Application Engineering Bulletin

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# AIR-TO-WATER HEAT PUMP CYCLES

Air-to-air heat pump systems operate with relatively low compressor discharge pressures, and are not designed as a high temperature heat source. Air-to-water systems, however, require much higher utilization temperatures (and resulting high compressor discharge pressures), whether for residential heating or domestic hot water.

A refrigeration compressor is designed primarily as a cooling device, and operating the compressor to high condensing temperatures on a continuous basis does introduce mechanical, electrical, and temperature stresses which must be considered in system design.

## Long Term Reliability

As a general rule, the life of mechanical and electrical equipment is directly related to the stress under which it must operate. Short term exposure to extreme temperatures or pressures may not materially affect a compressor's useful life, but continuous exposure to extreme temperatures, marginal lubrication, or high bearing stress may very well result in a compressor's life being substantially shortened.

In a consumer product vital to the comfort and health of the user, as is the case with residential heat pumps or hot water heaters, the user expects the same high degree of reliability he has experienced in the past with hot water heaters and furnaces which are not mechanical in nature. Short life expectancy or frequent failures cannot be tolerated. It is essential that the engineer design his system so that the compressor is operating well within its capability rather than at its extreme limits. Compromising reliability for lower first cost could very well create extreme user dissatisfaction to the point of endangering the heat pump concept.

## Temperatures

The system designer must be concerned with conditions which result in high motor temperatures, high compressor discharge temperatures, and high oil sump temperatures.

High motor temperatures can seriously affect motor durability, as insulation begins to degrade rapidly above 325°F. Operating conditions must be avoided which result in repeated excursions into this temperature range.

In addition, most refrigeration oils will start to break down or carbonize at 325°F even in a contaminant free system. In a typical system (which is seldom contaminant free) chemical reactions can occur at lower temperatures.

The oil film between the pistons and cylinder wall can become marginal at cylinder temperatures in the 310°F-325°F range with excessive ring wear resulting.

Regardless of the original viscosity of the lubricating oil, at sump temperatures above 200°F the oil becomes very thin, and as the viscosity decreases, its lubricating capability decreases. For dependable long term lubrication of bearing surfaces, continuous operation at external sump temperatures above 200°F should be avoided, although short term excursions 20 to 30°F above that level may not be harmful. Since the design of many reciprocating welded compressors is such that the internal discharge line is immersed in the lubricating oil, the oil temperature is directly affected both by the discharge temperature and airflow over the compressor shell. On applications with no air cooling, the sump temperature may go critically high before the discharge temperature reaches an unacceptable value. As a result, any application with the compressor in an insulated compartment must be carefully evaluated.

From a design standpoint, cylinder discharge temperatures should be kept as low as practical, hopefully below 300°F to obtain a reasonable safety factor. The choice of refrigerant may be dictated by the desired operating range. Table 1 illustrates typical cylinder discharge temperatures at identical operating conditions with different refrigerants.

**TABLE 1**
**Typical Cylinder Discharge Temperatures**
**Reciprocating Hermetic Compressors**

| Refrigerant | Evap. Temp. | Cond. Temp. | Return Gas Temp. | Cylinder Discharge Temperature |
|---|---|---|---|---|
| 12 | 20°F | 140°F | 40°F | 220°F |
| | 20°F | 140°F | 60°F | 240°F |
| | 0°F | 140°F | 20°F | 260°F |
| 22 | 20°F | 140°F | 40°F | 270°F |
| | 20°F | 140°F | 60°F | 280°F |
| | 0°F | 140°F | 20°F | 300°F |
| 502 | 20°F | 140°F | 40°F | 220°F |
| | 20°F | 140°F | 60°F | 240°F |
| | 0°F | 140°F | 20°F | 250°F |

Obviously, refrigerant R-22 is marginal at extreme operating conditions, while R-12 and R-502 have a comfortable margin of safety. Due to the undesirable temperature characteristics of R-22 at high compression ratios either R-12 or R-502 are more suitable for this type application. Because of heat transfer occuring in the discharge line, temperatures measured on the discharge line approximately 6 inches external to the compressor may vary from 30° to 60°F cooler than actual cylinder discharge temperatures. Therefore external discharge line temperatures of 250°F indicate the compressor is approaching a critical temperature level. Again, 20 to 30°F excursions above this level may not be harmful on a short term basis.

### Compression Ratio

High compression ratios not only cause high discharge temperatures, but can also cause wear on connecting rod pins. As the compression ratio increases, the residual pressure from clearance volume exerts a downward pressure on the piston for a greater percentage of the suction stroke. The piston riding the pin for both the discharge stroke and an increasing percentage of the suction stroke starves the pin for lubrication. Eventually, depending on the bearing surface and the loading, the compression ratio will reach a point where the connecting rod pin hole will start to wear.

The exact limit on compression ratio will depend on many factors including compressor design, but in general, compression ratios above 8 to 1 should be avoided on Copelaweld compressors.

Since the condensing temperature is usually fixed on air-to-water applications, the compression ratio may become critically high at low outdoor temperatures. Typically the compression ratio is limited on residential air-to-water heating systems by using a bivalent system, with compressor operation locked out at ambient temperatures below 35°F.

### Motor Loading

For reasons of both efficiency and stress, the condensing temperature must be maintained as low as possible on air-to-water systems. On residential heating systems, if the water temperature can be limited to 125°F to 130°F, the condensing temperature can be limited to 135°F to 140°F, and the motor is not loaded beyond its normal design point.

On systems designed for domestic hot water supply, higher water temperatures in the 140°F to145°F range are normally required, and in many systems the compressor must work at condensing temperatures of 160°F to 165°F. To avoid excessive compression ratios, the evaporator coil cannot be located outdoors, and with typical home indoor ambient temperatures, the evaporating temperature may be 45°F or higher.

Operation at these conditions results in a motor load far in excess of normal compressor design, and the most convenient and economical way to compensate for the high operating pressures and loads is to use refrigerant R-12 in a compressor originally designed for R-22. The change in refrigerant reduces the load on the motor by up to 30% when compared to R-22, with the result that the motor designed for R-22 at normal conditions has the capability of handling R-12 at the high condensing temperatures.