switch and motor overloads) so that the refrigerant solenoid valve will close when the compressor stops through the action of any one of these safety devices.

5. Low pressurestat settings such that the cut-in point will correspond to a saturated refrigerant temperature lower than any compressor ambient air temperature which may be expected. For example, if the ambient temperature can go as low as 50 F, the cut-in point of the low pressure switch must be lower than 46.7 psig (when using Refrigerant 12). If the cut-in setting of the low pressure switch is higher than this, then liquid refrigerant can accumulate and condense in the crankcase at a pressure corresponding to the ambient temperature. In this case, the crankcase pressure would not rise high enough to reach the cut-in point and effective automatic pump-down would not be obtained.

Crankcase Oil Heater with Single (Nonrecycling) Pump-out at the End of Each Operating Cycle (DX Systems)

This arrangement is not as positive as automatic pump-down control, in keeping liquid refrigerant out of the crankcase, but is a satisfactory substitute where pump-down control meets with customer objections, or results in excessive compressor short cycling.

Crankcase oil heaters cannot prevent liquid entering the crankcase during off cycles as the result of poor piping arrangements or leaking liquid feed devices. They will, however, maintain the crankcase oil at a temperature higher than other parts of the system, thus minimizing the absorption of the refrigerant by the oil and also the distillation process.

Operation with this arrangement is as follows. Whenever the temperature control device opens the circuit, or the manual control switch is opened for shut-down purposes, the crankcase heater is energized and the compressor keeps running until it cuts off on the low pressure switch. The crankcase heater remains energized during the complete off cycle and it is thus important that a continuous *live* circuit be made available to the heater during the off time. The compressor cannot start again until the temperature control device or manual control switch closes, regardless of the position of the low pressure switch.

The use of a crankcase heater with single pump-out at the end of each operating cycle requires:

1. A liquid line solenoid valve in the main liquid line or in the branch to each evaporator.
2. Use of a relay, or the compressor motor starter auxiliary maintaining contact, for obtaining a single pump-out operation before stopping the compressor.
3. A relay or auxiliary starter contact for energizing the crankcase heater during the compressor off cycle and de-energizing it during the compressor on cycle.
4. Electrical interlock of the refrigerant solenoid valve, with the evaporator fan or chilled water pump, so that the refrigerant flow will be stopped when either the fan or pump are out of operation.
5. Electrical interlock of the refrigerant solenoid valve with the safety devices, such as the high pressure cut-out, oil safety switch and motor overloads, so that the refrigerant flow valve will close when the compressor stops through the action of one of these safety devices.

Compressor Control with Flooded Type Evaporators

It is recognized that neither automatic pump-down control, nor a single pump-out operation, are practical in systems employing flooded evaporators, unless suction line solenoid valves are added to the system. Therefore, with flooded type evaporators, the following control arrangements are considered satisfactory:

1. Manual operation as described in following text. No crankcase heaters required.
2. Automatic control from temperature controllers, or other devices, provided crankcase heaters are used and energized on the off cycles and the liquid solenoid valve closes whenever the compressor is stopped. Where water cooling of the compressor is employed, a solenoid valve in the water supply line should close whenever the compressor is stopped.
3. Same as item 2 except with the added precaution of a single pump-down of the compressor for night or weekend shutdowns. This can be accomplished by manually closing the compressor suction stop valve. If the single pump-out procedure is used, the compressor will automatically pump down once, then shut-off on low pressure cut-out, and stay off until manually re-started. (This feature cannot be used if the low pressure cut-out also acts as the last capacity control step.)

Manual Compressor Operation

Compressors may be controlled manually without the use of automatic pump-down control, or single pump-out and crankcase heater, provided the system is at all times under the control of a qualified operator. The operator will pump-out the compressor by use of the manual valves and will keep liquid, suction and discharge valves closed when the machine is not operating. This method of manual operation may be used for any system, but is particularly applicable to flooded systems.

Effect of Short Operating Cycle

It is characteristic of the reciprocating compressor operation that oil will leave the crankcase at an accelerated rate immediately after starting. It is necessary, therefore, that each start be followed by a sufficiently long operating period to permit the regain of the oil level. Operation under normal control demand in response to room air temperature will, in most cases, provide sufficient operating time. However, if the compressor is controlled in response to supply air temperature, or to water temperature leaving a water chiller, a rapid cycle may result. Accordingly, thermostats used for compressor control from these indices should have differentials wide enough so that the running cycles will not be less than seven or eight minutes.

Short cycles caused by action of safety devices, such as low pressure cut-out or high pressure cut-outs, will, if continued, also cause the compressor to lose oil. This kind of service trouble should always receive prompt attention.

HOT GAS BYPASS ARRANGEMENTS

Most reciprocating compressors are equipped with capacity control facilities which allow the compressor to start with most of its cylinders unloaded and modulate compressor capacity down to within 25 to 50 percent of full load.

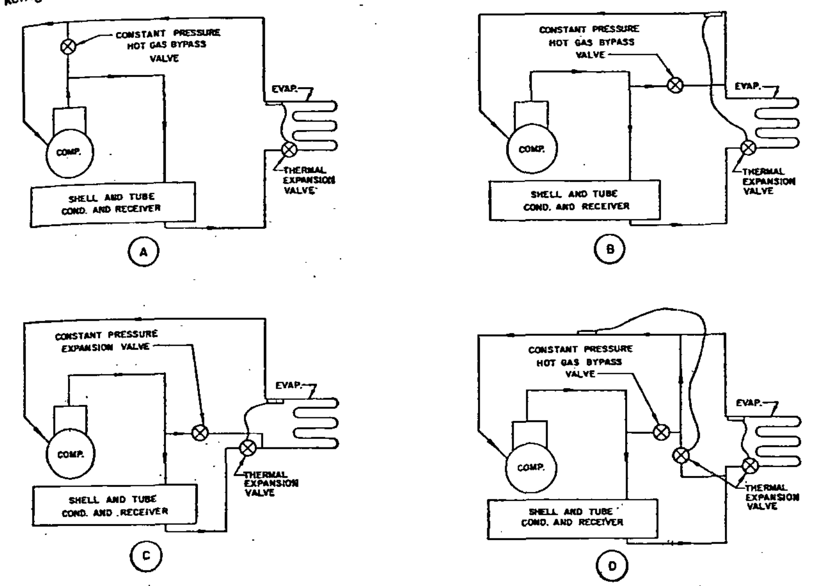
In spite of this feature, however, it is sometimes necessary to accomplish further unloading of the compressor for the following reasons:

1. *To reduce starting torque requirements*, so that the compressor can be started up with low starting torque prime movers, and also to allow starting of the compressor on low current taps of reduced voltage starters.
2. *To permit capacity control* down to 0 percent load conditions without stopping the compressor.

Full (100 percent) Unloading for Starting Purposes

When the requirement is for 100 percent unloading during the starting period only, this can be done with a manual or automatic valve in a bypass line between the hot gas and suction lines at the compressor.

This valve should only be open during the starting period, and then closed after the compressor is up to full speed and full voltage is applied to the motor terminals. Use of this bypass for longer periods will result in overheating.



A. Simple Hot Gas Bypass
B. Hot Gas Bypass to Exit of Evaporator
C. Hot Gas Bypass to Entrance of Evaporator
D. Hot Gas Bypass with Liquid Injection for Desuperheating

Fig. 49 .... Hot Gas Bypass Arrangements[2]

The sequence of control is as follows: The unloading bypass valve should be energized immediately on demand of the cooling thermostat, or other control calling for compressor operation. This permits equalization of pressures across the compressor. After an adequate time delay (time necessary for complete valve opening), a timing relay should close a pair of normally open contacts to start the compressor. After a further time delay (adequate to allow the compressor motor to come up to running voltage and speed), a pair of normally closed timing relay contacts should open, de-energizing the unloading bypass valve and closing the bypass.

Full (100 percent) Unloading for Capacity Control

Where up to 100 percent compressor unloading is required for capacity control purposes, it is possible to use hot gas bypass arrangements in ways that will not tend to overheat the compressor.

In using these arrangements, it is highly desirable that hot gas is not bypassed until after the last unloading step on the compressor has taken place. Some positive arrangement should be made to insure this.

Various methods of bypassing hot gas have been used. They do not all have equal merit. In selecting a hot gas bypass, careful consideration should be given to the following three requirements:

1. It should give acceptable regulation throughout the range of loads.
2. It should not cause excessive superheating of the suction gas.
3. It should not cause any slop-over to the compressor.

A hot gas bypass for capacity control purposes is an artificial loading device to maintain a minimum evaporating pressure, during continuous compressor operation, regardless of the evaporator load.

This is usually accomplished by means of an automatic or manual pressure reducing valve which acts to maintain a constant pressure on the downstream side.

Four of the more common methods of using hot gas bypass are shown in Diagrams *A*, *B*, *C*, and *D* of Fig. 49.

Diagram A illustrates the simplest type of hot gas bypass. It will dangerously overheat the compressor if used for protracted periods of time.

Diagram *B* shows the use of hot gas bypass to the exit of the evaporator. Here dependence is made on the evaporator