IFA Technical Conference

New Orleans, Louisiana, USA
1-4 October 2000

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Ammonia Plants : Past Accidents and Lessons Learnt

During fifteen years of operation of the two ammonia plants with consistent good production, energy efficiency and on stream figures, few accidents have taken place in the ammonia plants. Three of the accidents which lead to big fire and consequent loss of production, property and downtime of three to four weeks have been described here with special emphasis on reasons for the accident and action taken to prevent recurrence of the accident in future.

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En 15 années de fonctionnement des deux unités d'ammoniac avec une bonne production régulière, une bonne rentabilité énergétique et un taux de fonctionnement satisfaisant, peu d'accidents se sont produits dans les unités d'ammoniac. Trois des accidents qui ont provoqué un grand incendie et une perte consécutive de production, de possessions et un temps d'arrêt de 3 à 4 semaines ont été décrits ici en mettant l'accent sur les raisons de l'accident et les mesures prises pour en éviter le renouvellement dans l'avenir.

Introduction :

Krishak Bharati Cooperative Ltd (KRIBHCO) fait fonctionner un complexe d'engrais azotés à Hazira, Etat de Gujarat, Inde. Il comporte deux unités d'ammoniac et quatre flux d'urée (prillée). Chacune des unités d'ammoniac à base de gaz naturel à une capacité de 1 350 t/j et la technologie est fournie par M.W. Kellogg Co, USA. Deux unités d'urée de 2 200 t/j de capacité chacune, sont basées sur le procédé Snamprogetti. Les unités ont été réceptionnées en nov/déc 1985 et fonctionnent régulièrement à des capacités dépassant largement les 100%. La performance de production des unités d'ammoniac en terme d'utilisation de capacité de jours de fonctionnement figure ci-après :

Exercice	Utilisation de la capacité	Jours de fonctionnement
87-88	104.46	346.80
88-89	111.91	342.38
89-90	112.37	331.52
90-91	118.00	346.53
91-92	115.39	326.42
92-93	113.18	347.39
93-94	102.58	332.35
94-95	100.81	333.24
95-96	117.80	352.26
96-97	110.63	326.85
97-98	121.27	346.18
98-99	105.34	316.17
99-2000	106.25	310.47

Sur la base de l'excellente performance de production, nombre de jours de fonctionnement, consommation d'énergie et fiabilité, KRIBHCO a élaboré différents programmes de modernisation dans les unités d'ammoniac comme la remise en état du convertisseur de synthèse et la réhabilitation du reformer afin de réduire la consommation d'énergie et le débridage des unités.

Au cours des 15 années de fonctionnement il y a eu peu d'accidents / incidents dans les unités d'ammoniac, comme un incendie dans le préchauffeur d'alimentation, le feu dans la boucle de synthèse d'ammoniac, le feu dans la station d'évacuation de la vapeur, le feu dans la console d'alimentation d'huile de lubrification et le feu dans la ligne d'entrée du compresseur de synthèse. Presque tous les incidents ont provoqués de grands incendies et l'arrêt de l'unité entraînent une perte de production. Dans les 3 premiers accidents les arrêts ont duré 3 ou 4 semaines, mais il n'y a pas eu de dommage corporel grave. Les 3 premiers accidents ont été décrits en détails dans les pages suivantes.

Avant de décrire les accidents en détail, une brève description de procédé est donnée ci-après car les accidents ont eu lieu dans différentes section de l'unité.

INTRODUCTION :

Krishak Bharati Cooperative Limited, (KRIBHCO) operates a nitrogenous fertilizer complex at Hazira, in the state of Gujarat, India. It consists of two ammonia plants and four streams of urea (prilled). Each of the natural gas-based ammonia plant has a capacity of 1350 MTPD and technology is supplied by M.W. Kellogg Co., USA. Two urea plants of 2200 MTPD capacity each are based on Snamprogetti process. The plants were commissioned in Nov/Dec'1985 and are operating consistently at capacities well above 100%. The production performance of the ammonia plants in terms of capacity utilization and on stream days is given below :

Financial Year	Capacity Utilization %	On-stream days
87-88	104.46	346.80
88-89	111.91	342.38
89-90	112.37	331.52
90-91	118.00	346.53
91-92	115.39	326.42
92-93	113.18	347.39
93-94	102.58	332.35
94-95	100.81	333.24
95-96	117.80	352.26
96-97	110.63	326.85
97-98	121.27	346.18
98-99	105.34	316.17
99-2000	106.25	310.47

Based on the excellent production performance, on-stream days, energy consumption and reliability, KRIBHCO had implemented various modernization schemes in ammonia plants like synthesis converter retrofit and reformer revamp with a view to reduce the energy consumption and de-bottlenecking of the plants.

During the last fifteen years of operation there were a few accidents/incidents in the ammonia plants like : fire in the feed pre-heater, explosion and fire in the ammonia synthesis loop, fire steam letdown station, air compressor lube oil console and at the inlet line of synthesis compressor. Almost all the accidents resulted into a big fire and plant shut down causing loss of production. In the first three accidents downtime was 3 to 4 weeks but there was no major injury to the human beings. The first three accidents have been described in detail in the following pages.

Before the accidents are described in detail, brief process description is given below as accidents have taken place in different sections of the plant.

PROCESS DESCRIPTION OF THE AMMONIA PLANTS :

Both the ammonia plants receive high pressure natural gas (HPNG) and the low pressure natural gas (LPNG) from the adjacent gas processing complex (Figure 1).

The HPNG received by ammonia unit is sent to fired feed pre-heater (103-B) after removal of liquid condensate, if any, in natural gas separator 120-F. Part of HPNG is also sent to fuel system after removal of liquid condensate as above and mixed with LPNG which is exclusively used as fuel only. In the natural draft feed pre-heater (103-B), the gas is heated from room temperature to 350 degrees C in radiant and convection sections and is sent to CO-MOx bed before going to twin beds of ZnO. After sulfur removal, the gas is mixed with steam at 371 degrees C and 38.5 kg/cm2g pressure and heated to 470 degrees C. in the convection coil of primary reformer. After primary reforming mixture is sent to secondary reformer through a water jacketed transfer line where preheated air at about 415 degrees C along with small amount of steam is injected for further reforming.

The gas from outlet of secondary reformer at about 995 degrees C is cooled to 350 degrees C in two waste heat exchangers where high pressure steam is generated. process gas is sent to high temperature shift converter, low temperature guard vessel and to low temperature shift converter for further production of hydrogen and carbon dioxide.

Carbon dioxide is removed in low heat Benfield process and it is sent to adjacent urea plants. The process gas is sent to synthesis gas compressor after methanation reaction in methanator and removal of moisture in compressor suction drum. Synthesis gas is compressed in three stages to about 185 kg/cm2g and mixed with ammonia converter effluent gas which is further cooled to –23 degrees C in various exchangers and chillers and liquid ammonia is separated in ammonia separator, 106-F. The synthesis gas after separation of liquid ammonia is compressed in recycle stage of synthesis compressor and sent to converter inlet for synthesis reaction. There is a provision to send compressed synthesis gas from third stage discharge of the compressor, after cooling, to the adjacent processing complex and receive the same. There are motorized valves on the outgoing and incoming lines. Earlier the ammonia synthesis converter was of three bed axial design with a inter-changer at the inlet. After retrofit it has been changed to radial axial concept with additional inter bed heat exchanger.

A) <u>EXPLOSION AND FIRE INSIDE THE NATURAL GAS FEED PRE-HEATER (103-B)</u> :

Before this incident/accident can be described in detail, complete description of the process for this section is given below (see Figures 1 and 2).
Both the ammonia plants receive HPNG through a 8” header with a single gate type isolation valve at the battery limit of each of the plant. Flow, pressure and temperature of HPNG to each of the plant is measured and recorded by FR-19, PR-29 and TR-9 respectively and then the HPNG is sent to HPNG knock out drum, 120-F (for removal of any liquid condensate) and pressure at inlet to 120-F is controlled by control valves PRC-15A/B. These control valves have isolation valves and common non-indicative type bypass valves. Part of the HPNG from outlet of 120-F is sent to fuel header after letdown through pressure control valve PIC-3 and rest of the gas is sent to feed pre-heater (103-B) with flow measurement (FI-42) and through a gate type isolation valve.

There are four separate coils inside the furnace with flow measurement for each coil by annubar and associated low flow alarms. At outlet of each coil (inside the radiant section) tube skin temperature indication with high temperature alarm is provided. Outlet of all the coils join outside the furnace and after temperature measurement the gases are sent to Comox bed and then to twin zinc oxide beds for removal of sulfur. The single temperature measurement (TRC-13) at outlet of 103-B is used for total fuel flow control to the 103-B.

After removal of sulfur, gas is sent as feed to primary reformer with a isolation valve, control valve FRC-1 and motorized valve. From outlet of ZnO bed, gas can also be sent for heating of LTS catalyst during startup and for heating during its reduction. However this is used during start up, etc. only. There is also provision to vent the gas from outlet of ZnO bed through vent valve MIC-21 in the event of any problem/emergency.

This fired heater has four spider type burners with a strainer and plug valve for each burner and on common fuel gas line there is pneumatic valve (V-8) with solenoid which closes either on low pressure or high pressure of fuel gas to the burners. There is control valve TRC-13 with isolation and bypass valves for control of temperature at combined outlet of heater (Figure 1).

<u>Safety systems/trips provided for the safety of feed pre-heater (103-B)</u> :

For the safety of feed pre-heater following alarms and trips are provided.

1. Low flow alarm for low flow of HPNG through each coil and high tube skin temperature alarm (468 degrees C) for each coil.
2. Low and high fuel gas pressure alarm.
3. When the overall feed gas as measured by FI-42 through heater goes below 16000 NM3/hr, then total fuel flow is cut off by closing TRC-13 and gas is vented through MIC-21 at outlet of ZnO beds by fly opening of MIC-21. However, if car-seal/bypass valve of TRC-13 is open then small amount of fuel can still continue.
4. If the fuel pressure is either very low or very high, then total fuel is cut off by closing V-8 valve.

Normal/routine procedures/controls for operation of feed pre-heater :

Although low and high fuel header pressure trips were always in line, the other trip of automatic cutting off the fuel on low flow of HPNG through coils and automatic venting of gas through MIC-21 was kept bypassed since commissioning by making the solenoids of these valves inoperable. However TRC-13 was always on automatic control during normal operation or even at high loads with all four burners in line and both valves TRC-13 and MIC-21 were manually operable from the control room for any emergencies/jobs.

The normal practice followed (during upsets of HPNG flow to heater) since commissioning for control of feed gas temperature at outlet of heater was to cut off the burners one by one (out of four provided) completely or partially at low or decreasing loads (generally during stoppage/interruptions of natural gas supply from seller) so that TRC-13 is in controlling range in the control room. At the same time fuel pressure to burner was also monitored near the heater. Reverse procedure was followed during increasing the loads. Even when first burner light up, during start up, control is in the field with car-seal valve and only when appreciable/controllable fuel flow is required, control is passed on to control room mounted controller TRC-13. Apart from this, in case of low flow through the coil, small venting of gas through MIC-21 was taken.

Reasons for bypassing the trips :

Due to common HPNG header for both the ammonia plants, fly opening of MIC-21 in the affected plant used to vent large quantities of HPNG to vent header and the subsequent fall in pressure used to affect the other ammonia unit which is in normal operation and even in the affected plant where MIC-21 has opened it used to disturb flow of feed to reformer causing upsets in the reformer temperature. With closing of TRC-13 on actuation of trip, exit temperature of HPNG at outlet of heater used to fall sharply which increases chances of sulfur slip from the ZnO bed. Please refer Figure 2 for gas flow to the complex.

The fire incident :

1. On 9th of May 1998 at 17:32 hrs the process air compressor (101-J) tripped in Ammonia-II and while operators were rushing to start the compressor they noticed small fire at the bottom of 103-B and smoke from its chimney. There is no relevance in the tripping of compressor and fire at the bottom of 103-B and it is just a coincidence.
2. Decision to stop the plant was taken considering the small fire; feed to primary reformer was cut off and other shutdown actions were taken.
3. Within few minutes, the small fire erupted into a large fire with loud sound. At this stage, large flames were erupting out from the bottom of the furnace, from the inspection door and even from top of stack. All the unburned gases were burning outside the furnace. During first few minutes surrounding area up to 30-40 meters was not accessible and immediate water spray was started to prevent fire from spreading to adjacent area like HPNG/LPNG station.
4. Immediately from the control room PRC-15 A/B valves were closed and isolated in the field and the flames slightly reduced but continued. Bypass valve of PRC-15A/B was found to be open to some extent, hence closed. This reduced the extent of fire but flame were still coming out. Simultaneously HPNG , LPNG valves at battery limit and at inlet to 103-B were closed completely. The fire was completely brought under control within 55 minutes.

5. Although there was not much damage outside the furnace, but due to long duration of fire inside the heater had to pass various valves and the lengthy time required to close valves at inlet to heater and at battery limit, there was extensive damage inside the furnace.

Damage to the heater and the surrounding areas :

1. Spacers were installed in the gas lines and system purged out and furnace was accessible next morning. It was found that almost all the vertical radiant tubes were bent and entangled (Photo 1), convection section tubes and fins had melted out and burnt, even the HK-40 tube support plate for convection coil was partially burnt out. (Photo 2)
2. One tube in the radiant section was found to be burst open with length of rupture about 2 feet. (Photo 3)
3. The refractory in the area close to burst tube was found fallen and had loosened, resulting in exposure of shell of the furnace to heat and consequent bulging of the same.
4. The molten slag due to melting of convection section tubes and fins had fallen on burner and broken spider of one burner.
5. Outside the furnace, one foundation of heater was found damaged, insulation sheeting of adjacent comox bed and its piping was burnt out. Instrumentation, control valves of fuel system, cable trays, cable etc. were found damaged.
6. Top portion of stack was found overheated but no damage was found.

Investigation and findings :

1. The possible reason for the backfire and black smoke at the top of chimney may be blocking of tips of burners or due to small leakage through the tube. However, the coil inlet flow(FI-42) and feed to reformer flow (FRC-1) recorders indicate that no large leak was existing initially and even before the incident.
2. After seeing the fire, decision to shutdown the plant was taken and feed to reformer was cut off, immediately flow came down to 2400 NM3/hr and stabilized to 1800 NM3/hr and this small flow may be due to passing of control valve FRC-1 or readings may be erroneous at low range. After cutting of feed to reformer, no venting of gas through MIC-21 was taken and there is no indication of fuel cut off to heater as per normal procedure.
3. There was no appreciable increase in heater outlet temperature as indicated by TRC-13, as the thermocouple is located at inlet to comox bed (about 15 feet from the heater outlet) and flow through coil was also less.
4. The big rupture of tube occurred after 13 minutes of cutting of feed to the reformer as indicated by sudden increase in flow to coil (78000 NM3/hr), large consumption of gas, fall in pressure in the affected plant and also fall in pressure in the other Ammonia unit.

Inferences :

1. Feed to the reformer was cut off after seeing small back fire and smoke from the chimney but no gas venting through MIC-21 was taken and fuel to heater was not cut off immediately as per the normal procedure followed. This must have led to overheating of the coil.

2. Bypass valve of main control valve PRC-15 was found slightly open and was found to be passing during hydrotest at rehabilitation. HPNG battery limit valve and valve at inlet to 103-B

took long time to close as they are only operated during long shutdown, hence fire continued for a longer time. Even after closing these valves, small fire continued for a long time due to passing of valves.

Probable causes of accident & conclusion :

The big fire and subsequent damage occurred due to bursting of one of the tubes in radiant section. This tube had thinned down at the burst open portion probably due to large radial expansion at that place caused by overheating of the tube. The overheating of tube can take place because of (a) dislocation of the radiant tube from top support and tilted portion coming closer to the burner flame (b) flames of the burner touching the radiant tube due to mal operation of the burner (c) another tube near the burst tube might have a small leak and flame directly touching the burst tube (d) overheating of the tube due to low flow of feed gas through the coil.

Rehabilitation and remedial measures taken to prevent its recurrence :

1. All the four radiant and convection coils, were replaced, damaged refractory in the radiant and convection zone was redone, repairs of instrument and electrical items was carried out and foundation and shell of heater was repaired.

2. To prevent the recurrence of the accident, following actions have been taken.

(a) The trip system connected with the heater has been modified and if flow of feed through the heater is below 20,000 NM3/hr, the MIC-21 opens automatically but opening is restricted to 40% (so as not to disturb other plant) and if flow further reduces below 16000 NM3/hr, then fuel to heater is cut off by closing of TRC-13 and small flow of fuel can continue due to small opening of car seal valve.

(b) Bypass valve across PRC-15A/B has been removed and motorized valve at battery limit of HPNG and LPNG have been installed for quick cut off of total gas to the plant.

(c) Burner overhauling in each turnaround, regular inspection of 103-B for checking flame, hot spots, refractory condition and radiant coil support etc. are being repaired.

(d) For smooth expansion of radiant tubes (so that they do not come out of the supports and tilt inward), holes have been drilled in bottom plate of 103-B and filled with insulation for unrestricted movement of guide rods of radiant tubes.

B) EXPLOSION AND FIRE IN THE AMMONIA SYNTHESIS SECTION :

The description of the process for this section of ammonia plant is as follows :

Synthesis gas at 27.4 kg/cm2g and 40 deg.C is compressed to about 185 kg/cm2g in three stages in turbine driven centrifugal compressor with exchanger for heat recovery and inter coolers. Third stage discharge is sent to another water cooler 156-C and then to ammonia chiller 140-C for cooling to 5.6 deg.C. There is a provision to send this chilled gas to adjacent processing complex and receive at the same place. At the inlet of 156-C, one pilot operated relief valve (RV-156-C) is provided to safeguard the compressor from over-pressurization and exhaust of this RV is connected to the cold vent header. The syn gas from third stage discharge is mixed with ammonia synthesis converter effluent gas which has been cooled in water cooler and further cooled in various cold exchangers and chillers. The mixed gas is further cooled in cold exchangers and final chiller and the liquid ammonia is separated in ammonia separator, 106-F. The gases from outlet of separator are compressed in recycle stage of synthesis compressor after recovering its cold effect and then sent to ammonia converter for synthesis of ammonia. Motor operated valves are located at third stage discharge, inlet to synthesis converter and inlet to recycle wheel for isolation of high pressure synthesis loop during stoppage of plant or any emergencies.

Cold vent header handles the gases which are released from the pilot operated relief valves located in this section, venting of gases from the inlet of synthesis gas compressor through control valve PIC-4 and manual venting of gases from ammonia converter outlet. This whole of high pressure section is located exactly in front of the control room. The diagram of the section is shown in Figure 3.

The fire incident :

On 26th September, 1991 at 0117 hours a loud explosion was heard and simultaneously big fire was noticed near the third stage discharge line above the exchanger 156-C. Just before the incident, control room operator had acknowledged an alarm on the annunciater panel due to “low steam flow to reformer” and were still busy investigating the cause of the alarm, when a loud explosion was heard.

The plant was shutdown immediately, but while synthesis gas was being vented from compressor suction through PIC-4 for depressurization, it was coming out from the failed portion of RV-156-C tail pipe and caused a secondary source of fire in the area. Synthesis gas to the adjacent processing plant was isolated from other ammonia plant and also from the processing complex. Inlet valves at battery limit to this plant were closed and fire was brought under control within one hour. Motorized actuators of the valves and cables were burnt out.

Damage to the plant :

Due to fire, power cables and lighting cables in the area were burnt out, large amount of debris had accumulated due to burning of insulation, cables, cable-trays, piping etc. and breakage of compressor house asbestos sheets, hence area could be approached only after clearance of debris. Moreover as few of the ammonia lines were damaged, ammonia was being drained from the system and hence full assessment was done next day.

Following were the immediate observations after the incident :

1. The pilot operated relief valve RV-156-C was uprooted from its inlet position (Photo 4), the tail pipe was knocked out of position and was found sheared and blown open (Photo 5 and 6). Due to explosion the relief valve was blown away to the nearby pipe rack. Pilot valve was found detached and lying on the ground.
2. Due to fire nearby exchangers were exposed to heat and became red hot and subjected to water spray also during fire fighting.
3. Cold insulation of vessels/exchangers in nearby area had burnt.
4. Power cables, lighting cables, instruments/tubes, trays and motorized actuators were found burnt.

5. Almost all the low pressure pipes including ammonia lines were damaged.
6. The cold vent header on pipe rack was badly damaged and moved by almost by one meter. Relief valve on suction drum of synthesis gas compressor was also found damaged. Please see Figure 4 for general arrangement of cold vent header.
7. Control room window panes/frames and false ceiling were found damaged. Concrete foundation of two exchangers had cracks and some of the supports were also bent.

History, design criteria and observations :

1. RV-156-C had popped earlier in 1986 and 1988. The discharge was dislodged hence supporting system was modified and drain was provided in the tail pipe to drain any condensate. The vent header has provision for purging with steam which is used in shutdown only, but due to passing of valve some steam used to pass through it.
2. The orifice of RV-156-C was adequate for 100% capacity but plant used to operate above 100%. All the four pilot operated RV's were not tested for a long time.
3. A few deviations were there in the laying of vent header with respect to P and I diagram and no self draining provisions were given. Traps were provided but not functioning properly.
4. The supporting of RV was not proper and location was not as close to exchanger 156-C as possible as per P and ID instructions.
5. It was found that vent header can suck air even if small drain is partially open/not tight shut off.

Operating conditions at the time of accident :

1. The plant was running at 115% load for 100 days prior to the accident.
2. Minutes before explosion, steam to carbon ratio to reformer had dropped to 3.3.
3. Pressure recorder on the 3rd stage discharge was not working, hence actual pressure developed by the compressor at the time of accident could not be ascertained. However, in the adjacent plant (one Km away) where syn gas is sent for processing, the pressure increase of 1.2 kg/cm2g was recorded.
4. No other changes were noticed.

Observations on mechanical failure :

1. RV-156-C inlet lead pipe (3" NB Sch.140) was sheared off from parent pipe (10" NB Sch. XX) (Photo 7)
2. The failure took place at the Haz of welding, whereas there was no apparent damage to the parent pipe.
3. Sheared edges of the branch pipe clearly indicates reverse slant fracture which is usually associated with internal explosion. Tail pipe of RV was sheared off and ripped open and vertical support on exhaust pipe near RV-156C was pulled out of foundation.

Probable causes of the accident :

1. Explosive mixture can form inside the vent header/tail pipe of RV due to passing of RV or popping of RV-156-C or passing of other RV's connected to the vent system. Air ingress can take place through drain valve etc.

2. During popping of RV-156-C, mechanical failure of piping can take place due to inadequate supporting arrangement. Flammable gas rushing out from failed inlet pipe can explode/catch fire due to friction.
3. Accumulation of condensate in vent header can lead to water hammer and consequent mechanical failure.

After analyzing the probable causes, it appears that the strongest possibility exists for popping of RV-156-C causing explosive mixture in the vent coupled with ingress of air from the drain valve being left partially open accidentally after manual draining of condensate or was not closed tightly.

Reasons for popping of RV-156-C :

1. The trip logic at the time of accident was such that due to low governor oil pressure / shutdown of back end, all the three MOVs used to close, however, the compressor was not provided with unloading facility to minimum governor speed. With closing of MOV, discharge pressure of compressor can rise and RV-156-C can blow. Similar incident of RV blowing had occurred earlier but in this case there was no indication of compressor unloading due to process upset.
2. It is possible that the speed of the turbine might have fluctuated during the accident, but no speed recording was available at that time. During start up of the compressor, after rehabilitation, the speed of the turbine fluctuated between 8200 to 9700 rpm due to malfunctioning of the governor system which was probably due to pilot piston not moving freely.

   It may, therefore, be inferred that during accident the speed of the turbine fluctuated at high load leading to over pressurization of the discharge system momentarily causing blowing / passing of RV-156-C. Since the RV-156-C was not tested for long time, it must have passed / popped at lower pressure than the setting.

   The pressure rise in the adjacent syn gas processing complex (1 km away) and less MP steam to reformer (syn gas turbine extraction is only source of MP steam) support the above findings of speed fluctuation and momentary pressure increase.

Remedial measures taken to prevent recurrence of accident :

1. Synthesis gas compressor was provided with following trip interlocks :

a) Instead of earlier logic of isolating the high pressure synthesis loop, at low governor oil pressure, which was found unsafe, trip of compressor was provided.

b) Synthesis gas compressor was provided with a trip at high third stage discharge pressure of 205 kg/cm2g with pre-alarm at 196 kg/cm2g to avoid blowing of RV-156-C.

c) Speed of the compressor, even at 120 % load is close to 10,300 rpm, new trip of compressor is set at a speed of 10,700 rpm and pre-alarm set at 10430 rpm.

2. Provision has been made for continuous purging of cold vent header with nitrogen to purge out any explosive gases which enter the header due to passing of RV's etc.
3. All manual drains of vent header have been provided with water seal pot, to avoid ingress of air during draining of condensate.

4. Location of RV-156-C has been changed and kept on pipe rack with self draining arrangement and with proper support. New RV with “K” orifice has been installed instead of “J” type orifice. Supports of similar RV’s have been strengthened.

C) FIRE AT AND ABOVE THE STEAM LET DOWN STATION :

The ammonia plant generates all the steam required for driving the three compressors, as feed to reformer, steam for other turbines and for other miscellaneous uses. The steam is generated in waste heat exchangers located at outlet of secondary reformer and high temperature shift converter and in the auxiliary boiler. There is provision to import high pressure steam from the nearby steam generation unit in case of start up/shutdown and emergencies in the ammonia plant. The steam generated in steam drum at 105 kg/cm2g is superheated to 484 deg.C in super heater coils and sent to extraction cum condensing type steam turbine of synthesis gas compressor. The medium pressure steam drawn as extraction from above turbine at 38.5 kg/cm2g and 371 deg.C is used for driving turbines of other compressors and as feed to reformer. The extraction steam flow is adjusted from the control room as per the requirement of MP steam and rest of the steam goes to condenser.

The synthesis compressor is provided with necessary trips to safeguard the machine against damage and its inlet steam valve closes immediately on actuation of trip. Hence, to divert all the HP steam to MP steam header on tripping of synthesis compressor a suitable steam led down station has been provided which automatically opens in shortest time.

From the main HP steam header going to the synthesis compressor, two tappings have been taken and each of this branch line has a pressure control valve and let down valve in parallel with isolation valves. The outlets are connected to MP steam header. The pressure control valve PIC-13-A/B can be operated from control room to maintain MP header pressure and steam letdown valve MIC-22 and 29 open through the instrument interlock only when steam turbine trips.

For quick and reliable opening of these let down valves MIC-22 & 29 hydraulic actuators were provided at the valves with a oil connection from seal oil header of synthesis gas compressor. Whenever synthesis gas compressor trips, governor oil is drained and this fall in Governor oil pressure is sensed by a switch to activate opening of steam let down station. Figure 5 gives details of steam letdown station.

The fire incident :

On 6 th Feb’1986 when synthesis gas compressor tripped the steam letdown station opened promptly but 12 mm tubing supplying hydraulic oil to MIC-22 snapped away leading to large scale leakage of oil on the floor. Since the steam let down station operates at high temperature the oil vaporized and instantly caught fire.

The location of steam let down station is such that exactly above it on the pipe rack all the cables/ instrument tubing/power cables coming from control room/ MCC room meet and are then diverted along the main pipe rack.

Damage to the plant :

1. Due to oil fire all the four valves, actuators the instrumentation, tubing were damaged.
2. Pipes above steam letdown stations were overheated and insulation burnt out. Some of the low pressure pipes sagged.
3. Cable, instrument wiring and cable trays above the letdown station were completely burnt out.

Reason for the fire :

The oil supply tubing to the hydraulic actuator of MIC-22 valve snapped away from the ferrule joint when steam let down valves opened and this snapping away of tubing from the ferrule may be due to minor vibrations caused due to sudden flow of steam through the valves. All the four valves have small bypass valve with restriction orifice/isolation valves for keeping the lines in warmed up condition. There are chances that during the time of accident the station was not in properly warmed up condition and hammering might have taken place.

Rehabilitation :

1. The biggest job was to restore the cables and the instrument tubing / wiring and check them for correctness. As it was not possible to change the complete cables immediately, it was decided to replace the burnt portion with connectors. Later on complete cables were replaced.
2. Two steam let down valves MIC-22 and 29 actuators were replaced from Hydraulic to Pneumatic type and all hydraulic oil lines leading to the station sealed off. The opening time for valves with hydraulic actuator was 1 second and after changing to pneumatic actuators opening time increased to 3 seconds but during our initial operation and based on our experience it was found that there were no disturbances in the MP steam system with steam let down station opening of time of 3 seconds.
3. In the adjacent Ammonia-I plant the potential for the fire still existed as actuator were still hydraulic as they could be changed during shutdown only. Hence as a temporary measure, the area above the steam let down station was provided with a shield with insulation so that in case of even small leak of oil the fire did not spread to top cable area.

CONCLUSION :

As has been described above, all the three fire incidents took place due to various reasons : eg. running the plant with bypassed trips, following poor safety procedure for the operation of equipment, overlooking of the potential hazard during the design stage, non-implementation of the plant piping as per the P&ID supplied by the process licenser, overlooking of maintenance and neglecting to check important valves, etc.

Although corrective actions to prevent the recurrence of the accident in future specific to each of the accident have already been implemented, there were still chances of new problems/accidents in new areas. Hence, HAZOP study for the entire ammonia plants and other units was carried out in-house and as well as with outside experts. Even twice health assessment study has been carried out in-house and many of the suggestions of HAZOP and

Health Assessment Study have been implemented/being implemented. Complete relief valve system has been studied by the outside expert. Based on our experience of cold vent header and the operation of hot vent header, it was found that hot vent header has chances of liquid accumulation at various points and subsequent water hammering during gas venting. The inlet connections to the hot vent header were reviewed and re-routed to avoid damage to it due to water hammering.

Even for cold vent header system, all the implementations carried out are followed even today after a gap of nine years and checks are carried out regularly.

All the in-built trips systems have been reviewed.

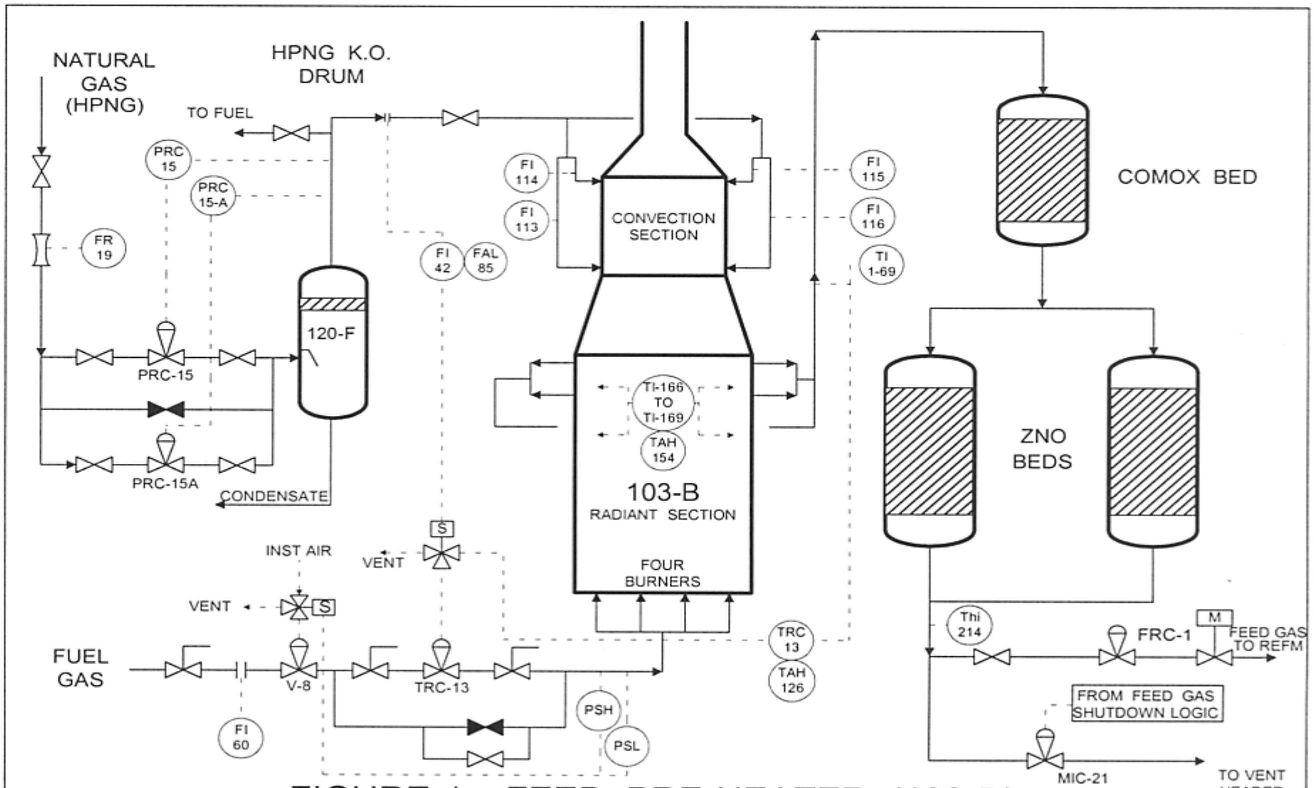


FIGURE-1 : FEED PRE-HEATER (103-B)

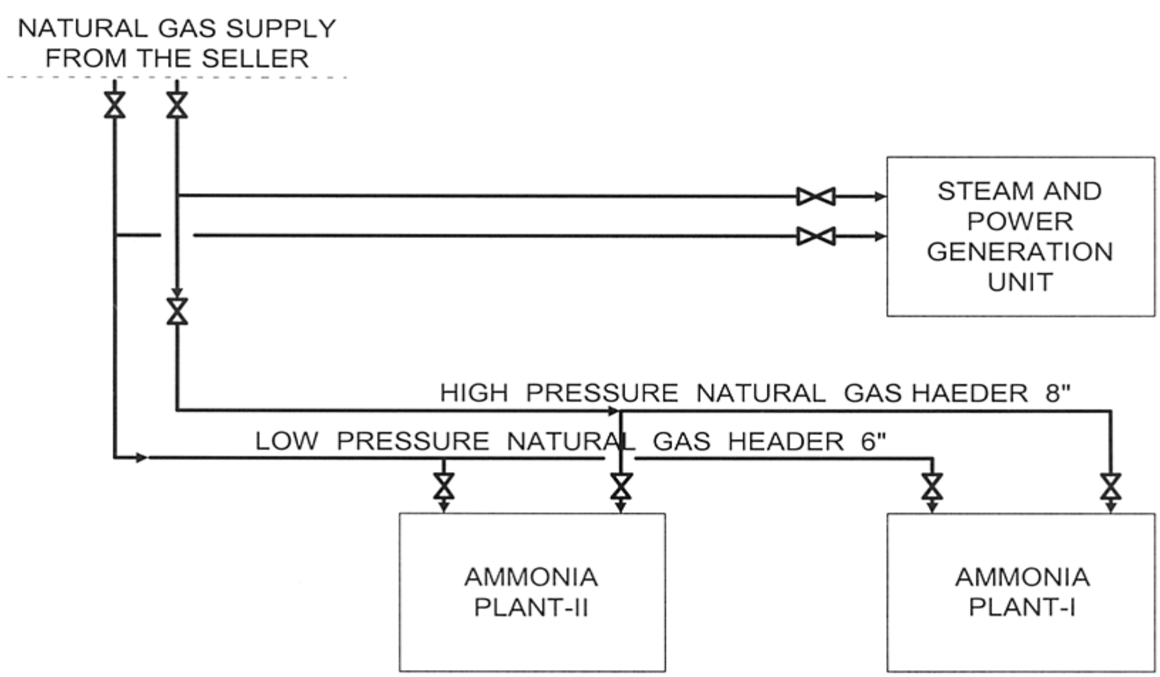


FIGURE-2 : HIGH PRESSURE AND LOW PREESSURE NATURAL GAS DISTRIBUTION TO KRIBHCO COMPLEX

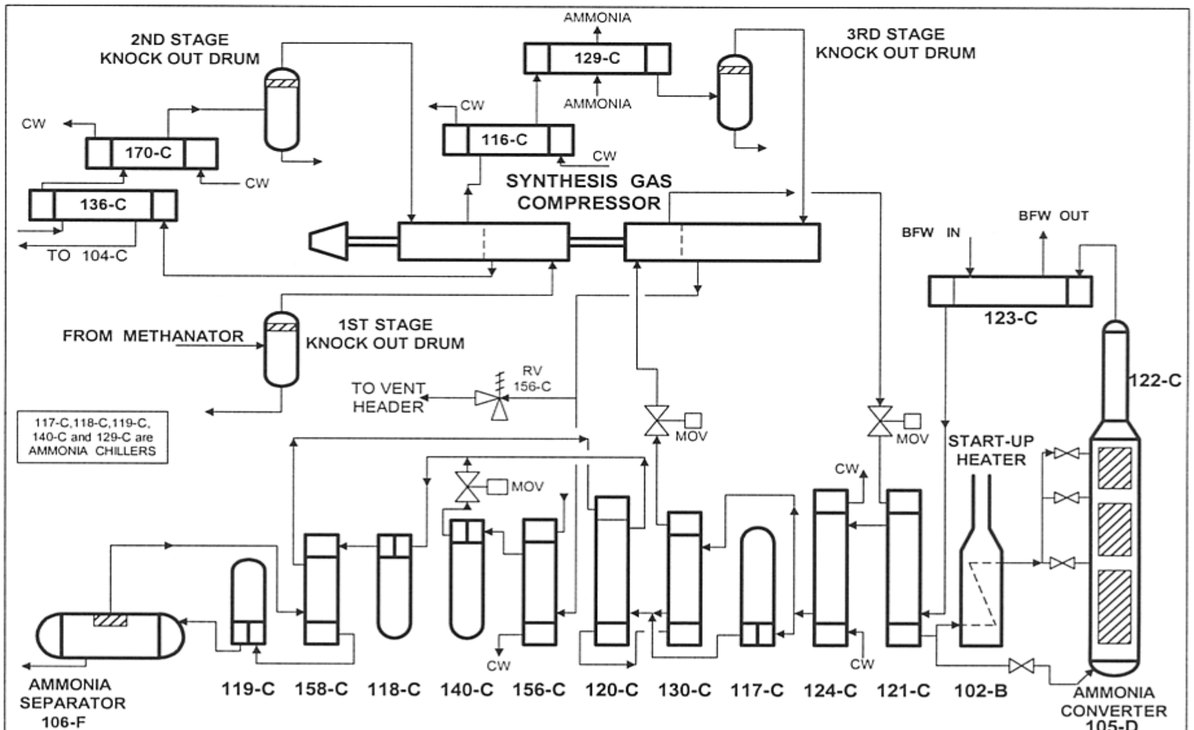


FIGURE NO. 3 :PROCESS FLOW DIAGRAM FOR AMMONIA SYNTHESIS LOOP

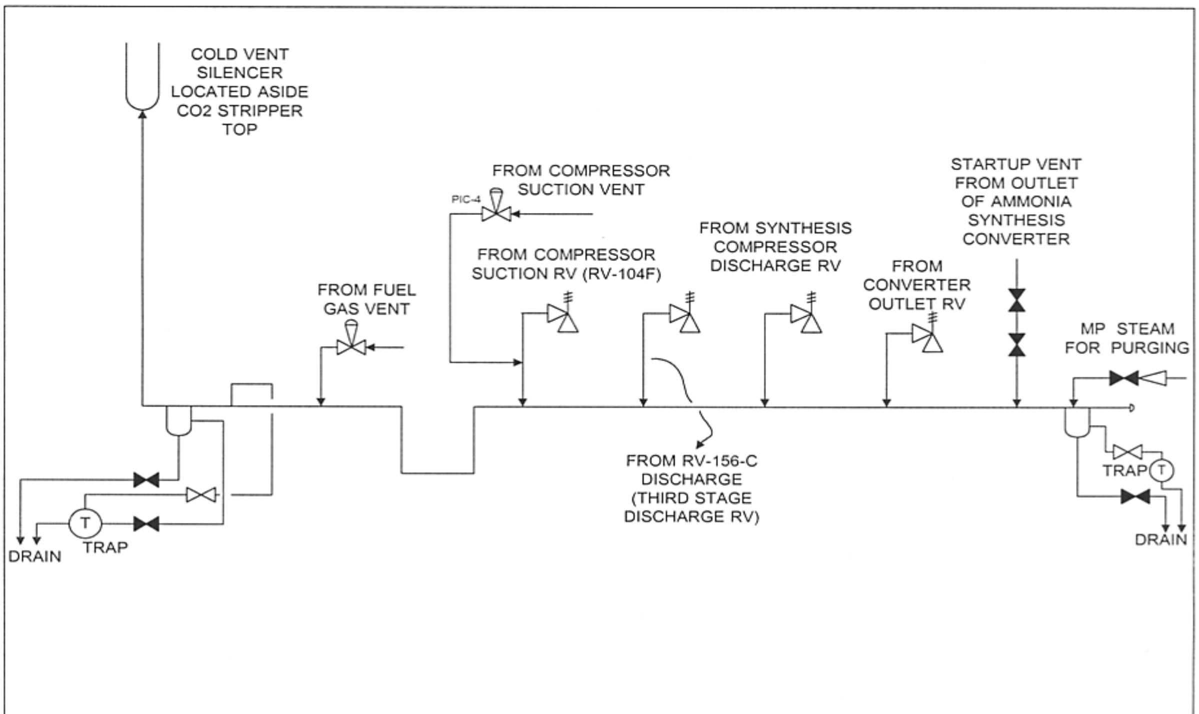


FIGURE NO. 4 :DRAWING OF COLD VENT HEADER

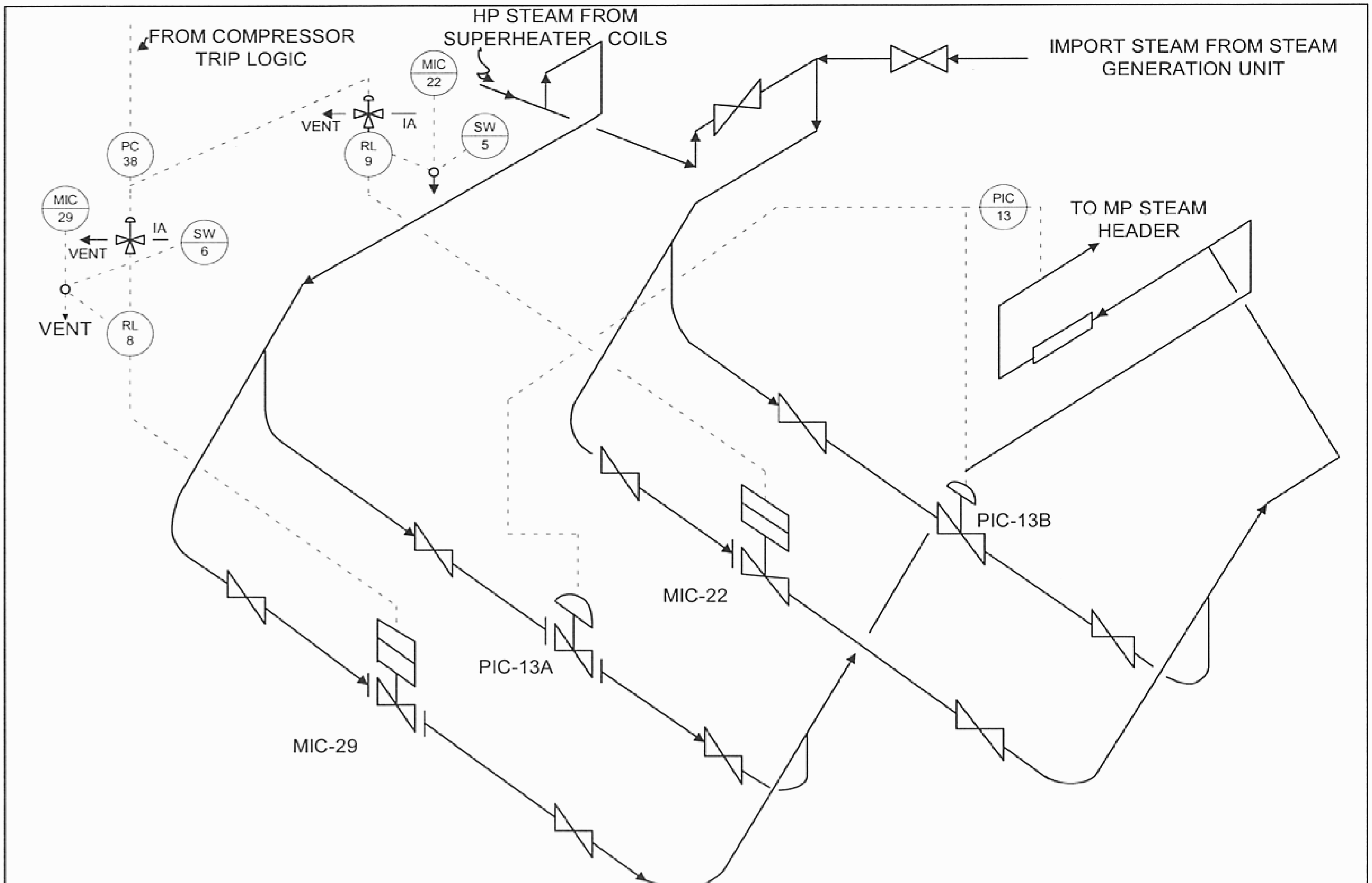
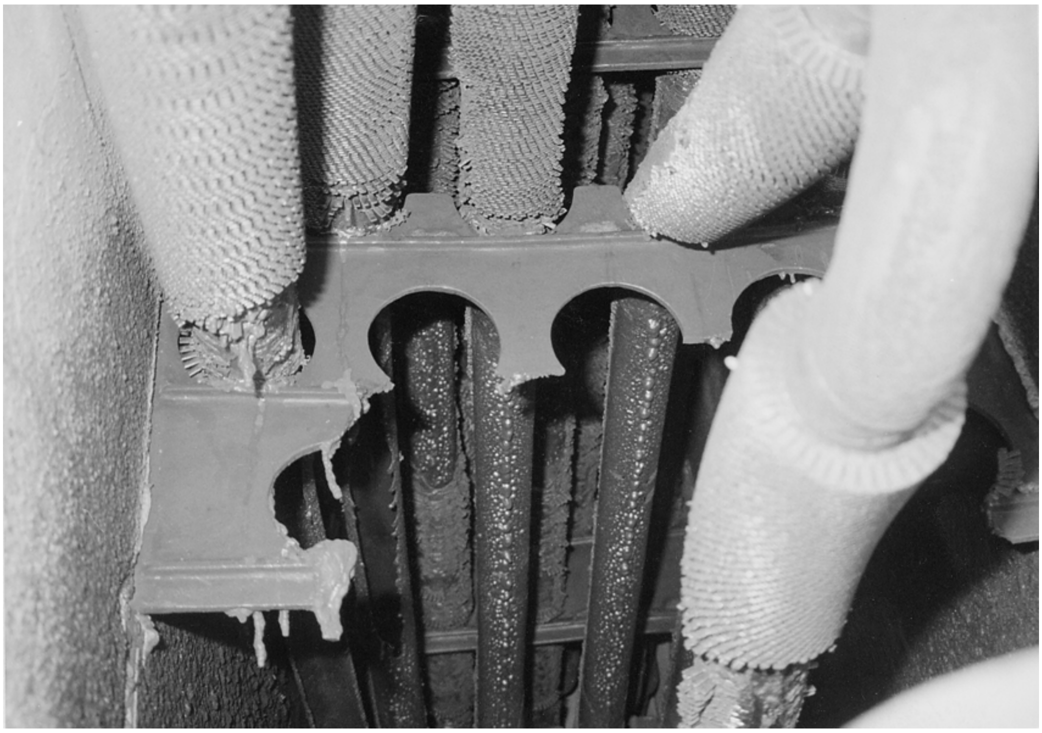


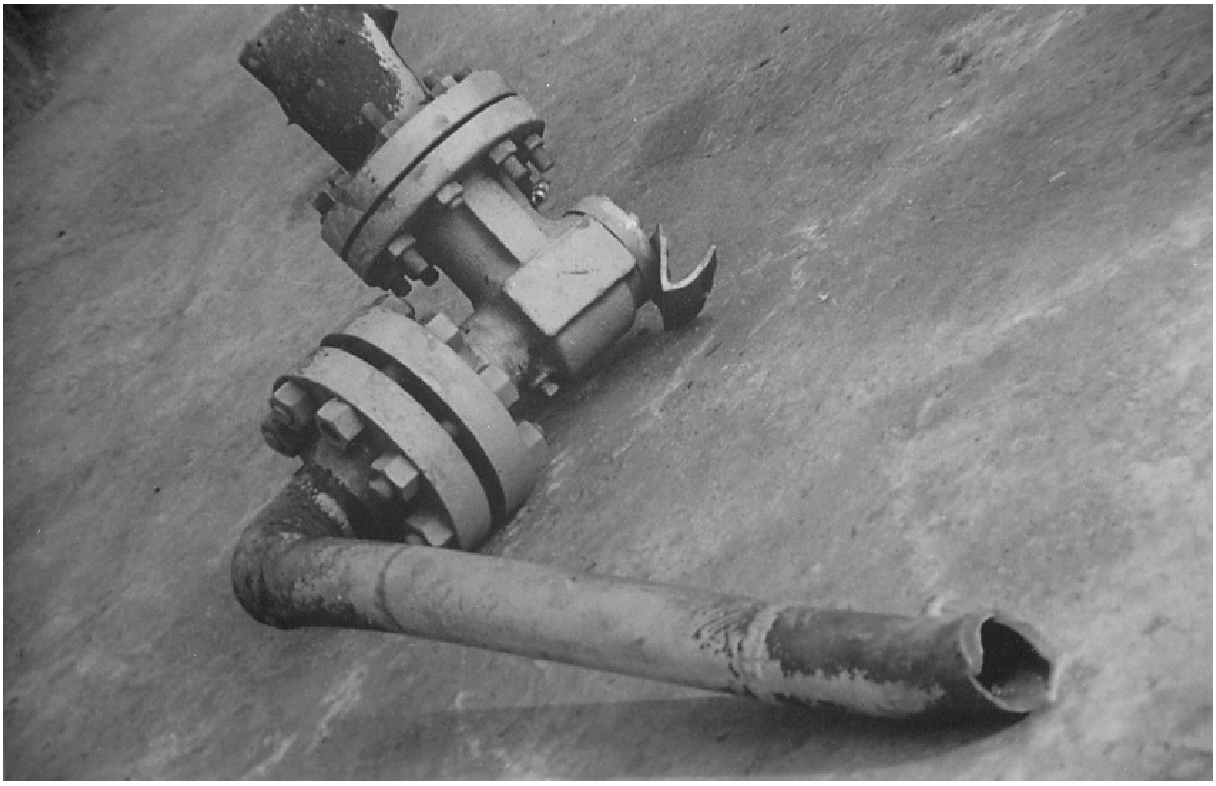
FIGURE NO. 5 : HIGH PRESSURE STEAM LET DOWN STATION

PHOTOGRAPH N°1 : TUBES IN RADIANT SECTION OF 103-B FOUND ENTANGLED DUE TO OVERHEATING

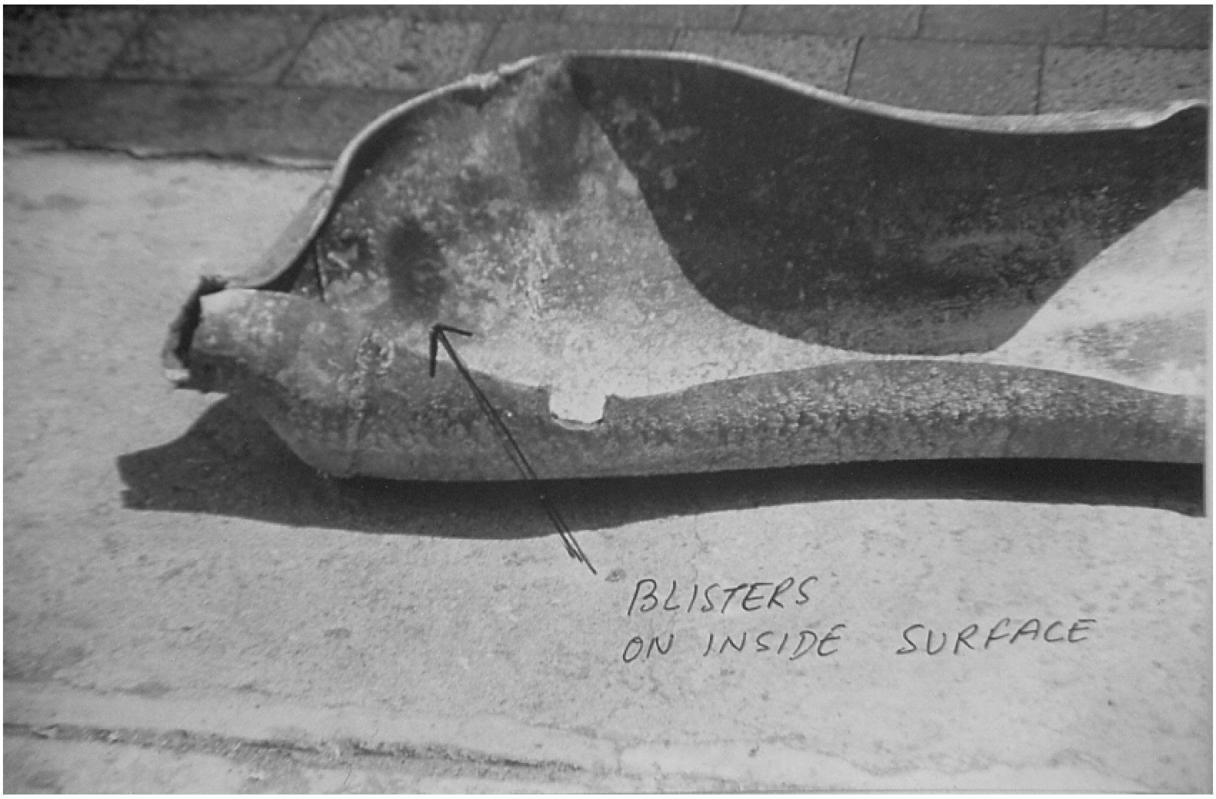


PHOTOGRAPH N°2 : TUBES IN CONVECTION SECTION OF 103-B FOUND MELTED, HK-40 TUBESHEET FOUND MELTED DUE TO OVERHEATING

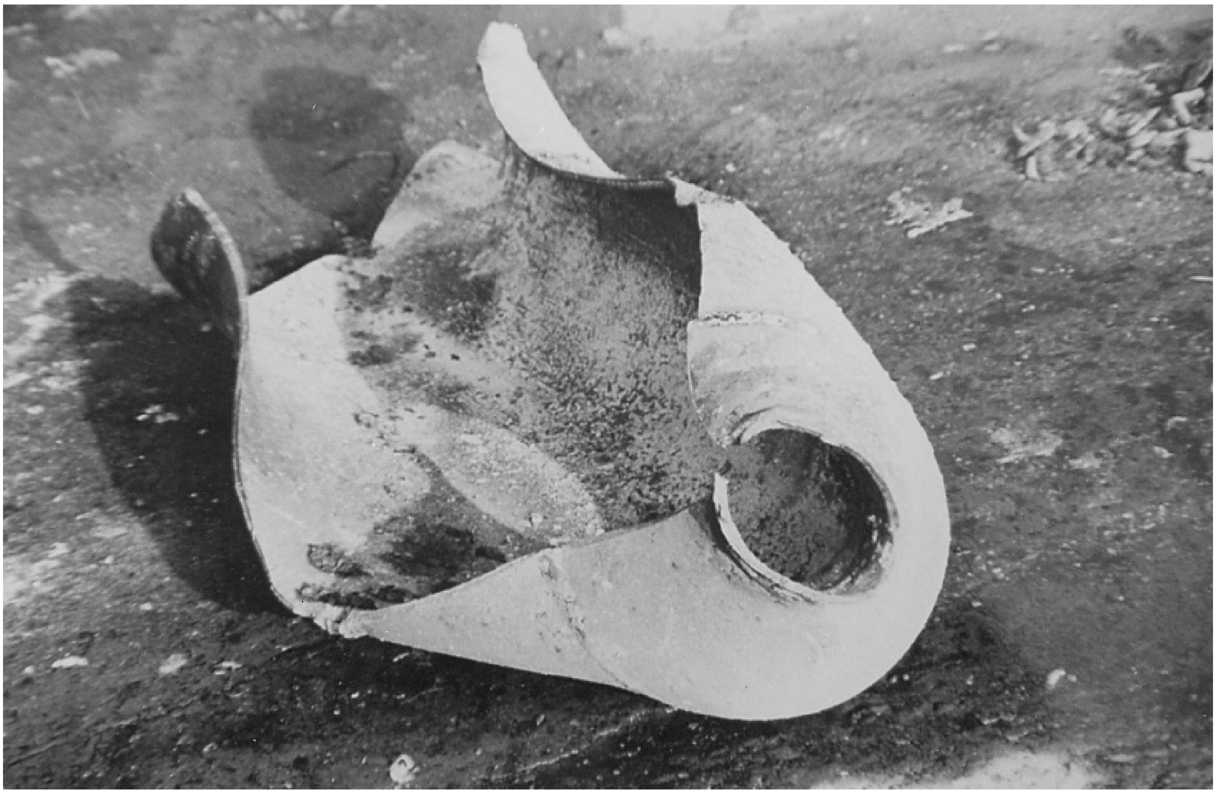
PHOTOGRAPH N° 3 : ONE TUBE IN RADIANT SECTION OF 103-B FOUND BURST OPEN



PHOTOGRAPH N°4 : RV-156-C SHEARED OFF FROM MAIN PIPE AND THROWN AWAY



PHOTOGRAPH N°5 : SHEARED OFF TAIL PIPE OF RV-156-C



PHOTOGRAPH N°6 : SHEARED OFF TAIL PIPE OF RV-156-C

PHOTOGRAPH N°7 : RV-156-C INLET PIPE SHEARED OFF FROM MAIN 100" PIPE