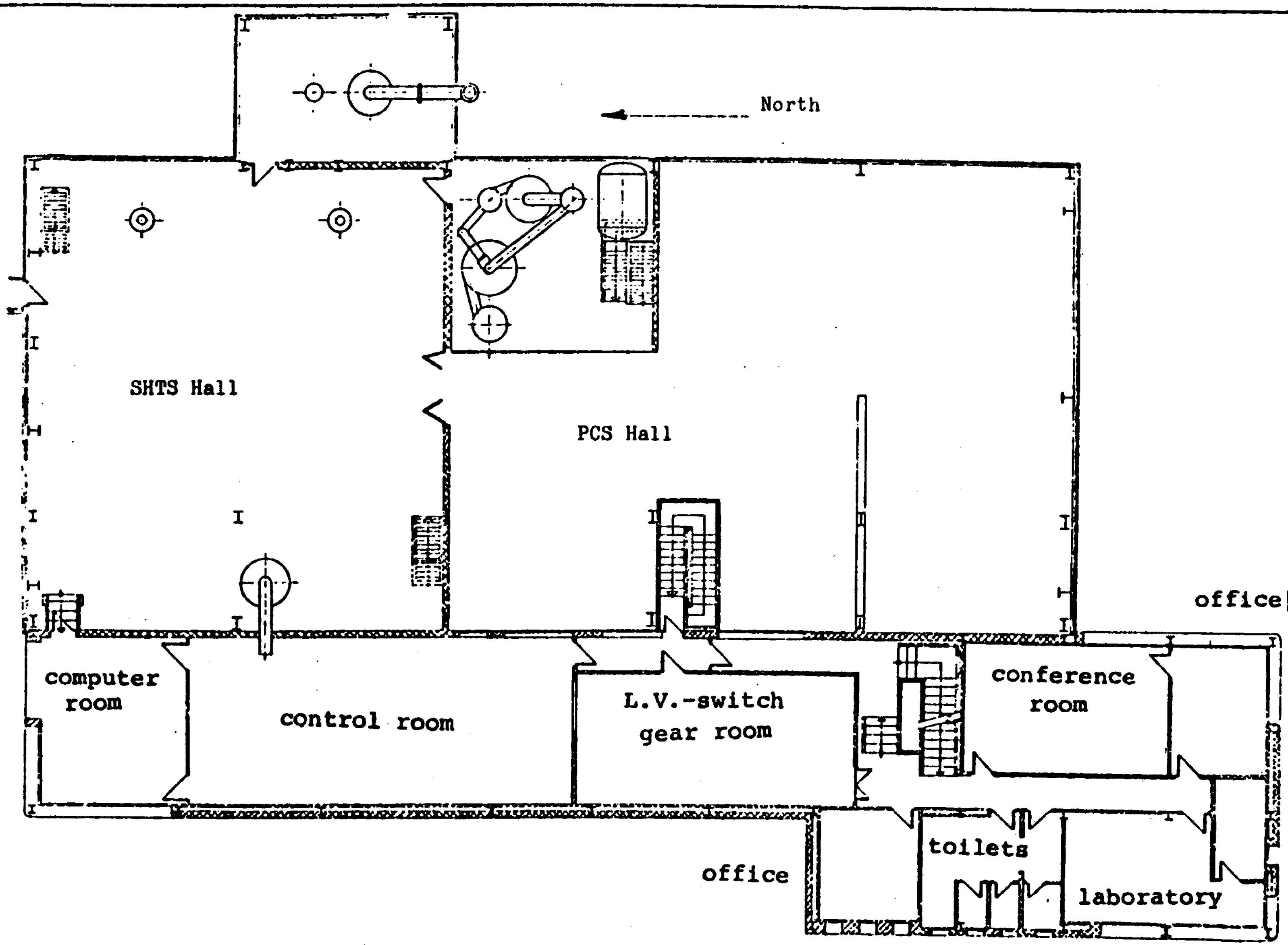


FIGURE 3

SSPS

IEA – SSPS PROJECT CRS

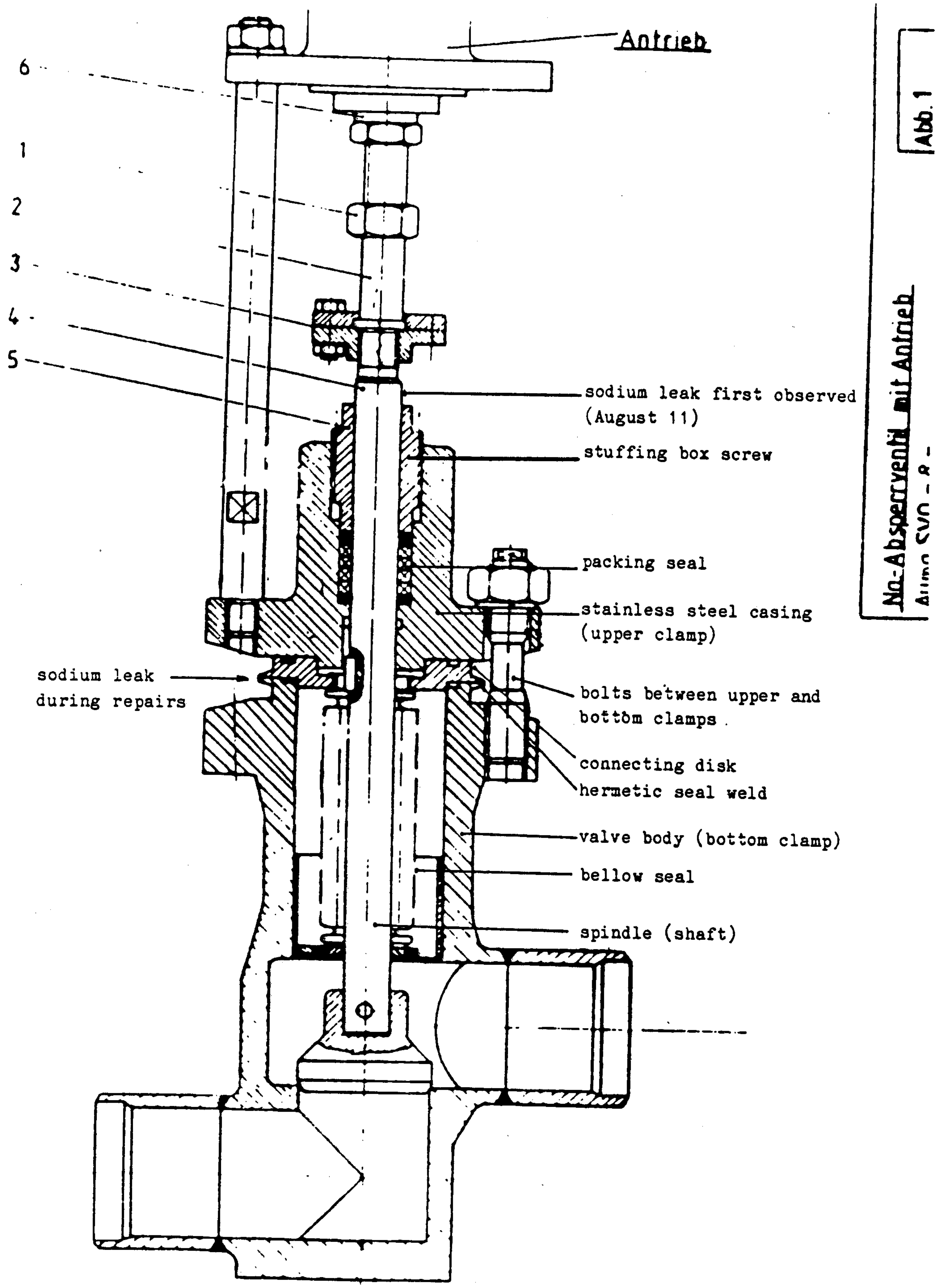
4.0 m Level Building Plot Plan

INTERATOM

INTERNATIONALE ATOMREAKTORBAU GMBH

11211/10-79/2 (SSPS/002/4000)

FIGURE 4



Valve LK01-AA06

APPENDIX 1

SSPS - CRS SODIUM FIRE INCIDENT

August 1986

This document was prepared by the plant operator and presented to the project executive committee as the formal record of the incident.

APPENDIX 1

PRELIMINARY

SSPS-CRS SODIUM FIRE INCIDENT

- AUGUST 1986

1. ORIGIN
2. INSTALLATION PREPARATIONS
3. VALVE REPAIR PROCEDURE
4. FIRE : ORDER OF EVENTS
5. CLOSING/SEALING OF SODIUM HALL
6. REMOVAL OF SODIUM AND ASH/RESIDUE
7. PERSONNEL INJURIES
8. MATERIAL DAMAGE
9. POSSIBLE CAUSE OF THE ACCIDENT

.. FUTURE ACTIONS

1. **ORIGIN** : August 11.

During the routine daily inspection of all the valves and components of the sodium circuit, solid or 'frozen' sodium (sodium hydroxide) was observed in the spindle (valve shaft) of valve LK01-AA06 between the valve body and motor (Figure 1) This valve is located between the receiver and hot sodium storage tank, and is located 18 m from the latter.

Failures of this type have occurred previously in two valves similar but smaller than an LK01-AA06: LK02-AA15 and LK02-AA14.

This failure consists of sodium leaking past the packing seal along the spindle (shaft), which in the past meant that the bellow seal was leaking.

The repair procedure followed in each of these cases consists in freezing the sodium line containing the defective valve, after which the spindle, bellow, and connecting disk are replaced with new parts. The spindle, bellow, and connecting disk are a prefabricated subassembly.

Whenever an unprecedented failure occurs at the plant, the standard procedure adopted by the O+M team is to consult with the plant designer (INTERATOM). This type of failure has occurred before, and is considered 'routine', hence INTERATOM was not contacted in this case. The last consultation of this type was made concerning a sodium leak in the rupture disk of the steam generator, on April 23, 1986.

2. INSTALLATION PREPARATIONS

Once it was decided to repair the valve, operation personnel performed the necessary tasks to freeze the piping section (LK01-BR03) between the hot tank and the valve (Figure 2); these tasks were composed of the following:

(A) August 12. Purification of the sodium to ease filling later. During this operation the sodium was heated using the receiver and all the sodium was sent to the cold tank. After the sodium regeneration cycle, both tanks were equally full. The plugging temperature was measured as 100°C. During this operation, valve LK01-AA06 was opened and closed several times. A watcher was near the valve at this time, to note any leakage and correct spindle movement. This watcher was provided with the required protective equipment and a graphite extinguisher in case the valve leak caused a fire.

(B) August 13. Draining of all sodium piping except for LK01-BR03. First, the receiver circuit was drained following the usual procedure. All the valves were opened except for LK01-AA06. Then, the steam generator sodium circuit (LK02) and water circuits were drained.

(C) To ensure that pipe LK01-BR03 would not drain if valve LK01-AA06 was not well seated, argon pressure of 4.5 bar was maintained in the receiver. This was performed by manipulating the valve (LK01-AA22) connecting the argon (LK01-BR06) in the receiver and hot tank, as well as the tank vent valves (QGO-AA12 and QG01-AA35). At the end of this operation, both tanks had 5.1 bar pressure. This pressure difference of 0.6 bar between the receiver and the tanks should ensure that the sodium level in the line remained 6.7 m above the level in the tanks. Valve LK01-AA06 is located 3.3 m above the sodium level in the tanks (Figure 2).

(D) The electric trace heating in piping sections LK01-BR03, LK01-BR07, and the receiver was disconnected on August 13 at 17:00, and valve AA09 was closed.

3. VALVE REPAIR PROCEDURE

On August 18 at 8:30, the temperature in the section 3 m from the valve was 43°C and in the proximity of the valve, 35°C. The operator pushed the 'OPEN' and 'CLOSE' buttons of the valve, and no spindle movement was detected. This indicated that the valve was, indeed, blocked with frozen sodium.

Consequently, preparations were made prior to repairing the valve, composed of the following:

- Mounting of a platform allowing access below the floor, at the level where the valve is located.

- Removing part of the floor grill, allowing the operator to move freely.

- Removing the thermal insulation of the valve.

- Placement of the following items near the work area:

  - A portable lamp.
  - A hand drill.
  - A complete tool box.
  - A temperature sensor.
  - A graphite extinguisher
  - A sodium collection tray with sacks of graphite, placed below the valve.
  - Equipment pertaining to personal protection for the personnel directly involved in the reparation (hard hats with protective face shields, shoulder/neck covers, glasses, coveralls, etc.).

The following personnel assigned to this repair:

- One first class tradesman with 20 years experience in construction and adjustment of thermal and nuclear power plants. He has repaired similar valves many times, and has worked in the SSPS Project since 1981.

- One mechanics foreman, with more than 20 years experience in industrial constructions. He has worked at the Plataforma since 1981.

- Two qualified assistants; both working on the Plataforma since 1981.

- One electrician with ample experience in construction and maintenance of thermal and nuclear power plants. He has worked in the SSPS project since 1981.

Supervision of the work was carried out by the Maintenance Head, and the Operation Head was present at the repair site.

The reparation started at 10:00. The spindle, bellow, and connecting disk are attached to the valve body by means of the stainless steel casing and the connecting disk (Figure 1). The casting disk is clamped to the valve body (bottom clamp) with ten bolts. To ensure a hermetic seal, INTERATOM welded the connecting disk to the valve body (Figure 1), making any repair work in this area difficult.

To remove the hermetic seal weld, the upper clamp had to be removed since it restricted access of the drill to the weld. The ten bolts between the upper and bottom clamps were removed. This allowed the motor and the stainless steel casting (upper clamp) to be removed permitting access to the mermetic seal weld. Next, the drill was applied to the weld, at small intervals to avoid excessive heating of the disk. When approximately 230° had been cut, the disk opened suddenly and projected bits of frozen sodium, immediately followed by a gush of liquid sodium which reacted instantly upon reaching the air; this happened at 11:00. The tradesman performing the work received the impact of the sodium, but was not injured due to the protective equipment. However, when he jumped to the floor from the platform, he lost this equipment and received burns on his head and neck from the sodium. The foreman and Operation Head were also slightly burned by the sodium.

4. FIRE : ORDER OF EVENTS

The valve being repaired was located at the North end of the SHTS Hall (Figure 3).

Due to the immediate characteristics shown by the fire, and the fact that it was uncontrollable since the valve was connected directly to the pressurized hot tank, the following actions were taken:

- Vent valves were opened to remove pressure in the tanks. Seconds after opening these valves, the electric grid coincidentally went off. The auxiliary diesel generators were put in service and remained connected to ensure that the vent valves were opened.

- The Director of the Plataforma was informed of the incident, and ordered the immediate evacuation of the plant, due to the unbearable atmosphere and possible danger of a water/sodium explosion. This action was taken due to the water storage existing in the PCS hall, adjacent to the SHTS Hall (Figures 3 and 4) within reach if the fire assumed greater proportions.

- At this time, the fire was burning at the North end of the SHTS Hall and in the computer room (Figure 4). The Control Room, adjacent to the Computer Room, was filled with smoke (Figure 4). It is assumed that the fire entered the Computer Rom from the SHTS Hall through the connecting door (Figure 4).

- No other immediate action was taken, since the fire could not be controlled until pressure in the tanks was reduced.

- The firemen arrived on site at 12:00, with normal extinguishing equipment.

- At 12:15 it was observed that the fire had reduced and action was [illegible]en first, to avoid spreading, and second, to try and extinguish it.

- The fi[illegible]t actions were to take the raw water pressure tank out of service, cl[illegible] the manual valves of thermal oil to the CRS-PCS, disconnect the au[illegible] [illegible]l generators, and disconnect the H.T. line.

- At 12:25 the Director and Security Technician (with gas masks) made an inspection of the PCS hall, and found that the water tanks were intact. There was fire in the Southwest zone (workshop), which was extinguished immediately by the firemen.

- At 12:35, after verifying that the fire could be spread from the Computer Room to the Control Room and auxiliary generator fuel tanks, and diesel room, the Computer Room fire was extinguished using the firemen's extinguishers; first with the manual 12 kg powder extinguishers, followed by the 50 kg extinguishers.

- A 12:40, the Director and Security Technician (with gas masks) went to the Sodium Hall through the Southeast door checking if any sodium was burning in the collection ditches. With the help of the Plataforma personnel, all the graphite in this area (level 1) was dumped in the ditches. It was noted that the graphite acted immediately, putting out the fire in the first three compartments.

  More graphite was brought from the upper levels and dumped in the four remaining compartments, with access through the North door. At this time, the fire was considered as controlled in the collection ditches.

- At 13:00, the steam generator room (Figure 3) was inspected and apparently this had suffered no damage. It was decided to take the graphite from this area and use it to control points where the fire reignited.

- At the same time, the fire in the Computer Room which had started again was fought from the outside by firemen, and was wholly extinguished at 13:30. This is the room where the Director of the Plataforma burned his hands and arms when the false floor fell beneath him.

  Even though the sodium fire was controlled at 13:00, occasional fires still ignited and were extinguished with graphite.

  Sacks of salt (from the Raw Water Treatment Plant) were placed inside the area to use instead of graphite if all the graphite on site were used. However, there was no need to use the salt as both graphite (8 sacks) and 2 extinguishers were left over.

- Eight persons remained on site during the night.

- The firemen left at 24:00.

5. CLOSING/SEALING OF SODIUM HALL

On August 18 at 17:00, the first attempts were made to find a company capable of sealing of the SHTS Hall. At the same time, strong plastic was sought to use to cover the holes produced by the fire in the roof above the SHTS Hall.

On August 19 at 9:00, attempts were made to find a crane capable of reaching over 35 m.

The Meteorological Station of Malaga was contacted, and the forecast was favorable.

At 17:00 the plastic arrived.

On August 20 at 8:00, the crane arrived on site and repair started on the SHTS Hall removing damaged sheet metal roofing so that the plastic would not be ripped.

Metal beams were welded across the opening to the roof of the building to support the plastic cover.

The plastic was placed over the open areas and those places where water could enter the building.

On August 21 at 18:00, the plastic was in place over the most affected parts of the roof.

On August 21, it was decided to place tarp over the plastic to ensure that air would not lift the plastic from those zones least protected by the metal sheets.

On August 23, it was decided to pass more ropes over the cover from East to West to secure it in the case of high winds.

6. **REMOVAL OF SODIUM AND ASH/RESIDUE**

On August 20 at 13:00, representatives from the insurance company authorized the performance of clean-up works in those areas affected by the fire.

INTERATOM was contacted; D. Weyers and H. Jacobs were sent as their representatives and sodium experts.

On August 21, Thursday, temperatures were measured in the tanks and sodium collection areas, and found to be over 100°C in some areas. At 15:00, a meeting was held to decide how to proceed with the sodium residue, transport, exterior storage, and security measures, with the following conclusions.

- The removal will be effected by hand using: picks, shovels, spatulas, etc.

- The material will be put in plastic sacks, which will be as hermetically sealed as possible.

- This packaged material will be deposited in the zone destined to chemical storage, located in the outside warehouse.

- The personal protection equipment used by the workers will be:

  - hard-hat with protective shield
  - plastic suits (e.g., foul weather)
  - acid-proof gloves
  - rubber boots
  - masks to protect against solid particles

- The works started by first removing all objects located in high places that could fall over the work area.

  evacuation paths were left free of obstacles.

  The show - and 'eye-washing' zone will be lit, as well as the whole removal area.

  Provisionally, the first aid services will be in the SSPS.

Fine, anti-humidity treated salt will be bought to use as an extinguisher if necessary.

The removal work will be supervised constantly by a responsible technician.

The removal work will be carried out as follows:

1. Removal and cleaning of zones adjacent to sodium collection trays.
2. Removal and cleaning of collection trays, starting in the East zone.
3. Removal and cleaning of residues below the storage tanks.
4. The teams will be consist of 4 laborers and 2 supervisors.

- One team will start, making way for the second team.

- On Friday, August 22 at 9:00, actual removal work started.

The first problem observed was the excessive sweating of the laborers, due to the high temperature of the area, approximately 50°C, and the fact that the plastic suits had little or no ventilation. This sweat produced small explosions and fires when it contacted the sodium residue, so it was decided to change the plastic suits for cotton coveralls and have towels in the zone to dry the perspiration. These measures took care of this problem.

The next problem was due to the fact that the sodium residues were so hot that they ignited the plastic sacks; subsequently the removal procedure was modified. The sodium was placed in metal containers and transported on the forklift to the disposal area, where they were allowed to cool, and then put in metal barrels of greater capacity, hermetically sealed.

A point was reached where the removal was most difficult, due to the formation of a hard mass; hnce, the pick and shovel were substituted by a jackhammer.

The procedure was [illegible]wed to remove the residues. At the same time new outbreaks of fire were extinguished until the area, ditches, and trays were clean; this being the case on August 26 at 20:00.

- This same day, August 26, 30 samples of residue were taken from the area to check the possible presence of sodium. The result was negative.

- On August 27, the trays and ditches were cleaned by dumping dirt and then sweeping with metal brushes to eliminate the sodium carbonate and other residues.

- This same day, the water proofing where the cables from the heliostat field enter was reenforced with silicone, and the tubes cut from the cold tank were plugged.

- On August 27 at 12:00, work was halted in the sodium area, awaiting the arrival of the INTERATOM experts planned to arrive on August 28.

7. PERSONNEL INJURIES

The following persons suffere sodium burn of diverse consideration:

- **Ricardo Carmona Contreras,** Director of the Plataforma. Burns in both hands and right arm, occurring while extinguishing the fire. He was two days under observation in the hospital, and on the third day returned to work.

- **Angel Navarro Martínez,** Operation Head. Superficial burns caused by splatters of sodium. He was treated at the hospital and returned to work two hours later.

- **Domingo Morgado Hermoso,** First Class Tradesman. Sodium splattered on his head and neck. He was three days under observation at the hospital.

- **Sebastián Ronda Sánchez,** Foreman. Sodium splatter on his head. He was treated at the hospital and left instantly.

8. MATERIAL DAMAGE

See telex from INTERATOM. (Appendix 2)

9. POSSIBLE CAUSE OF THE ACCIDENT

Based on the characteristics with which the sodium came out of the valve, it seems clear that the line joining the hot tank and the valve was not filled with sodium, only a small plug in the valve body.

A double failure had to have happened for this to occur:

1. Poor seating of valve LK01-AA06. This would allow the argon coming from the receiver ciruit to penetrate the line joining the hot tank and the valve.

2. Loss of the sodium column maintained by the 0.6 bar pressure difference.

For (2) to happen, initially two possibilities are considered:

(A) Blockage of receiver pressure gauge (LK01-CP03) indicating 4.5 bar. Blockage of this gauge has occurred previously (Marh 27, 1983), and was due to a sodium plug in the meter, the consequence of insufficient trace heating. In addition, the argon valve (LK01-AA22) joining the hot tank to the vent circuit of the reciver would have to have leaked. In this way, pressure in the receiver would increase, undetected by the pressure gauge.

(B) Calibration error between the receiver and hot tank pressure gauges. An appropriate measurement error in one or both pressure gauges would reduce, or even erase, the pressure differences observed (0.6 bar).

Aimed toward determining the possible cause of the accident, the following test was made on August 30.

Argon was injected in vent line of the receiver (LK01-BR06) to presurize it. Two precision pressure guages (A and B) were installed at the line's inlet. The pressure indicated was compared with that indicated by the reciever pressure gauge (LK01-CP03), with the following results:

Pressure gauge A	: 5.05
Pressure gauge B	: 5.10
Pressure gauge LK01-CP03	: 4.75

These results reject the first possibility (A), because the pressure gauge LK01-CP03 was not blocked (even though the trace heating was disconnected), making the second valid (B). Supposing that the gauge of the hot tank accurately indicates the pressure, the difference would then be 0.3 bar. This difference corresponds to a sodium height in the line of 3.3 m; the same height at which the valve of the horizontal section of line LK01-BR03 is found.

The sodium column could have filled only the vertical section just above the hot tank (Figure 2) of the line (measured temperature of 206°C), and in this case would be liquid due to the proximity of the hot tank. This explains why, when removing the spindle of the valve, solid sodium particles came out (from the plug in the valve), followed by liquid sodium from the vertical section of the line and hot tank.

10. FUTURE ACTIONS

As yet undetermined. Will be discussed Madrid (JEN-IER), E.C. Meeting, etc.

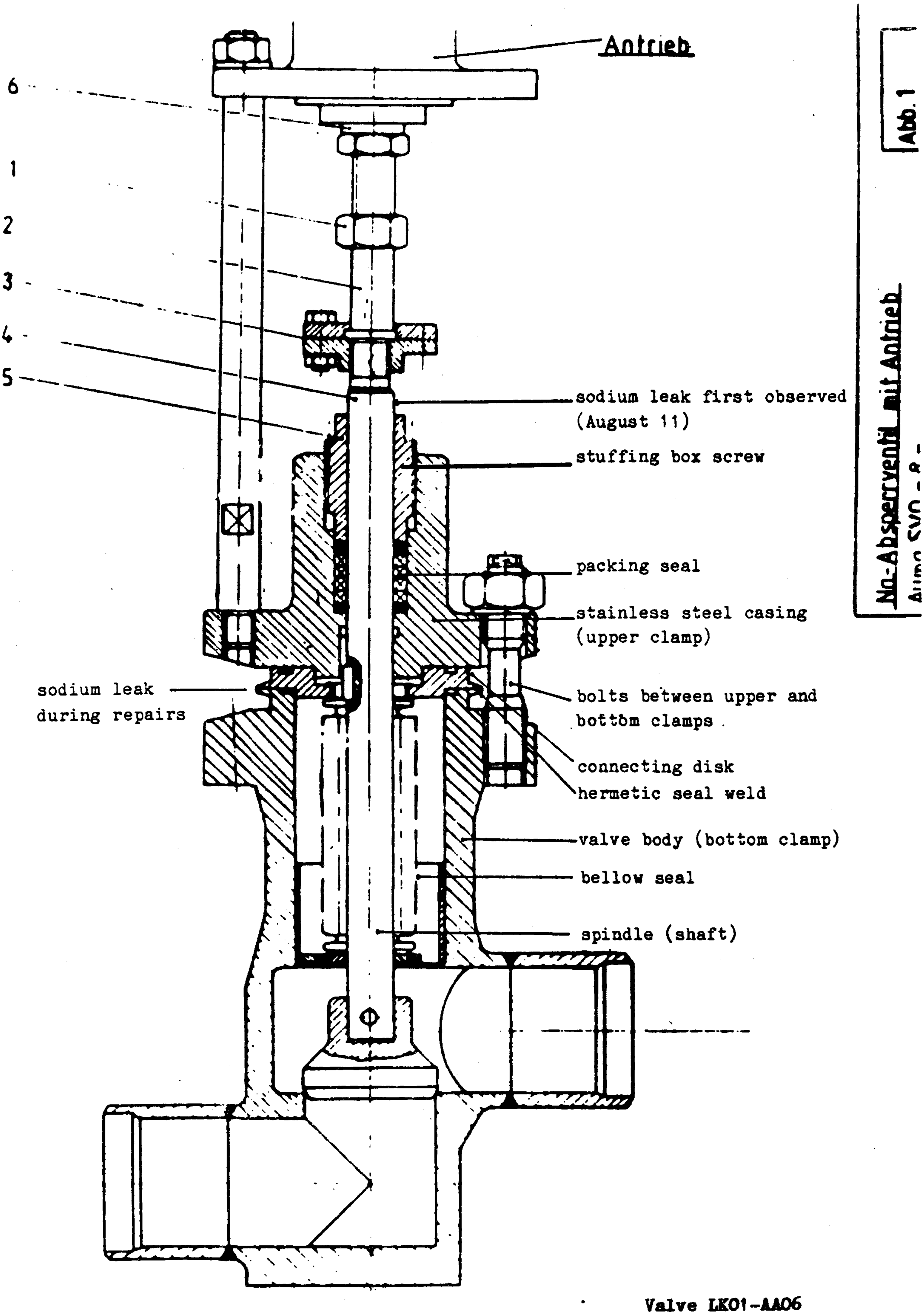

Antrieb
6
1
2
3
4
5
sodium leak first observed (August 11)
stuffing box screw
packing seal
stainless steel casing (upper clamp)
sodium leak during repairs
bolts between upper and bottom clamps
connecting disk
hermetic seal weld
valve body (bottom clamp)
bellow seal
spindle (shaft)
Na-Absperrventil mit Antrieb
Abb. 1
Valve LK01-AA06

Figure 1

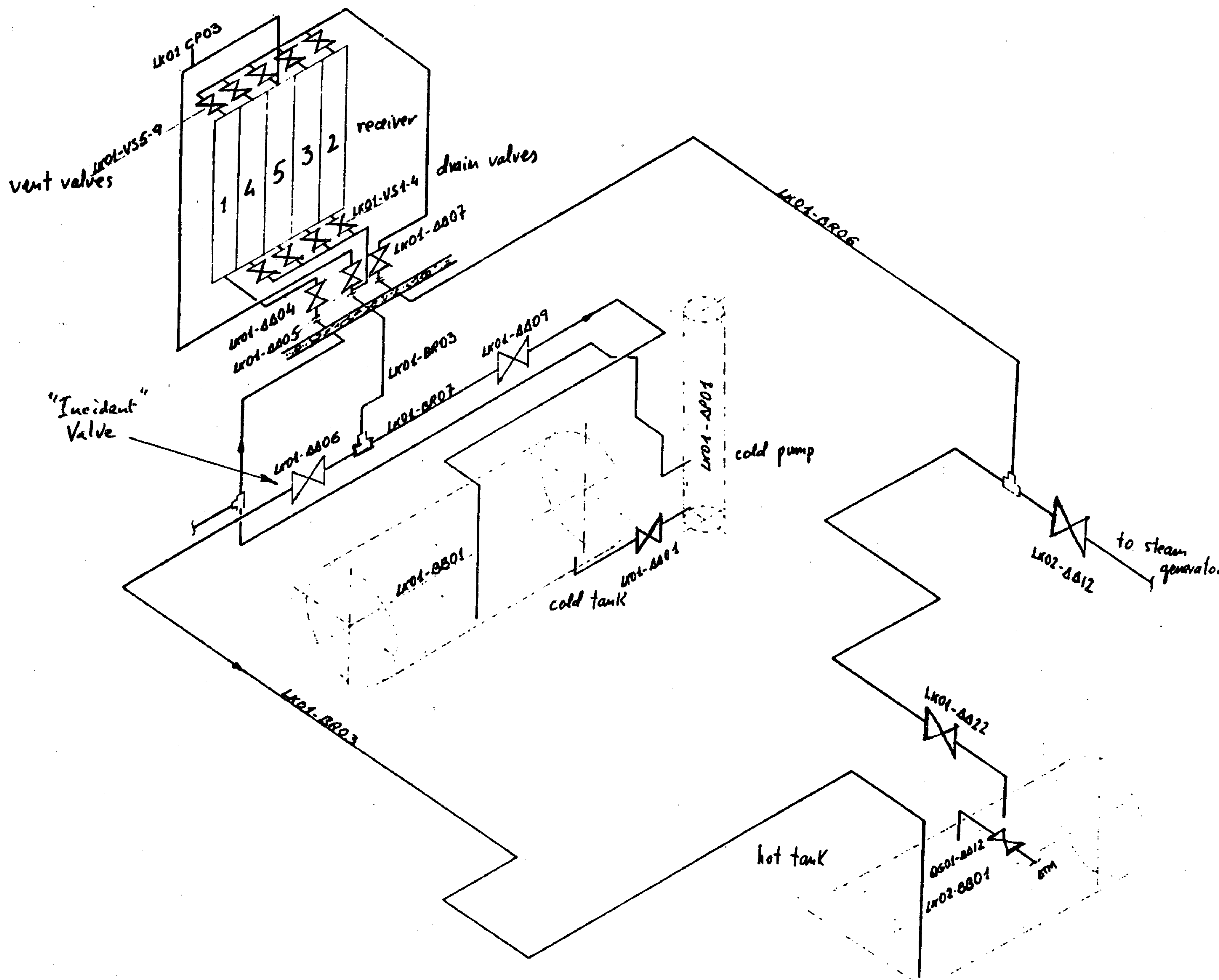
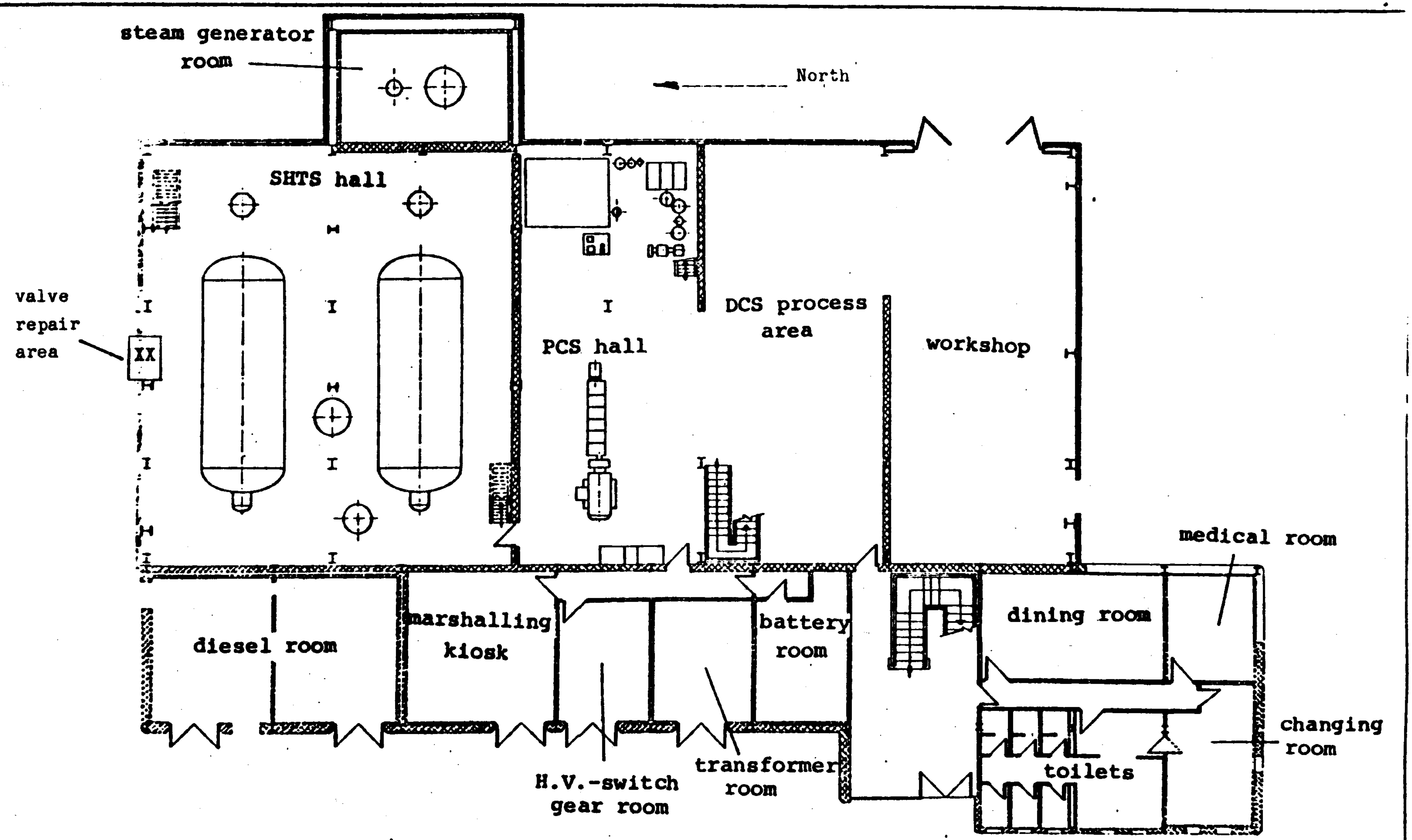

LK01 CP03
receiver
1
4
5
3
2
vent valves
LK01-VS5-9
drain valves
LK01-VS1-4
LK01-AA07
LK01-AA04
LK01-AA05
LK01-BR03
LK01-AA09
LK01-BR07
"Incident" Valve
LK01-AA06
LK01-BR06
LK01-AP01
cold pump
LK01-BB01
cold tank
LK01-AA01
LK02-AA12
to steam generato.
LK01-BR03
LK01-AA22
hot tank
QS01-AA12
LK02-BB01
STM

Figure 2



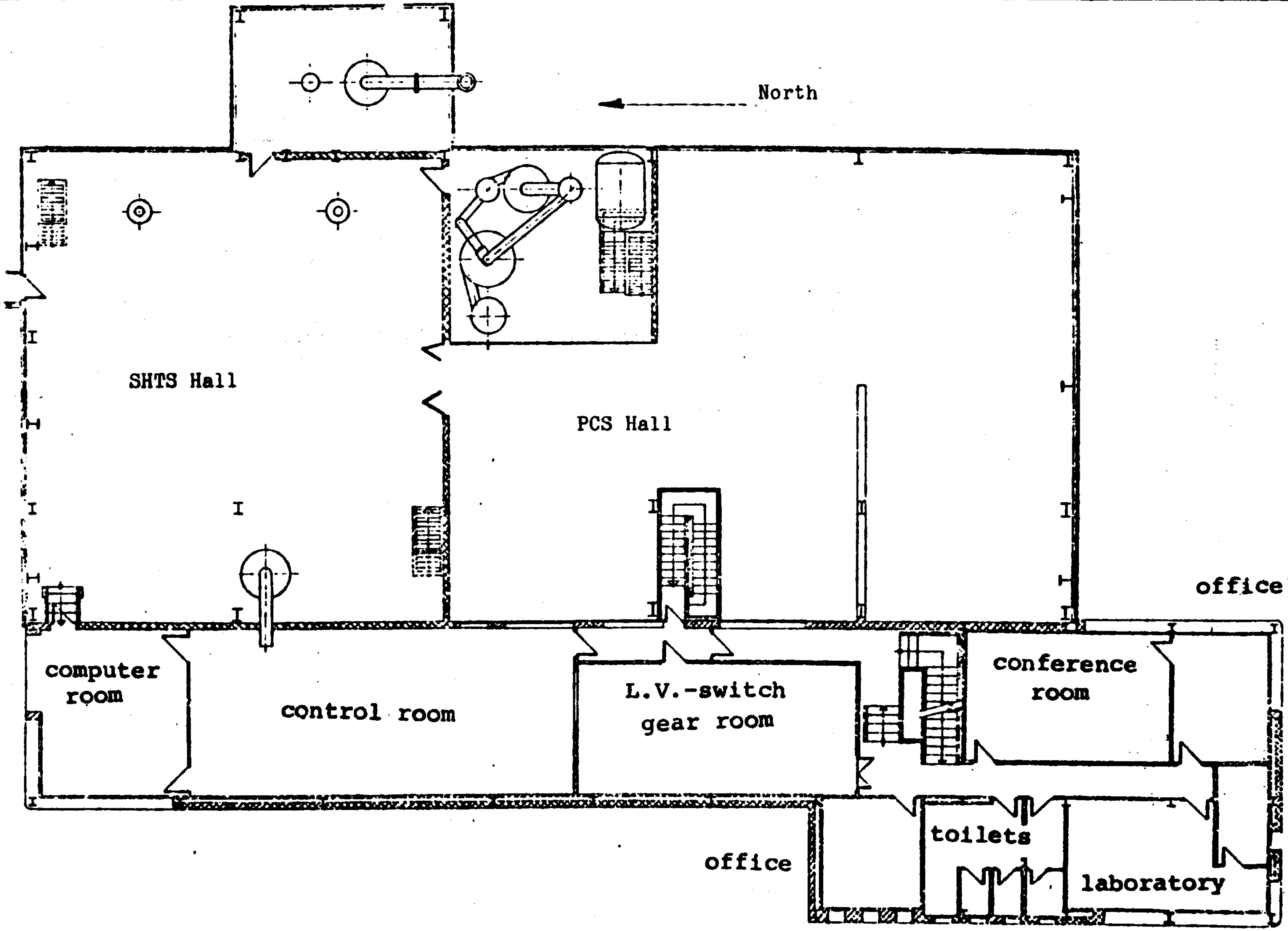
IEA – SSPS PROJECT CRS

FIGURE 3: 0.0 m Level Main Building Plot Plant

INTERATOM

INTERNATIONALE ATOMREAKTORBAU GMBH

11211 40-78 2 (SSPS/002/4000)



IEA – SSPS PROJECT CRS

FIGURE 4 4.0 m Level Building Plot Plan

INTERATOM
INTERNATIONALE ATOMREAKTORBAU GMBH

SSPS

1211/10-79/2 (SSPS/002/4000)

APPENDIX 2

Telex from INTERATOM to which reference is made on Page 13 of Appendix 1

APPENDIX 2

INTERATOM

[x] Fernschreiben
[ ] Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. 6135 Datum 01.09.86

FS-Nr. 2850

Eingangsstempel

Bearbeiter Floss

OE PA212 Hausruf 25 18 Kurzz.

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

1. Mr. Louis Crespo, Instititi uto Energia Renovarbles, Madrid
2. Dr. Ricardo Carmona, Plataforma Solar, Almeria
3. Mr. Dieter Weyers, Plataforma Solar, Almeria

CRS-Solar Power Plant, Almeria
Sodium Incident

Dear Mr. Crespo,

Based on your telex dated Aug. 26th, 1986, we checked the existing CRS-system and came to the following picture:

1. From our todays point of view with the accident in the sodium heat transfer systems on Aug. 18th, 1986, the following equipment has been damaged resp. has to be repaired in case the CRS-system shall operate in the future again:

1.1 SHTS-Hall

- Cold storage

  . dismantling of thermal insulation; cleaning of tank outside (evtl. sand blasting); inspection of tank; renewing of fixed tank support; renewing of trace heating system and thermal insulation.

- hot storage

  . renewing of steel sheets of thermal insulation

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

Verfasser Datum Unterschrift

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Blatt 3: TVS/Sekr. — Verbleib (gelb)

9412/11-83/20

INTERATOM

☐ Fernschreiben
☐ Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. ____________ Datum ____________

Bearbeiter ____________

OE ____________ Hausruf ____________ Kurzz. ____________

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

FS-Nr.

Eingangsstempel

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile : Firmenkurzbezeichnung, OE, Namen der Unterzeichner

- sodium pump - cold storage
  . renewing completely
- sodium pump - hot storage
  . renewing of E-motor drive and oil-system; complete technical inspection; renewing of steel sheets of thermal insulation;
- regenerating vessel
  . renewing of complete thermal insulation
- cold trap incl. heat exchanger
  . renewing of air cooling system and thermal insulation
- pluggingmeter
  . renewing completely
- piping systems and valves (sodium and gas systems)
  . renewing 30 % of piping systems, trace heating systems and valves
  . renewing 50 % of thermal insulation
  . renewing 100 % of steel sheets of thermal insulation
- instrumentation (sensors)
  . has to be renewed completely

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

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Blatt 3 TVS/Sekr. — Verbleib (gelb)

9412/11-83/20

INTERATOM

☐ Fernschreiben
☐ Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. ______ Datum ______

FS-Nr.

Eingangsstempel

Bearbeiter ______

OE ______ Hausruf ______ Kurzz. ______

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

- measuring and power cabling
  . has to be renewed completely
- electrical distribution panels
  . have to be renewed completely
- electrical motor drives and valve drive mechanism
  . have to be renewed completely

1.2 Steam generator room

. renewing of cabling of control and measurement equipment

1.3 Tower

. renewing of power- and measurement-cabling up to the top.

1.4 Field cabling

. renewing of power- and measurement-cabling from CRS-distribution up to the cable channel (north-side C&S-building)

1.5 Control room

. renewing in complete incl. cabling

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9412/11-83/20

INTERATOM

☐ **Fernschreiben**

☐ **Telegramm**

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. ____________ Datum ____________

FS-Nr.

Eingangsstempel

Bearbeiter ____________

OE ____________ Hausruf ____________ Kurzz. ____________

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

1.6 Emergency diesel room

- renewing of power- and control-cabling (between power distribution and diesel board)

1.7 Battery room

- none

1.8 High voltage distribution room

- none

1.9 Marshalling kiosk (low voltage distribution)

- renewing of all income and outcome control- and measurement cabling

1.10 Electrical power distribution room

- cleaning
- renewing of cabling to CRS systems and control room

1.11 Power conversion system

- cleaning completely
- renewing of all electrical drive motors and mechanism
- inspection of alternator
- renewing of 40 % of the measurement equipment (sensors)
- general inspection of system

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

Verfasser Datum Unterschrift

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9412/11-83/20

INTERATOM

☐ Fernschreiben
☐ Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. ____ Datum ____

Bearbeiter ____

OE ____ Hausruf ____ Kurzz. ____

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

FS-Nr.

Eingangsstempel

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

1.12 General

- after the renewing procedure the complete CRS-systems have to be checked in line with the existing functional test programs

- a new commissioning procedure has to be elaborated and executed.

2 Renewing resp. disassembling procedure

The necessary disassembling of equipment depends on the decision

1. whether the sodium heat transfer system will be refurbished resp. renewed and whether it shall operate in the future again

2. and whether the sodium heat transfer system will be taken out of the building.

Because the necessary working steps are completely different, this decision should be made before starting with the disassembling procedure.

2.1 Disassembling and renewing procedure of CRS-systems as per item 2.1

- installation of a washing place for sodium components (steam-generator, basin 4 x 4 m, possibility for drainage of waste water, neutralization tank equipment, etc.)

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INTERATOM

Fernschreiben

Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

FS-Nr.

Eingangsstempel

TVS-Nr. ____________ Datum ____________

Bearbeiter ____________

OE ____________ Hausruf ____________ Kurzz. ____________

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

- SHTS-hall

  1. disassembling of all thermal insulation up to the regions in which it is obviously not damaged

  2. cutting out of all obviously defect piping systems (incl. valves) and closing of the open pipes with PVC-caps

  3. disassembling of thermal insulation of cold storage and regenerating vessel

  4. disassembling of all cabling and cabling supports (incl. cabling in other rooms which has to be renewed)

  5. disassembling of all electrical distribution panels

  6. inspection of piping systems in detail, cutting out of additional damaged piping work

  7. disassembling of cold-tank sodium pump

  8. cleaning of complete SHTS-Hall

  9. renewing of complete building and steel structures

  10. renewing of mechanical equipment

  11. renewing of thermal insulation and steel sheets of thermal insulation

  12. renewing of cabling, instrumentation, electrical equipment, etc.

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

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9412/11-83/20

INTERATOM

Fernschreiben

Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. Datum

Bearbeiter

OE Hausruf Kurzz.

FS-Nr.

Eingangsstempel

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

- PCS-System

  1. cleaning procedure (of fire fighting powder)

  2. renewing as per item 1.11

- Control room

  1. disassembling completely

  2. room cleaning and renewing procedure

  3. renewing of all control board panels incl. cabling, etc.)

- other systems

  . renewing in parallel as explained in item 1.

  The working steps 1 - 8 SHTS-hall, item 1 in PCS-system and item 1 - 2 in the control room area should be done in parallel.

2.2 Disassembling of CRS-system as per item 2.2

- installation of a working place for sodium components (as per item 2.1)

- SHTS- hall

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Verfasser Datum Unterschrift

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9412/11-83/20

INTERATOM

☐ **Fernschreiben**

☐ **Telegramm**

An Fernschreibzentrale (Rohrpost BG 47)

TVS-Nr. ______ Datum ______

Bearbeiter ______

OE ______ Hausruf ______ Kurzz. ______

FS-Nr.

Eingangsstempel

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

1. cutting of all pipes from sodium tanks and equipment (cold and hot storage, regenerating vessel, steam-generator, cold trap, sodium pumps, receiver) and closing of the openings by welding

2. hot storage in stand-by position

3. cold storage; disassembling of thermal insulation; than stand-by position

4. regenerating vessel; dismantling of thermal insulation at the upper part; than stand-by position

5. clarification of sodium disposal in parallel

6. disassembling of all thermal insulation at the rest parts

7. disassembling of all not-sodium piping systems

8. disassembling of all sodium piping systems

9. opening of one wall of the building

10. sodium disposal (after clarification of sodium disposal)

11. disassembling of all equipment in the building

- Other systems

  (still open until today)

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

Verfasser Datum Unterschrift

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9412/11-83/20

INTERATOM

☐ Fernschreiben
☐ Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. ____________ Datum ____________

FS-Nr.

Eingangsstempel

Bearbeiter ____________

OE ____________ Hausruf ____________ Kurzz. ____________

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

3 Referring to your telex dated August 26, 1986, we herewith like to recommend and offer to you today the following:

1. one advisor from Interatom during the disassembling procedure of the sodium systems at the site.

   From our today's point of view the execution of the working steps item 1 - 7 SHTS-hall, item 2.1 or 1 - 8 SHTS-hall, item 2.2, takes approx. 6 weeks, expected working time Interatom approx. 1.5 man-months.

2. Elaboration of a cost estimation for renewing of the CRS-systems; expected working time Interatom approx. 0.75 man-months

3. Advising and assistance in clarification and elaboration of a sodium disposal procedure plan; expected working time Interatom approx. 1.0 man-month

General:

The hourly rates today in our company are

- for one high qualified engineer 137,-- DM/hour
- for one high qualified technician 114,-- DM/hour

excluding travel expenses which will be paid separately.

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

Verfasser Datum Unterschrift

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9412/11-83/20

INTERATOM

Fernschreiben

Telegramm

An
Fernschreibzentrale
(Rohrpost BG 47)

TVS-Nr. ____________ Datum ____________

FS-Nr.

Eingangsstempel

Bearbeiter ____________

OE ____________ Hausruf ____________ Kurzz. ____________

EMPFÄNGER (Name / Anschrift)

Telex-Nr.:

z. H. von Herrn / Frau

Betreff / Bezugszeichen / Text / Unterschriftenzeile: Firmenkurzbezeichnung, OE, Namen der Unterzeichner

We hope that our roughly technical execution will be helpful to you to come to a decision of the future of the CRS-plant in due time and we would appreciate if you are able to accept our offer.

All further details should be clarified after the decisions of the first milestones and if there are any further questions, please do not hesitate to contact us.

Best regards,
Interatom
PA22, Brakelmann
PA212, Floss

(Nur der in diesem stark umrandeten Feld enthaltene Text wird an den Empfänger weitergeleitet mit Ausnahme des internen Verteilers.)

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APPENDIX 3

THE FORMATION OF FROZEN SODIUM SEALS

The objective in the formation of a frozen sodium seal is to produce a plug of solid sodium which completely fills the pipe, thus preventing any leakage of sodium past it, and is of sufficient length that the friction forces between the plug and the pipe wall are large enough to prevent the plug being blown out by the sodium pressure.

Liquid sodium contracts on freezing. Hence, if no precautions are taken, the frozen sodium plug may not completely fill the pipe, and thus may not produce a seal. A convenient way to ensure a complete plug in a vertical pipe is to progressively cool the pipe from the bottom thus allowing liquid sodium to flow down to fill the voids caused by the sodium freezing lower down the pipe. Similarly, when melting a frozen sodium seal, it is good practice to start heating at the top, so as to prevent the sodium expansion bursting the pipe. In a horizontal or nearly horizontal pipe it is necessary to ensure in some way that liquid sodium is available to fill the shrinkage voids.

It is of vital importance to ensure that the pipe in question is full of liquid sodium before starting to form a freeze seal. This can sometimes be achieved in a flowing loop by decreasing the flow to zero in such a way that the pipe must remain full, but more frequently it is necessary to use other methods. Experience has shown that it is unwise to rely on differential pressure measurements as proof of the existence of a column of sodium in a pipe; false indications can arise because of:

- inaccurate pressure gauges
- blockage in pressure gauge lines
- blockage in the main pipework
- trapped gas pockets

and numerous other causes. Amongst the more reliable methods of determining the existence of a liquid sodium column are:

(1) Temperature indications when filling

If the pipe in question is equipped with wall thermocouples and liquid sodium at a higher temperature than the pipe is introduced from the bottom by increasing the storage tank pressure, the progress of the sodium free surface up the pipe can be monitored by noting the temperature changes in the thermocouples.

(2) Electromagnetic method

If a pair of coils is wound round the pipe, the mutual inductance between the coils is altered when sodium enters the pipe. A number of commercial instruments are available which work on this principle and if suitably adapted to the particular circumstances, could be used to follow the progress of the sodium free surface as it moves up the pipe. It must be noted that the instrument cannot show that the pipe is completely full of sodium; it can only indicate absence or presence of a sodium column.

(3) Ultrasonic method

Ultrasonic equipment similar to that used for non-destructive crack detection in structures can be used to determine the presence or absence of a sodium column. Again, it must be noted that this type of instrument cannot show that the pipe is completely full of sodium.

From the foregoing it will be seen that ensuring a leaktight sodium freeze seal can be complicated and difficult. It must also be appreciated that a small leak in a freeze seal can cause progressive failure; the hot sodium leaking through carries in heat which, if the cooling is inadequate, will lead to melting of some of the frozen sodium and increased leakage, leading eventually to catastrophic failure.

Therefore, it is highly desirable to test the integrity of the freeze seal after it has been made. Whether this can be done or not clearly depends on individual circumstances.

The sequence of operations in making a freeze seal must be:

- stop sodium flow in the pipe in such a way that the pipe is guaranteed to remain full

- fill the pipe with liquid sodium, monitoring the progress of the sodium free surface as it rises up the pipe

- freeze the sodium progressively from the bottom upwards

- test the integrity of the seal

If the integrity of the seal cannot be tested, then the consequences of seal failure must be examined and appropriate precautions taken.

SSPS TECHNICAL REPORTS

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3/81	CRS INSTRUMENTATION REVIEW (BY BELGONUCLEAIRE)	JUNE 1981
4/81	INTERNATIONAL ENERGY AGENCY SMALL SOLAR POWER SYSTEMS (SSPS) PROJECT REVIEW (JANUARY 1981) (BY A.F. BAKER, SANDIA)	JULY 1981
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