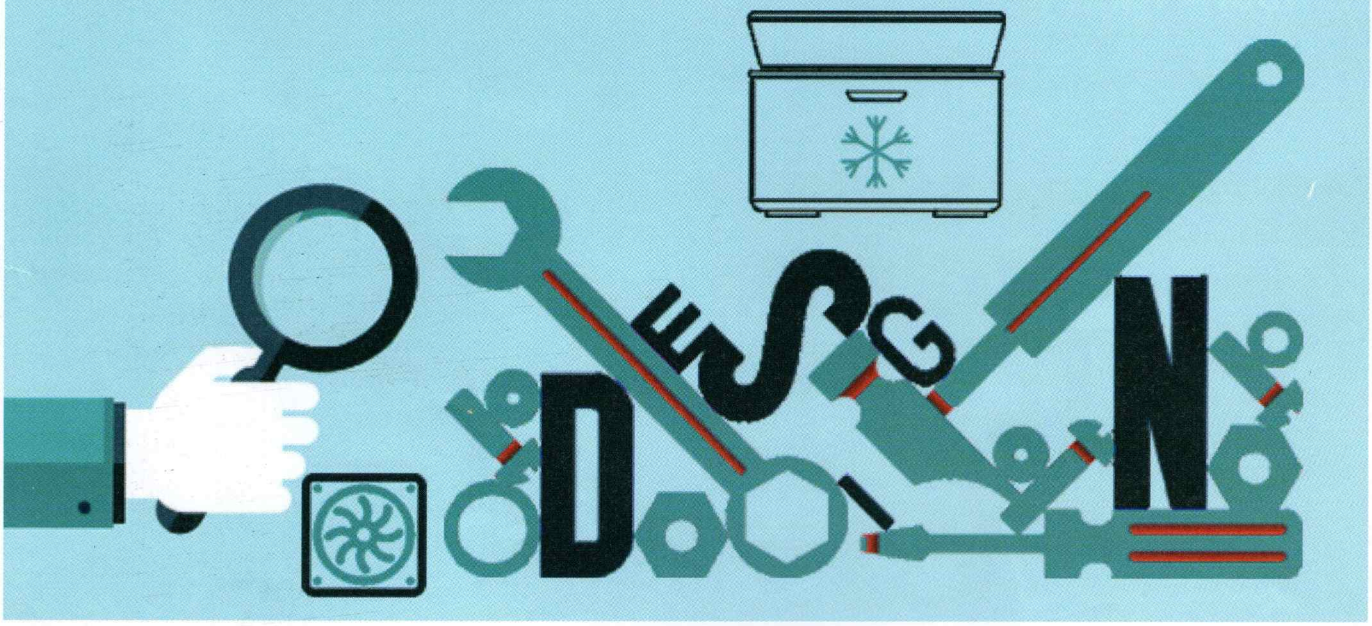
# Challenging Problems and Easy Solution In Refrigeration

# CHALLENGING PROBLEMS & Easy Solutions IN REFRIGERATION



**Internationally acclaimed HVACR expert Ramesh Paranjpey narrates his own experience in terms of dealing with the common problems that baffle almost everyone in the refrigeration domain.**

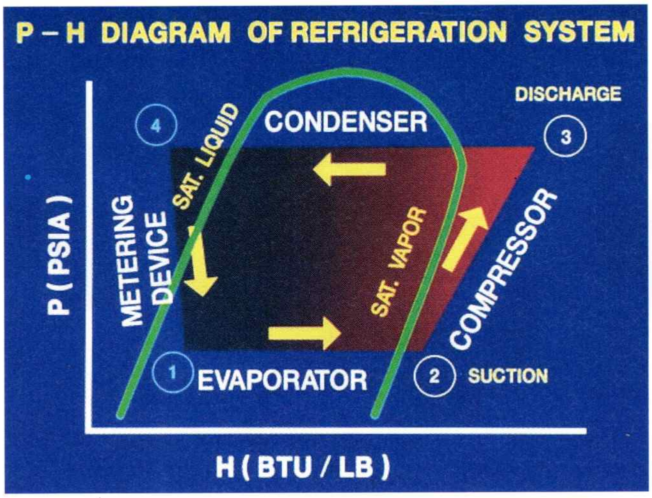
If you are involved in manufacturing and designing of field engineered process plants and air conditioning systems for more than 5 decades, you are bound to come across many situations, which appear to be baffling even to the most experienced engineers.

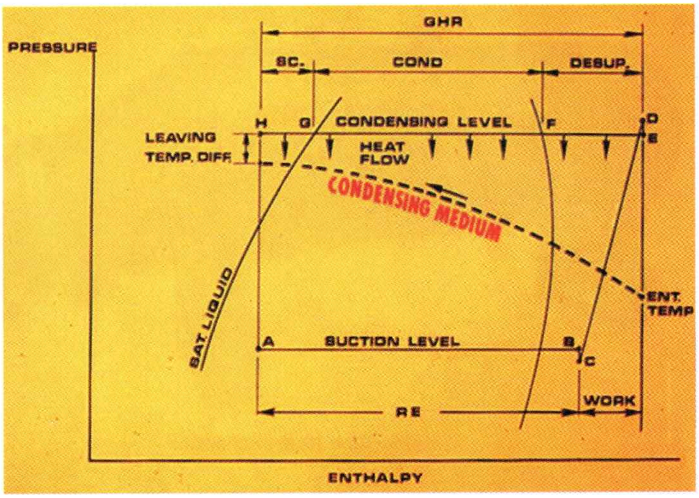
Many times, once the solution becomes evident, it appears to be too simple, but till such time many manhours are spent and expenses incurred before you meet someone who has either already gone through similar problem, or is able to tell confidently with logical explanation, what needs to be done.

More than 99 per cent problems can be solved with systematic analytical approach, using step-by-step elimination process, to arrive at correct diagnosis and then to eliminate root cause, rather than working on symptomatic short-term solutions.

The remaining 1 per cent problems, for which any amount of theory or practice does not lead to solution, could be due to various reasons, not likely to be imagined, but can be broadly categorised in one of the following heads:

- Equipment designing and manufacturing related issues
- System engineering and component design errors
- Lack of communication or clarity between supplier and buyer
- Over confidence, or insistence by consultant or buyer
- Not adapting technology to suit local conditions
- Lack of proper knowledge in installation and piping practices
- Lack of understanding on proper working of system components




- Ignorance of relevant clauses from applicable codes or standards.

Some of the common problems that baffle almost everyone in the domain are narrated here:

## Equipment Designing & Manufacturing Related Issues

Normally if the manufacturer strictly follows drawings, specifications and methods given by his principals or collaborators, chances of errors are few and even if they occur, they can be easily identified and rectified.

A reputed manufacturer of reciprocating compressor supplied these compressors for various applications ranging from low temperature to comfort applications.

After installing more than 1,000 of these compressors for such varied applications, the designer/installer started facing typical problem of suction valve plate chattering and breaking, only on applications involving comfort air-conditioning applications using R-22 refrigerant. The same compressors working on ammonia installations did not face this problem, and they could not identify the reason for such premature failures. After exploring all possible avenues such as checking and rechecking drawings, inspecting components thoroughly, it was finally decided to approach the manufacturer's principals in Holland, expecting a usual answer to recheck all over again, the areas they had already covered.

To their surprise, the manufacturer immediately got a response stating that the collaborators had also encountered similar problem and asked to increase the tolerance between stroke limiter diameter and the valve ring by few microns. Once this was carried out, the problem got resolved.

Now the interesting point is how increasing this tolerance helps in solving problem with R-22 comfort air conditioning applications?

On subsequent interaction with the collaborators, it was revealed that at higher suction pressures, the density of R-22 being very high, and due to uneven pressure exerted by small coil springs the inner rim of valve plate was hammering against stroke limiter diameter, leading to failure. As soon as the suction pressure reduced, the problem used to disappear as the gas density reduces and the valve plate rests firmly in the recess provided since the suction pressure is higher than the cylinder pressure. On pistons upward stroke as the cylinder pressure rises over suction pressure, the springs force the valve plate on to its seat.

R-22 vapour density at 40-degree F is 1.524 lb/cu.ft, whereas for ammonia it is only 0.2523 lb./cu.ft at the same temperature. Subsequently, manufacturer changed the design and instead of many small springs, replaced with two much stronger sinusoidal springs.

This problem was beyond the imagination of the engineers and could only be resolved with such assistance. The important point is the property of refrigerant inducing this problem and had nothing to do with manufacturing accuracies.

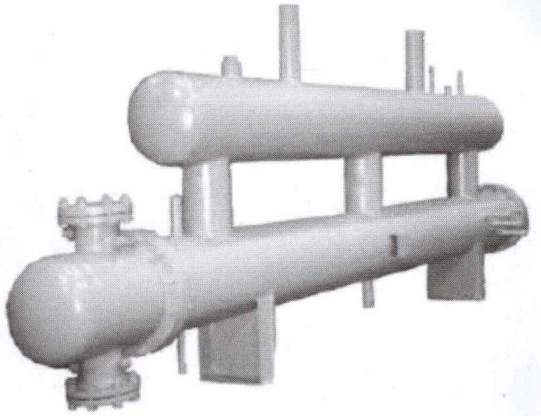
## System Engineering Component Design

The condenser heat rejection is higher than the evaporator load. For air-conditioning application, it is nearly 1.2 to 1.25 times as a thumb rule. It is however always a good practice to actually calculate the same. Normally the safety factor is taken into account and actual operating conditions, which as a rule are always less than design load conditions, especially in comfort air conditioning applications. The problem of missing this aspect of correctly sizing the condenser may remain unexposed, however, on low temperature, process plants, not taking in to account heat of compression for condenser heat rejection can lead to serious problems.

In one of the major installations using eight (–) 25-degree C brine chilling packages, the system designer had selected condensers suitable for evaporator load. As the compressors employed were uni-built two-stage design, they had to start with one cylinder of high stage getting loaded first, till such time the temperature dropped to such an extent, when low stage cylinder could be switched on.

Due to obvious error, in selecting condenser, to cater for correct heat rejection, the plant could never be started and run continuously without tripping on high pressure cut out.

Kettle Type heat exchanger



Heat exchanger with surge Drum

There was no place also in the plant room to install additional condensers for each package or to replace existing condensers with bigger size. Thus, the project commissioning faced severe problems and the contract finally ended with litigations, leading to huge losses for both client as well as suppliers besides bad publicity.

On a similar smaller plant, using one package, the problem could be resolved by supplying one additional condenser. So that two condensers shared initial cool down load, till temperatures dropped to reasonable level.

To highlight this issue, if we look at the typical ratings of two-stage compressors, KC 21 compressor with R-22 refrigerant, when starts initially from ambient conditions with one high pressure cylinder operating, has a capacity of 45 tonnes at (+) 40-degree C or (+) 10-degree C, whereas when it operates as two stage compressors with (+) 40-degree C or (-) 30-degree C conditions, it has a capacity of 18 tonnes.

One can appreciate, if a condenser is designed for 18 tonnes heat rejection, how one can start and operate the plant automatically, without tripping on high pressure, unless one manually throttles the suction?

Similar precaution needs to be taken while selecting the electric motor of adequate capacity to take care of initial starting and cool down load conditions as well, for a low temperature application.

A selection of brine tank capacity also needs careful consideration, if one is not able to load compressor to full capacity at start-up, then to cool the stored quantity of brine in the tank from ambient temperature could take a very long-time which customer would not be willing to accept.

## Lack of proper communication

A chemical plant operating with Ethylene Glycol brine at (–) 20-degree C brine was installed in Mumbai, using ammonia-flooded chillers.

Similar plants were earlier executed and were working well. The sequence of events in this particular instance was as under.

The project commissioning was delayed due to certain reasons and the completion of refrigeration plant and the main chemical plant were ready for start-up simultaneously. There was no time available to test the refrigeration plant in advance and keep it ready before chemical plant could be started. The German engineers, responsible for process design were present and our most experienced erection crew was also at hand. The engineers were quiet confidant that the plant would work well without any hitch. When the plant trials commenced, the charging of gas in the refrigeration unit was done simultaneously. Within short span, instead of expecting smooth operation resulting in brine temperature drop, liquid refrigerant started coming to compressor, and the suction pressure was not dropping. The commissioning crew did normal checks such as brine pump operation, all line valves in open position, liquid level controller functioning etc. Everything appeared to be normal. The German chemical engineers thought that, the chiller design is faulty and adequate area has not been provided. The site engineers were of the opinion that the liquid level controller was not at the correct height and needs to be lowered. As there was no consensus, an urgent call came to me at 4 PM to rush to site immediately as all the engineers were waiting at the plant.

Immediately, everyone cornered me and started telling me their analysis and theory as to what is wrong with the system design. I requested them to restart the plant, and as expected, liquid started coming to compressor within short time, without expected reduction in brine temperature. I then tried to throttle the suction valve manually, to prevent liquid stroke, but the plant had to be stopped. I could not understand, why this is happening, when all other parameters looked normal, and I had confidence in my design of heat exchangers as well as in piping layout. It was evident that not much heat transfer in chiller is taking place.

Then the user was requested for the design specifications. The supply and charging of Ethylene Glycol brine was part of client's responsibility. The recommended specifications, called for brine of 45 per cent concentration. The user was asked about the source of procurement of brine. On searching the records, it was found that it was a reputed supplier and therefore the question of quality of brine was beyond suspicion. The scrutiny of the order further revealed that he had placed order for 45 per cent concentration of brine as a requirement. Anticipating something wrong, I asked about the person who has prepared the brine mixture and ensured required concentration. To my surprise, client replied that there was no question of preparing brine concentration at their end and they had charged the system with the supply as received from the manufacturer, assuming that the manufacturer has taken care of necessary concentration as specified in the order.

In short, client had charged 100 per cent Ethylene Glycol solution, in the system directly from the drums received from supplier.

Refrigeration designers do not need further explanation as to why the plant was misbehaving. With 100 per cent concentration, obviously with high viscosity, there was hardly any heat transfer taking place. The viscosity of Ethylene Glycol at (–) 5-degree F is 18.00 cSt, with 45 per cent concentration, whereas it increases dramatically 180 cSt (to 10 times) if the solution concentration is 100 per cent. Similarly, the thermal conductivity reduces from 0.26 to 0.18 when solution concentration increases from 45 per cent to 100 per cent, (44 per cent reduction). Also, the specific heat of the mixture drops from 0.72 to 0.52 (38 per cent reduction).

I then requested to restart plant and started filling water in the tanks with the hoses and simultaneously removing excess quantity. As the pure Glycol started getting diluted with water, the brine temperature started dropping and finally at 4 O'clock in the morning we got desired results when right concentration was achieved, without any liquid coming to the compressor.

It can be thus seen, that this problem was due to taking certain things for granted leading to unexpected situations. Clarity on requirements, what is expected from each agency and dialogue with all concerned people could have avoided such situation.

## Over Confidence of Consultants

ASHRAE Refrigeration handbook chapter on refrigeration for chemical industry summarises this beautifully. Chemical engineers expect refrigeration as any other utility, like steam or air and feel that refrigeration will be available in the similar manner when the tap or the valve is opened. They, very rarely, are willing to share process side data and designs.

Refrigeration engineers know that their systems work in conjunction with chemical processes and knowledge on either side is essential for trouble-free design and operation of entire plant.

At one of the plants designed by a leading consulting firm from USA, the author's company was associated to provide refrigeration. The plant was supposed to manufacture CFC refrigerants and therefore used R-22 for refrigeration plant as well. The battery limit conditions specified quantity of R-22 refrigerant in the liquid form to be made available at a particular pressure and temperature. This liquid refrigerant was then used in various process heat exchangers using refrigerant on the shell side and fluid on the tube side the heat exchangers were located at considerable height on third floor, where as the refrigeration plant was in the basement. In order to protect compressors, there was a big size knock out drum (accumulator).

When the plant was commissioned, it was found that the liquid was getting filled up in the drum and then subsequently entering the compressor suction header. In short accumulator was only delaying liquid stroke. Obviously, the system fault existed.

The consultants and the client were reluctant to take us in confidence and show the process side stating that it is confidential information. However, on urging them finally the client took us to the plant. All the liquid level controllers were checked for proper operation. These were pneumatically operated instruments with control valve and all related controls and indicators or alarms like high or low level etc. The entire process was monitored from remote location from the central control room.

It was obvious that as the liquid was boiling, the suction drag force due to powerful compressor suction was picking the liquid droplets to suction against gravity force. Once the droplets entered suction, they had to travel only in the direction towards compressor suction and could not come back.

The process heat exchangers were kettle type design, regularly used by chemical engineers and not the flooded design similar to what refrigeration engineer normally provides.

Normally a flooded cooler with liquid level controlled at 75 per cent to 80 per cent height is provided. In addition, a surge drum on top of the cooler is provided, so that in case the liquid droplets are dragged upwards, due to reduction in velocity to approximately 100 to 150 fpm, the heavy liquid droplets fall back in the vessel instead continuing its journey towards compressor.

After three days of discussions, although consultants were reluctant, and client had no other alternative suggestions coming forward from consultants, they agreed to modify process heat exchangers as per the recommendations.

The plant was shut down for 5 weeks and all process heat exchangers were modified and provided with surge drum on top to effectively separate vapour and liquid. After the plant was recommissioned, everything worked well.

Finally, consultants agreed that they should have taken us in confidence earlier, which could have avoided such costly repairs and wastage of client's valuable time.

## Understanding Relevant Codes & Standards

The author's company was associated with India's largest petrochemical plant at Baroda. The total plant capacity was 2,200 tonnes, using ammonia refrigeration and the temperatures up to (-) 27.5-degree C. The project being executed under the consultancy of the largest public sector consultancy engineers and was under strict requirements of all relevant international codes and practices.

The material requirements were also to international standards and in those days (1975), it was difficult to get raw material to required codes, hence client supplied the material.

The heat exchangers were designed to TEMA-B standard and construction was as per ASME SEC VIII Div. 1. The drawings of each heat exchanger were routed through various groups of consultancy engineers, such as thermal and, process design, maintenance group, strength checking and to ensure that the design strictly meets the code requirements. After many interactions and incorporating requirements of various groups, the drawings were finally approved and the fabrication of heat exchangers was carried out under the strict supervision of inspecting engineers. The heat exchangers were huge, compared to normal refrigeration condensers or chillers which one is used to. And the sizes were 38-inch diameter by 20-foot long using 670 tubes of 1.25-inch diameter and weighing 18 tonnes each.

After the heat exchangers were manufactured and were stamped by inspection engineers, arrangements for organising dispatch were made.

Suddenly, we received a fax from the chief engineer of the consulting firm that all the low temperature vessels and heat exchangers stand rejected, since we have not carried out impact test on raw material before using it for fabrication and vessels are likely to fail in operation.

As per ASME code for use on low temperature applications, it is mandatory to carry out this test. This requirement had also escaped the attention of their inspecting engineers. However, the consultants squarely put the blame on the suppliers.

This communication was bolt from the blue, and all our efforts stretching over two years came to naught, leading to huge financial loss to the company if we had to start all over again.

In desperation, ASME committee in USA was approached to find whether any concessions to such requirements is available for refrigeration duty, since we had never done such testing earlier in any of our low temperature plants and all of them were working well for long periods without any damage.

To our great relief we received the letter stating that as per UCS-66(c)(1), no impact test is required on any material for use at temperatures of (–) 20-degree F or (-) 28.9-degree C and above, if the pressures and temperatures do not occur simultaneously.

The code states that materials subject to temperatures, below (-) 20-degree F, except as under shall be impact tested as required by Para UG-84 of Section VIII Div 1 of the ASME Boiler and Pressure Vessel Code, and will have Charpy impact value at the operating temperature of not less than 15 ft lb. using keyhole notch.

## Exception

Carbon, low alloy and high alloy steels (but not austenitic ductile iron) may be used at low temperatures not lower than (–) 50-degree F or (-) 46-degree C without impact testing if the operating pressure will not be more than 25 per cent of the maximum design pressure at ambient temperature

The reason being, in refrigeration applications pressures and temperatures do not occur simultaneously, unlike chemical process heat exchangers. In other words when the vessel is operating at low temperature, the corresponding pressure is very less, and since the vessel has been designed for much higher pressures, it is always safe for operation at low temperatures.

The ASME volumes are large and to read and master all the information is not a regular requirement of refrigeration engineers, but we should learn such clauses, which are relevant to our industry, to avoid any such happenings. The consultants and chemical engineers are experts in heat exchanger designs, but are also not aware many times of special requirements of refrigeration industry.

The importance of understanding each other's requirements has been highlighted nicely in ASHRAE Refrigeration volume as stated earlier.

It is therefore essential that both the parties are fully aware of required codes and practices, to avoid such misunderstandings.

If we would have accepted consultant's rejection, one can imagine what would have been the outcome.

## Technology adaptation to suit local conditions

Our company's strength was in designing refrigeration plants for low temperature applications.

One of the early plants involved selection of two-stage ammonia compressors for a brine chilling plant-supplying brine at (–) 28-degree C to process. The installation was in Mumbai for one of the pesticides company using German Technology. The chief engineer was also German posted by the principals.

The plant was commissioned and worked well. All handing over formalities were completed to everyone's satisfaction.

After a period of one week we received a call from user, indicating that there is abnormal wear out on cylinder liners. We promptly deputed our service staff and, on their suggestion, replaced a batch of 12 liners for one compressor. We, then started investigating why such premature wear out are taking place.

There was no liquid carry over and thereby affecting lubrication. We also checked cylinder alignments to confirm that the axis for each cylinder was true as per drawing, and hence possibility of wear out due to incorrect manufacturing or fabrication did not exist.

Having completed this study, we thought that probably, the particular batch of liners might be defective and not having material composition as per specifications.

After replacing the cylinder liners and supplying correct liners after thorough inspection, we were reasonably sure that the problem would disappear.

This did not happen and we again got call after few days indicating the repetition of the same phenomena.

The German chief engineer thought our liner material is not correct and we either change the material or do some hard chrome plating or change the design of piston rings etc.

He also suggested that we should seek

assistance from our sister concerns who had immense experience in manufacturing reciprocating machines, particularly diesel engines.

We did not want to take such route since in all other installations the compressors were working well without such premature liner wear out.

Meanwhile we continued replacing liners at regular intervals, costing enormous expenses to company.

The compressors were built as per collaborators design and client insisted that we call their expert since they also knew our collaborators well, as they were using similar compressors in Germany.

Accordingly, we requisitioned services of our principal's expert, and when we took him to site, everyone was eagerly awaiting to find out what is his diagnosis and remedial suggestions. We took him around the plant along with German chief engineer.

We then assembled in the conference room to eagerly hear from him. He indicated to client that he has found the solution but would convey the same next day after he holds the discussions with our team.

On reaching Pune he informed us that the problem was not serious and suggested that we change currently used oil Zerice R 44 (43/44 cSt at 40-degree C) with a higher viscosity grade oil and confidently said that the problem would be resolved. When we told him that we are using oil as per collaborators recommendations, he then clarified that the recommendations are basically for European countries with cold or moderate climatic conditions. In India for higher ambient conditions, the chart needs to be modified. Normally it would be alright for any other application but with Ammonia refrigerant and with two-stage application for such extreme low temperature use, the compressor discharge temperatures are high and affect lubricating properties of oil adversely. It is therefore suggested that thicker grade oil should be used.

When we carried out this change, the problem of liner wear out disappeared. We then changed our oil recommendation chart incorporating Indian Oil Servofriz-68 or Seetul 68 from high pressure which has a viscosity of 68 cSt at 40-degree C for all users resulting in improved performance for all installations and reduced maintenance costs.

The lesson to be learned is many technologies need to incorporate requirements to suit local conditions instead blindly following foreign technologies.

## Proper understanding of working of component

We were manufacturing flake ice machines using ammonia as well as R-22 refrigerants. The icemaker used flooded design, in which low temperature refrigerant was filling up the double walled cavity in the cylinder. The water sprayed on the inner wall was getting converted into ice.

The fabrication of icemaker drum was subcontracted and machining process was in house operation. The liquid refrigerant to ice maker is fed with the normal arrangement of hand expansion valve and solenoid valve combination controlling liquid level in a vessel, connected to icemaker with the liquid and gas equalising connections.

We installed one such icemaker in a chemical or dyestuff plant in Mumbai. No sooner the ice plant was started, we observed that the liquid is directly filling the surge vessel and entering the compressor without producing ice.

We then carried normal checks, such as operation of float switch, ensuring all equalising valves are open etc. Our site engineer thought the liquid level is too high and we then lowered the drum and reduced the height, without any success. We then opened the system to find whether any plastic cap is blocking the liquid flow to the icemaker drum. Many times, erection staff forgets to remove plastic caps and join the piping in a hurry. When the system is put on vacuum, the caps may get sucked in the line and thus blocking flow path. On this installation we did not find any such problem.

Finally, when no solution was in sight, we decided to bring the icemaker to factory and decide to cut open the cylinder to find what is blocking the refrigerant flow.

To our horror, we found that the fabricator had provided a complete round strengthening ring above the refrigerant liquid inlet connection, instead providing just the four small joining pieces to hold the cylinder inner and outer wall. This resulted in liquid not entering the icemaker at all, but was directly going to surge vessel and finally entering the compressor.

When we asked the fabricator, who incidentally was not our regular supplier, why he had done so, he indicated that since he was doing the job for first time, he wanted to do a good job and thus thought of strengthening the design further by providing complete support instead of few small ribs. If he had known the application and the operation of icemaker the situation would not have arisen.

The best intensions, without knowledge of system operation, could thus lead to puzzling problems. ■

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