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Trouble Shooting ACR Systems

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When problem arise in the field with equipment performance and technicians cannot find the answer, senior engineers are called in by the company to help solve the problem.

One such engineer recounts in this article the field problems he has been refrigeration theory, familiarity with p-v, T-S and p-h diagrams and experience has helped him to find the right answers.

1. Refrigeration System for a Cold Storage

The system consisted of two K20 x 110 compressors (one working and one stand by) two cooling units, oil separator, condenser, receiver, and piping. The refrigerant used was Ammonia.

The problem

The room temperature was not coming down even after running the compressor continuously for a long time. The company tried to run the stand-by compressor also at start up, saying that two compressors are required during the initial cooling down. Even after running both compressors the temperature refused to come down. Reasons were not known and temperature of the cold storage room remained high even with no load in the rooms.

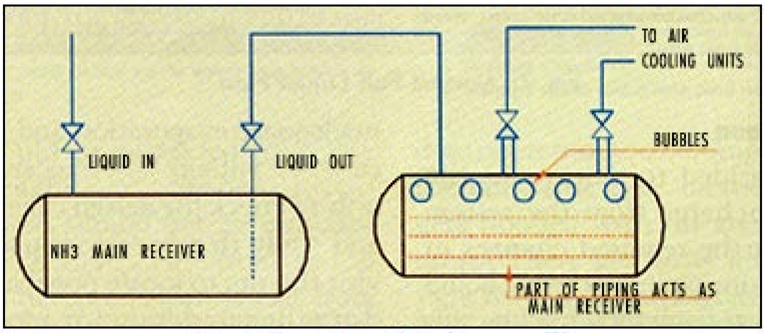

Fig. 1: Poor Liquid Refrigerant Flow

Analysis and observations

Design and selection data were checked, and it was found that no safety factor was considered and the selection was barely enough to achieve temperature was not going down even with no load ad even after using both compressors meant that there was some other problem apart from the design problem.

All the drawings for the project were studied, which included plant room lay outs, P & I diagrams, electrical diagrams etc. From the drawings it was not possible to detect the error. Hence it was decided to visit the plant site.

During the site visit, it was found that the receiver was located at a slightly higher elevation than the condenser. The main liquid line from the receiver terminated into another pipeline from where several connections from the upper portion of he pipe were taken to air cooling units in two different rooms.

The receiver should always be located, preferably, directly below the condenser but definitely at a lower level location than the condenser. The elevation of the condenser and receiver could not be changed due to site conditions. It was suspected that the main liquid line, which terminated into another pipe, was acting as a mini receiver. The liquid outlet connections taken from this mint receiver were from the topside of the pipe, thereby giving rise ti vapor locking of the refrigerant flow. Once the vapor formed, the liquid refrigerant could not flow properly and hence flow of the liquid ammonia to the air cooling unit was not continuous. The air cooling units were designed for gravity flooded operation and since the liquid ammonia flow was not continuous, the liquid level in the surge drum of the air cooling unit was not being maintained. As sufficient liquid refrigerant was not available in the units, the refrigeration capacity was very poor which resulted in inadequate cooling of supply air.

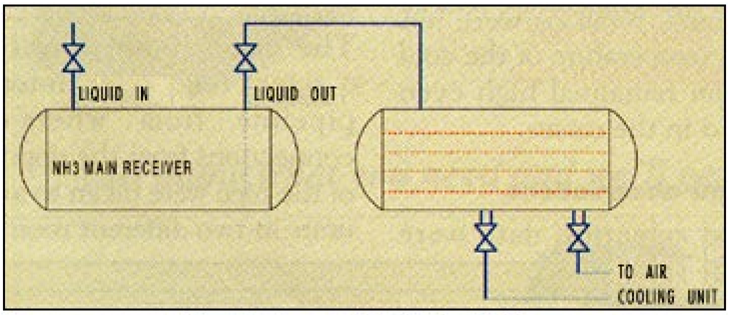

Fig. 2: Assured Full Liquid Flow

The solution

It was decided to empty out the complete charge from the system and make the require changes in the liquid line piping such that liquid connections to the air cooling unit are taken from the bottom of the mini receiver to avoid any vapor locking. When a number of units are to be fed with liquid refrigerant, it is recommended that separate liquid lines be taken directly from the outlet of receiver or the condenser. After the complete charge was removed and modifications in the piping done as suggested, the entire plant was pressure tested before recharging with ammonia and re-commissioning.

The system was run with only one compressor, as the other compressor was a 100% stand-by. The room temperatures started dropping by about 6 deg C per hour and the desired design temperature was achieved in about six hours time. These tests were conducted at a time when the rooms were not loaded with the product. Eventually the product was loaded and the rooms achieved the desired temperatures within acceptable parameters.

The plant was operated successfully and handed over to the customer.

In conclusion, if liquid refrigerant does not flow continuously at the required rate, there will be inadequate evaporation and cooling capacity will suffer. It is necessary not only to check the design calculations and study the drawings but also to visit the site to locate possible faults, if any, in actual layout in piping and other accessories. It is necessary to take a complete set of readings and plot this data on the p-h diagram for the particular refrigerant being used for the cycle and then co-relate observed readings with design parameters and take corrective action for achieving the results required.

2. Problems of Oil Return

Oil return to the compressor in any system whether it is R - 22 or Ammonia, DX or flooded is very important, as the plant cannot operate unless oil returns to the compressor continuously. There are several instances where operators go on charging copious amount of oil to the compressor. The oil disappears from the sight glass and migrates to other parts of the system where it remains behind and does not return. As more and more oil is added to the system, it gets accumulated mostly in the evaporators thereby reducing the cooling capacity of the plant. In some cased it has been observed that in flooded systems the capacity goes down to as low as 15-20% of full load capacity. All remedial actions must be taken in time so that oil is recovered and excess oil is not unnecessarily charged.

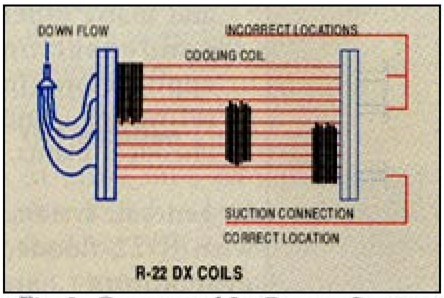

Fig. 3: Correct and In Correct Suction Connections

DX cooling coils or evaporators are commonly used in standard AHUs or built up AHU's These cooling coils are generally multi-parallel circuited to minimize refrigerant side pressure drop through the coil. The liquid refrigerant invariably enters these coils through thermostatic expansion valves with distributors and the distributor tubes are usually of 6 mm size. It is recommended that the distributor be installed in a vertical down-feed position for best results. All tube outlets from the distributor should be of equal length and should have smooth curves to the inlet of coils, so that there is an equal pressure drop through all the tubes and hence equal distribution of liquid and flash gas. The suction connection i.e. the outlet from the coil should be provided from the bottom of the coil outlet header. This connection should not be provided either from midpoint or from the top end. If the connection is not from the bottom, the entire column of the header gets filled up with oil which does not returns to the compressor and the crankcase gets starved, the coil gets flooded with oil and capacity drops. There are many installations right from small packaged units both split and self contained type to large built up AHUs, where connections were wrongly given from mid point or the top point and had to be cut in the field and relocated at the bottom of the header. By doing this, all the oil accumulated in the coil is driven back to the compressor and the crankcase does not starve of oil.

PLANT A/C UNIT WITH 1 NO CONDENS ING UNIT AS 100% STANDBY

Major Equipments are:

2 Nos AC-70 Compressor	1 Working + 1 Standby
2 Nos Motor for Compressor	1 Working + 1 Standby
2 Nos Water Cooled Condenser	1 Working + 1 Standby
2 Nos AHU	2 Working
2 Nos Water Pump	1 Working + 1 Standby
1 No Cooling Tower	Working

While one set of working condensing unit is in operation, the standby equipments are totally isolated and the system is operated in the following manner:

A) Refrigerant side

1. Suction valve of standby compressor is in closed condition.
2. Discharge valve of standby compressor is in closed condition.
3. Hot Gas inlet to standby condenser is in closed condition.
4. Liquid outlet of standby condenser is in closed condition.

B) Water side

1. Water inlet to standby condenser in closed condition.
2. Water outlet of standby condenser in closed condition.
3. Discharge of standby cooling water pump in closed condition.
4. Suction of standby cooling water pump in closed condition.

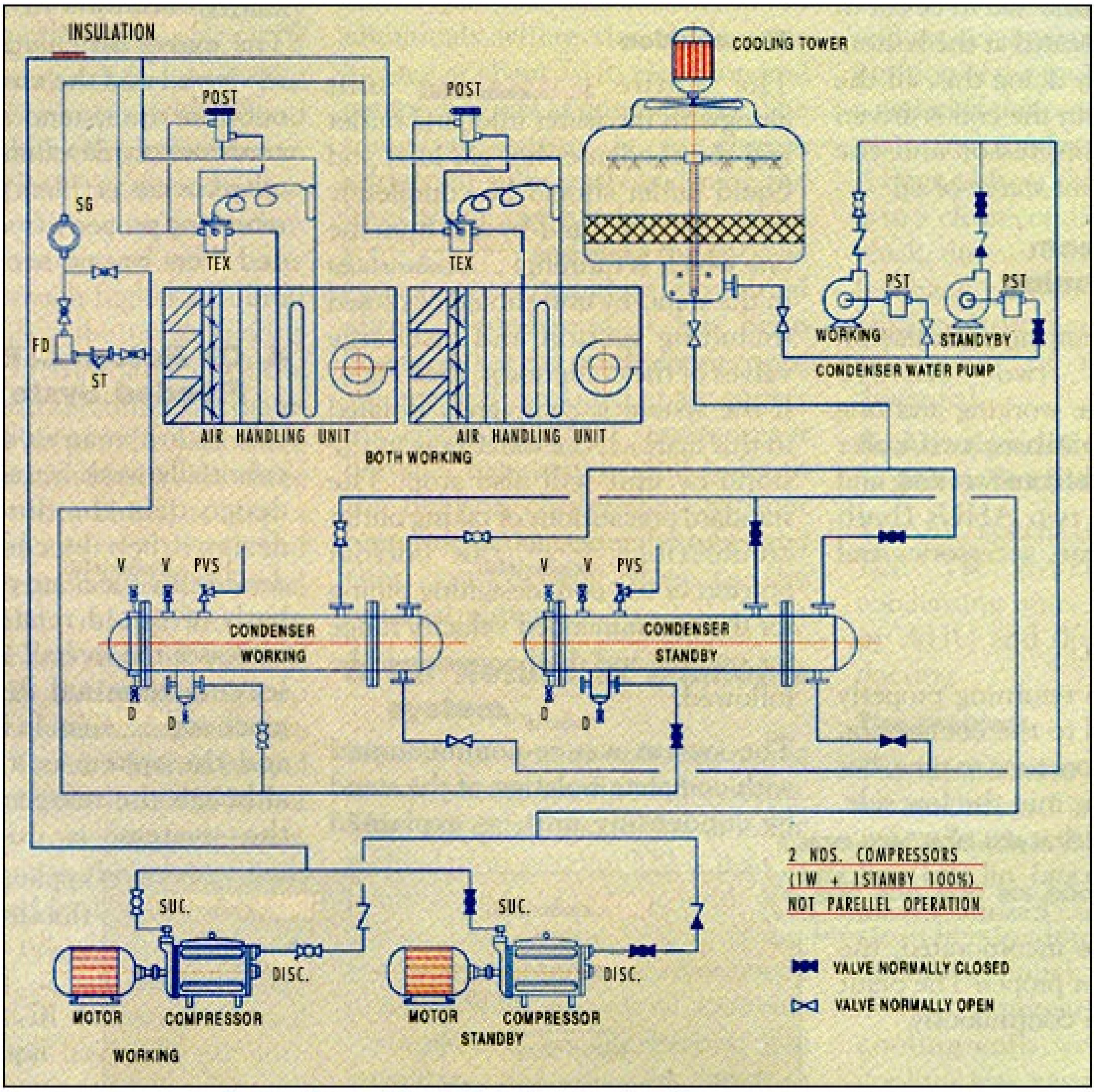

Fig. 4: Control Room Air Conditioning System

3. Control Room Air-conditioning

The air conditioning installation consisted of two AC-670 compressors (one working and one stand-by) with valves, two water cooled condensers (one working and one stand by), two AHUs (both working), pipeline, accessories and controls.

The problem

The oil was not returning properly from the AHU's to the compressor. Oil was added, from time to time, but kept disappearing into the low side. It was suggested that equalizer lines be added for oil and vapor to both the compressors. Even after this modification was incorporated, the oil return was not proper. The plant could not be run continuously.

Analysis

The two compressors in the system are not to operate simultaneously. One of them runs and the other is full stand-by. In principle, it amounts to one condensing unit acting as stand-by and one working, with the possibility of either of these condensers being used with any one compressor.

The solution

The entire condensing unit along with the water inlet and outlet and the condenser hot gas inlet and liquid outlet should be completely isolated in the stand-by unit from the one which is running. All the valves in the stand-by unit should be closed including suction and discharge valves of the compressor. If the system is completely isolated in this manner, the water flow in the standby unit will also stop. The standard precautions of taking outlet connections from the bottom portion of the coil, designing piping for the recommended velocity range for suction and discharge should be followed.

The system was re-commissioned with complete isolation of the stand by condensing unit, as explained above, and run continuously. Oil started returning to the crankcase. The excess oil charged earlier was recovered and the same was drained out from the system. The system ran continuously day and night with no oil recovery problem as the oil was returning properly from the low side and there was no need to add more oil.

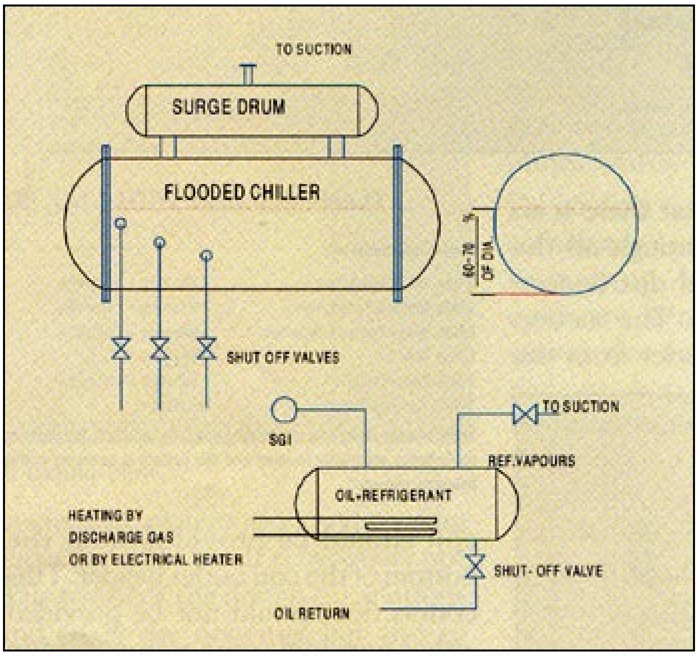

Fig. 5: Oil Rectification System in R-22 Flooded Evaporators

4. Oil Return in R-22 Flooded Systems

There are many systems, which essentially work better with flooded design than the direct expansion design (DX) In case of flooded deigns the tubes are permanently in bath of liquid refrigerant which increases the overall 'U' valve. The leaving terminal differences are much smaller than in the DX systems and the system is more compact although the refrigerant charge in the system is high. Typical applications of R-22 flooded evaporator are:

- Chlorine liquefaction
- SO_2liquefaction
- Chilled waiter systems
- Cooling of methylisocynate and many other condensation applications in refineries and chemical plants.

In general, systems with R-22 flooded evaporators are candidates for oil return problems.

Analysis

All flooded systems are generally designed for liquid refrigerant levels of 60 - 80% in the chiller shell. The oil in R-22 systems is not heavy and does not get collected at the bottom of the shell. The oil is not so light as to float on top of the surface either. The concentration of oil in the refrigerant is much higher at a level somewhat below the upper boiling surface of the refrigerant. Since the liquid level in the chiller fluctuates within limits as per the load, it is customary to provide two or three outlets from the shell, to tap a concentrated mixture of oil and refrigerant. Depending on the actual level of the refrigerant, an appropriate hand shut off valve is opened while the remaining two valves remain closed and the mixture is taken to a vessel, which is heated either by an electric heater or by hot discharge gas from the compressor. The refrigerant in the mixture boils and is returned back to the suction, whereas the oil which remains in liquid form, is returned to the crankcase. Oil retrieval for all flooded chillers has to be put into operation continuously so that oil enrichment does not take place in the chiller. The oil return problem in flooded systems becomes more severe as evaporating temperatures become lower. This problem of oil return is flooded R-22 chillers is common not only for reciprocating compressors but also for screw compressors.

The solution

At many sites, oil retrieval systems were found to be nonfunctional, as the level of R-22 in the chiller was not properly maintained. Some of these jobs included chlorine liquefaction plants with horizontal liquefiers, chillers installed in refineries for condensation of chemicals where the chiller was located at about 70 ft. Elevation and compressor was at ground level. The remedial action is to charge refrigerant sufficiently and raise the level above the nozzle and raise the level. In such circumstances it becomes necessary to drill holes in the field on chiller shell without rupturing or damaging the tubes and then connecting them to the retrieval systems.

5. Oil Return in ammonia systems

Most of the systems using ammonia as refrigerant are flooded systems. They are either gravity fed or pump recirculation systems. Oil is heavier than liquid ammonia and gets accumulated at the bottom of the chiller, condenser or receiver over a period of time. Almost all ammonia systems use oil separators. Oil separator is the only component in the system, which should preferably be slightly undersized than oversized. The efficiency of the oil separator gets reduced if it is oversized. Since oil separator cannot be 100% efficient, some oil does escape to the system and collects in the chiller bottom - oil being heavier than Ammonia liquid. The refrigerant level in a flooded chiller is normally designed to be between 60-70% of the shell diameter. The chiller is provided with a drain connection with a valve. Oil can be drained from the chiller even while the chiller is in a running condition.

The receiver is generally installed in a slightly inclined position the angle of inclination is about 10 deg - 15 deg. Oil will get accumulated near the lower position of the inclined receiver over a period of time and it can be drained easily in a similar manner as the oil is drained from the chiller.. If the oil is in a clean condition i.e. if it is not black, dirty or burnt, then it can be fed back to the crankcase of the compressor; otherwise it should be taken out of the system and discarded.

6. Air conditioning System for a Textile Plant

The AC system comprised of three 100 TR R-22 water cooled condensing units with a huge built up AHU and floor level concrete ducting.

The problem

The temperature in the space to be air conditioned in the textile plant was higher than the ambient of 40 deg. C

Observations and analysis

All the condensing units were operating under abnormally high discharge pressures. None of the cooling coils were sweating and cooling was very ineffective. The sight glasses of all the three systems showed presence of a lot of vapor bubbles. Discharge pressures were in excess of 20 kg per cm^2 when the condenser water inlet temperature was around 30 deg. C.

It was initially felt that non-condensables might be present in the system. Purge valves were operated and suspected non-condensables were let-off to the atmosphere and discharge pressures were observed. No significant improvement was noted, It was further suspected that the condenser tubes might have fouled. A tube cleaning operation was undertaken for all the three units. The discharge pressure dropped only marginally and that too for a short time. The pressure soon shot back to over 20kg/cm^2 as before.

The plant parameters were studied and designs were checked. Originally 3-pass condensers were selected as per design but actually 2-pass condensers were installed. It was not possible to convert a 2-pass condenser into a 3-pass condenser in the field, as the tube sheet layout is quite different for 3-pass configuration. Even with a 3-pass original design, the selection was just marginal and there was no safety factor. The water velocity through tubes in the 2-pass design was much lower than if it had been a 3-pass design. Based on the 2-pass condenser reality, as it existed in the field, calculations were done to check the quantity of water that could be sent through the tubes at a velocity not exceeding 8 ft/sec. By increasing the water quantity the gpm/tube/pass would increase and hence the "U" value. This would increase the heat rejection capacity of the condenser. The pumps were checked if they could handle larger quantity of water sufficient to achieve 8ft/sec velocity through the tubes. On checking the pump design it was found that if the impellers were changed to a higher size, in the same casing, they would deliver the required gpm. This required higher power consumption but was within the capacity of the existing motors, However, this necessitated a change of starters and cables for the next higher sized capacity.

The results

The required changes were incorporated one by one over a period of two weeks for all the three condensing units. Water quantity was increased and condenser heat rejection capacity raised. The condensing pressure came down substantially. This gave rise to full condensation and 100% liquid flow in the sight glass. This ensured full liquid refrigerant reaching the expansion valve with no flash gas. This improved the capacity of the expansion valve and consequently cooling capacity of the AHU coils. The coil started sweating heavily and a lot of condense started collecting from the cooling coils. The discharge pressure in all the three systems came down to 15 kg/cm² gauge and if became possible to load all the eight cylinders of the compressor and achieve full capacity of the condensing unit, which was not possible earlier due to very high discharge pressure. The reduction in condensing pressure with full condensation and no flash gas, gave a spectacular improvement in the performance of the cooling coil and thereby resulted in excellent temperature conditions inside the textile halls as desired.

7. Centrifugal Chillers:

Many air conditioning and refrigeration systems include centrifugal packaged chillers either open or hermetic, working with refrigerants such as R-11, R-12, R-123 or R-134a. These packaged chillers are complete with cooling tower, chilled water pump, condenser water pump, piping and controls.

The problem

Very often these chillers don't produce full capacity. It is difficult to assess the exact capacity they give and therefore difficult to take corrective action in improving the performance. The unit invariably goes into a "surge" condition and gives unstable performance.

Analysis and solution

- Obtain all the correct design parameters for the chillers. These include capacity, power consumption, temperature in and out for the chiller and for the condenser, flow rates across chiller and condenser, fouling factors, electrical voltage characteristics etc. The flow rates across chiller and condenser should usually be adjusted by maintaining the design pressure drops. The flows are established to correct values by adjusting globe valves in the out lines till correct pressure drops are obtained. It is recommended that the same pressure gauge be used at the inlet and the outlet, to eliminate any built in inaccuracy of different gauges.

- The temperature readings should be accurately taken. It is recommended to have at least two digital thermometers, which should be checked for accuracy.
- Tube cleaning in both the chiller and the condenser must be undertaken at least once in 3 months or sooner, depending on the cleanliness of water. Tubes get clogged partially or fully or get fouled, giving rise to surging conditions. The chillers may invariably give a maximum of 60 -70% of the full load capacity but never achieve 100% capacity Non achievement of full performance and surging at lower capacities is also caused due to inferior quality of tinned tubes used in the evaporator. The type of tubes are invariably "Turbo B"type and it is impossible to exactly measure various parameters of such tubes physically. Tubes manufactured by certain small manufacturers are not consistent in quality. In one case there were two chillers both identical except one had American (Wolverine) tubes and the other Korean. It was decided to replace the Korean tubes with Wolverine tubes. The chiller was then decommissioned and found to achieve full 100% capacity without surging, exactly as the other unit with Wolverine tubes.

Multiple chillers

In one installation where 3 chillers were working in parallel with common headers on the waterside, one of the chillers kept tripping, although all the chillers had been successfully run for over 50 hours. All points were checked and it was almost impossible to pinpoint the fault as to why one unit was tripping again and again. The flow switch was giving an indication of 'no-flow' but it was suspected that it may be a faulty indication. The flow switch was bypassed and the unit was started. The water circuit was studied and only one pump was kept running by stopping he other two units and closing the inlet/outlet condenser water valves on these two units. It was found that although the pump was running, there was no flow through the condenser and no spray at the cooling tower nozzles. The globe valve stem was broken inside and the valve remained shut. After knowing the fault, all the water in the condenser was drained and the globe valve removed and opened. The valve was found to have been broken inside in the shut position so the valve stem was rotating without the seat. This was giving a wrong impression that the valve was open. The valve was replaced with a good new valve and unit was re-commissioned. The unit ran continuously thereafter without a ny problem and produced full capacity.