

Fig. 7 . . . Effect of Steam Pressure on Steam Demand at 100°F Condenser Temperature

ating effect) per ton of refrigeration will likewise increase. This characteristic is valuable for a quick pull-down at start-up and for absorbing high, sudden loads which may be thrown on the system. If the refrigeration effect is reduced by throttling the steam, the ejector is liable to break if the condensing temperature continues to remain high. This is because the lower kinetic energy in throttled motive steam is insufficient to permit compression over the design pressure ratio. It is therefore better to operate the system intermittently by means of automatic controls set to maintain the chilled water temperature within fixed limits than to throttle the steam.

The typical characteristics of the steam-jet refrigeration indicate that its economy of operation is very sensitive to condensing temperature, particularly when the evaporator temperature is 50 F or lower, as is common in air-conditioning applications.

Because the motive steam of ejectors flows through a critical flow nozzle, its steam consumption does not change with load variations except by on-off or throttling control. The latter is not a preferred control method.

When a refrigeration system must utilize condensing temperatures over 100 F, it is usually not economical to use a steam jet in place of an absorption machine or mechanical refrigeration unit. Evaporative or barometric condensers on steam-jet units can usually maintain condensing temperatures below 100 F. This enables the steam-jet cycle to be used economically in comfort air-conditioning applications which would be uneconomical if a surface condenser were employed.

An undesirable characteristic of the steam ejector is its limited ability to operate over temperature lifts (condensing temperature minus evaporator temperature) much above its design temperature lift. An ejector will operate satisfactorily at design lift or lower, but usually if operated at lifts about 5 F above design, the ejector becomes unstable and will break, i.e., completely stop pumping vapor from the evaporator. The margin of stable lift over the design value can, within limits, be made broader only at the expense of rapidly increasing steam consumption. In order to be competitive with other refrigeration cycles the steam jet typically has only 3 to 5 F of stable lift above design. Controls can be provided to shut the system off just below the break temperature, so that the break does not occur.

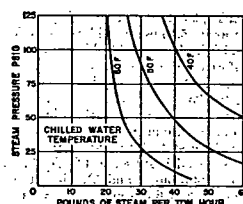


Fig. 8 . . . Effect of Steam Pressure on Steam Demand at 110°F Condenser Temperature

Another control procedure at high lifts is to provide an over-ride control on the chilled water temperature thermostat that will raise its set temperature in proportion to any excess in condensing temperature, in effect maintaining a constant lift during those rare operating conditions that exceed design expectations. A lowering of motive steam pressure below the design value will also decrease the ability of the ejector to provide any lift margin. With properly applied controls, modern steam-jet ejectors rarely if ever break in service.

The use of multiple or parallel ejectors is an effective means of load control of the steam-jet system. As cooling load drops, ejectors are sequentially deactivated or shut off. This provides a series of load change steps (equal to number of ejectors). Load control within a given step can be obtained by varying the chilled water or evaporator temperature, the condensing temperature, or by throttling the inlet steam supply to the ejector.

In order to start a steam-jet refrigeration unit, the air ejector must evacuate the system to operating vacuum before the main jet ejector is activated and any chilled water produced.

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ABSORPTION AIR-CONDITIONING AND REFRIGERATION EQUIPMENT

Basic Cycles, Lithium Bromide-Water Cycle, Coefficient of Performance, Influence of Condenser and Chilled Water Temperatures and Heat Source Temperature, Ammonia-Water Cycle, Basic Equipment, Evaporators and Coolers, Condensers, Absorbers, Generators, Control of Generator and Absorber, Auxiliaries, Limit and Protective Controls, Equipment Sizing and Selection

THERMODYNAMICALLY, the absorption cycle is the oldest known cycle for producing a refrigeration effect; mechanically, it has the simplest operating cycle of the systems in common use today. Whereas a detailed knowledge of the thermodynamics of the absorption cycle remains the responsibility of the equipment designer, an understanding of the cycle will assist the air-conditioning engineer to determine the relative merits of different refrigerating cycles.

This chapter has been divided into three parts: the first reviews the basic absorption cycles discussed in Chapter 1; the second describes basic equipment, and gives data on performance and operating characteristics; and the third suggests equipment sizing and selection criteria.

BASIC ABSORPTION CYCLES

The absorption cycle and the mechanical compression cycle have in common the evaporation and condensation of a refrigerant liquid, these processes occurring at two pressure levels within the unit. The two cycles differ in that the absorption cycle uses a heat-operated generator to produce the pressure differential where the mechanical compression cycle uses a compressor; the absorption cycle substitutes physical-chemical processes for the purely mechanical processes of the compression cycle. Both cycles require energy for operation; heat in the absorption cycle, mechanical energy in the compression cycle.

A complete thermodynamic analysis of the absorption cycle is relatively complex. Several excellent discussions of the many different absorption cycles may be found in Reference 1. A detailed analysis is not necessary to obtain an understanding of the operating principles of the cycle.

The importance of good thermal properties in refrigerants and absorbents is evident; it is also important that the refrigerant and absorbent have certain chemical and physical properties. Experience and research have established that the properties of an ideal refrigerant, absorbent, and refrigerant-absorbent combination are:

1. The ideal refrigerant will have: (a) vapor pressure characteristics that will permit boiling at 35-50 F and condensation 100 F or above, at pressures not far from atmosphere, (b) high critical temperature, (c) large latent heat of vaporization, (d) low specific heat, (e) low molecular weight, and (f) chemical stability.
2. The ideal absorbent is a liquid under operating conditions, and will have: (a) high boiling point, (b) low viscosity, (c) low specific heat, and (d) chemical stability.

The general responsibility for this chapter is assigned to TC 4.6, Absorption Machines.

3. The ideal refrigerant-absorbent combination will: (a) have a high degree of negative deviation from Raoult's law, (b) give a solution with low specific heat and low viscosity, (c) be non-corrosive, and (d) yield a solution with as small a heat of dilution as is compatible with the other properties.

Of the many combinations that have been tried, only the lithium bromide-water and the ammonia-water cycles remain in common use in air conditioning equipment. In addition, ammonia-water absorption equipment is often used in large tonnage industrial applications requiring low temperatures for process work.

LITHIUM BROMIDE-WATER CYCLE

Fig. 1 shows, diagrammatically, the components of a lithium bromide-water cycle unit.

Diagram A shows two closed, connected vessels. The non-toxic hygroscopic salt (lithium bromide) solution is in one, water in the other. Water vapor in the evaporator is attracted to and absorbed by the salt solution in the absorber. The water remaining in the evaporator is cooled by the consequent boiling of some of the evaporator water. To utilize the refrigeration effect, a coil is placed in the evaporator as shown in diagram B. A pump circulates refrigerant water from the evaporator sump to a spray header to assure that the surfaces of the coil are wet at all times, assuring high heat-transfer rates. The evaporation of the water at the surface of the cooling coil chills the water in the coil as it is circulated, in a closed circuit, to the load. These two vessels operate under a high vacuum (approx. 0.15 psia) and deliver chilled water at temperatures as low as 38 F. The evaporator temperature is kept above 32 F so that the refrigerant water will not freeze.

The absorbed water vapor continually dilutes the salt solution, reducing its ability to absorb additional water vapor. To maintain the salt solution in the absorber at the proper concentration, a generator is added to the system, as shown in diagram C. The weak (dilute) solution is pumped from the absorber sump to the generator where heat boils off a portion of the refrigerant water, concentrating the solution. This strong (concentrated) solution is then returned to the absorber to continue the cycle. The water vapor refrigerant released from the weak solution in the generator is now condensed in the condenser (added in Diagram D) and returned to the evaporator.

A heat exchanger is added to the system to conserve heat in the cycle by using the hot strong (concentrated) salt solution from the generator to preheat the cooler weak (dilute) solution from the absorber. This improves the efficiency of the system by reducing the input required to heat the solution in