Purging Noncondensable Gases Improves System Efficiency and Reduces Costs

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In this era of corporate “right-sizing” and departmental “down-sizing,” the word purging has multiple meanings. For management, it means cutting the “deadwood” out of an organization or “out-placing” staff in the interest of improving efficiency and reducing costs. It means “cleaning house” and removing the undesirable, less efficient and costly personnel.

For a refrigeration engineer, purging also means removing the “undesirables.” As we will see, purging a refrigeration system of undesirable noncondensable gases can likewise improve the company’s bottom line by improving the system’s efficiency and reducing waste of valuable resources. For the purpose of this discussion, the term “air” and “noncondensables” are used synonymously. In addition, ammonia systems are used in our examples, although the same principles apply to all other refrigerants.

In the past, purging noncondensable gases from (ammonia) refrigeration systems usually was accomplished by simply opening a hand valve. This allowed the undesirable gases to escape to atmosphere. When the visible vapor cloud became pure white (indicating a high concentration of ammonia), it was time to close the valve.

This method was simple and effective, but wasteful in terms of labor, energy, refrigerant and system performance.

Regardless of whether the suction side pressure is above or below atmospheric, air can accumulate in refrigeration systems through one or more ways:

1. The refrigerant, when delivered, can contain up to 1.5 percent noncondensables.
2. Inadequate system evacuation before charging with refrigerant.
3. When opening the system for repairs on equipment such as compressors.
4. Break-down of the refrigerant and/or lubricating oils.
5. System leaks, which allow air to migrate into the system through valve packing and seals, especially when the suction pressure is below atmospheric.

Air Reduces System Efficiency

Plant operators know that air in the condensers raises head pressure. But why does the head pressure increase and what does that have to do with the system’s efficiency?

Essentially, air is a very effective insulator. It can impede the refrigerant from doing its primary job. Also, air in the refrigerant gas means more work for the compressor, since it must compress the air as well as the refrigerant.

When the condenser’s inside surfaces are crowded with air molecules, refrigerant molecules find it difficult to reach the cold surface as shown in Fig. 1. Thus, the presence of air reduces the size of the condenser surface exposed to the refrigerant. This effective size reduction can be offset only by increasing the temperature (and pressure) of the refrigerant gas so that all of the gas coming from the compressor will be condensed. It should be noted that more cooling water for the condenser improves this situation but cooling water is also expensive.

![Figure 1](image-url)
Air in the Condenser is Costly

Research indicates that each four pounds of excess head pressure, caused by air in the system, increases compressor power costs by 2 percent. In addition, the compressor capacity is reduced by 1 percent. Excess head pressure due to air shortens the life of drive belts, bearings and motors. Table I shows the savings achieved by reducing excess pressure. From the table, it can be seen that a 100 ton system operating 6,500 hours per year with 20 psi excess head pressure is costing more than $2,100 a year. This is based on the price of electricity at four cents per kilowatt-hour and it multiplies dramatically as the cost of electricity increases. By reducing the excess head pressure to just five psi, one can realize electrical energy savings of $1,600 per year.

In addition to operating costs, there are other costs associated with air in the system. For example, higher temperatures shorten the life of the compressor valves and promote the premature breakdown of lubricating oils. Furthermore, when the head pressure goes up, more stress is placed on gaskets and seals, which contributes to early failure.

A Thermodynamic Refresher

Dalton’s “Law of Partial Pressures” helps to explain what happens when a mixture of two or more gases is compressed. The “partial pressure” of each gas in a mixture is the pressure it would have if it filled the total volume without any other gases present. The partial pressure of all the gases adds up to the total pressure, which can be measured on a gage.

Also, the partial pressure of the gases in a mixture is directly proportional to the volume of each gas. Thus, if a refrigeration system is contaminated with 10 percent air (by volume), then 10 percent of the total pressure is due to the air. The interesting (and useful) point about all this is that the refrigerant behaves according to its partial pressure, not the total pressure in the system. Note that calculations involving gas mixtures need to use absolute pressure values, rather than gage pressure.

How to Tell if Air is Present

Figure 2 shows an ammonia system with a temperature of 80 °F and a pressure of 150 psig or 165 psia. To determine if air might be present in the system, check the condenser pressure and the temperature of the liquid against the data in Table 2. It shows that the pressure at 80 °F should only be 138 psig or 1.53 psia. The difference of 12 psi is due to the air. Using absolute pressure, one can calculate that the partial pressure and volume ratios of ammonia to air are 153/12 or 12.75 to 1. Caution - Air is not the only cause of excessive condenser pressure. A condenser that is too small or has fouled or scaled tubes causes excess pressure without air. Air, however, is by far the most likely cause of excess condenser pressure, and the air must be purged before head pressure can be brought down to the proper levels.

Manual Purging

Manual purging is too expensive and too troublesome in most cases. Under the conditions above, manual purging to remove one cubic foot of air wastes 12.75 cubic feet of ammonia. A lot of compressed refrigerant gas is lost to atmosphere just to eliminate a small amount of air. Besides wasting valuable ammonia, manual purging:

- requires considerable time;
- does not completely eliminate the air;

| Savings in Compressor Operating Cost Achieved by use of refrigerated purging to reduce excess high-side pressure |
|---|---|---|---|---|---|---|
| Annual dollar savings per 100 tons, at 6500 hr/yr | Power cost per Kilowatt-Hour |
| Pressure Reduction, psi | $0.03 | $0.04 | $0.05 | $0.06 | $0.08 | $0.10 | $0.12 |
| 5 | 400 | 530 | 670 | 800 | 1070 | 1330 | 1600 |
| 10 | 800 | 1070 | 1330 | 1600 | 2130 | 2660 | 3200 |
| 15 | 1200 | 1600 | 2000 | 2400 | 3200 | 4000 | 4800 |
| 20 | 1600 | 2130 | 2660 | 3200 | 4260 | 5330 | 6390 |

Table 1
permits escape of refrigerant gas that may be both dangerous and disagreeable* to people and the environment; (*Refer to RETA Technical Report - Volume 6, Number 2 - May 1993) and is easily neglected until problems arise in the system.

Refrigerated Purging

If a stream of this same purge gas is refrigerated to substantially suction temperature, while maintaining a constant pressure, the conditions shown in Fig. 3 are obtained. As illustrated, a large part of the ammonia has condensed back to liquid, the partial pressure of the ammonia vapor has been lowered to 30 psia, and a partial pressure of the air has increased to 135 psia. The partial pressure and volume ratios of ammonia to air are 30/135 or 0.22 to 1. Purging this refrigerated gas to remove one cubic foot of air now wastes only 0.22 cubic feet of ammonia. The efficiency of the purging process has improved by a factor of $\frac{12.75}{0.22}$ or 58 times.

Where to Make Purge Connections

Any type of purging device can vent only the noncondensable gases that reach the purger. Therefore, purge connections must be at points where the air can and will collect.

With multiple condensers, receivers, etc., it is difficult to determine the exact location of the air. Condenser piping design, component arrangement and operations each affect the location of air.

Seasonal weather changes have an added effect on the location of the air. During the summer, the air may be driven to the cooler, high pressure receivers located inside the building. Whereas, during the winter months, the opposite may be true and air may migrate to the cooler outdoor condensers, especially during off cycles. Because of these varying conditions, multi-point purging may be your best answer.

Refrigerant gas enters a condenser at high velocity. But by the time the gas reaches the far (and cool) end of the condenser, its velocity is practically zero. This is where air accumulates and where the purge connections should be made. Fig. 4 shows where...
the purge connections should be made on evaporative condensers. Similarly, Fig. 5 and Fig. 6 show where the most effective purge points are located on shell and tube condensers. Should you purge from the condenser or receiver? Be prepared to purge from either. Air can migrate from condenser to receiver and back again depending on load and plant conditions. Air remains in the condenser when receiver liquid temperature is higher than the condenser liquid temperature. Conversely, air migrates to the receiver when condenser liquid temperature is higher than receiver liquid temperature. Fig. 7 locates the purge point for a receiver.

Conclusions

It is inevitable that noncondensables can and will enter refrigeration systems and, as described above, they must be removed so that the refrigerant can do its job. In order to achieve maximum results from the system, and to overcome the costs of manual purging, it is important to incorporate full time purging. Not only will you have energy savings, but with a fully automatic purger, emissions (which are costly and sometimes offensive to those exposed to the fumes) can be greatly reduced when compared to manual purging.

Automatic purging of air from refrigeration systems, like “right-sizing,” “down-sizing,” and “out-placing,” can improve the economic conditions within a business. The inefficient systems and the refrigerant losses due to inadequate or neglected purging that were tolerated in the past are no longer an acceptable alternative in this new energy, economic and environmental era.

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