



Guidance Notes for Installation and Use of Hermetically Sealed Refrigeration Pumps

The Institute of Refrigeration Safety Code provides good criteria for the protection against excess pressure due to temperature rise but does not mention the design problems with gas bubbles during operation or cavitation of liquid prior to entering the pump.

Refrigerant pumps are not covered by the recently introduced Pressure Equipment Directive (PED) and should always be supplied with factory test pressure certificates.

Low voltage EU – Conformity Declaration to 73/23/EEG and EMC Directive 89/336 EEG should be complied with.

Refrigerating systems should not be put into use until it has been proven that the complete refrigeration system in which the pump is installed is in accordance with the regulations of the EC Machinery Directive 98/37/EC and the PED. With the new European regulations and the high costs of new refrigerants the use of special hermetic type refrigerant pumps has become necessary, replacing the older design open type pumps. In some countries the hermetic type pump has already become mandatory for new plants.

The direct on site substitution of hermetic type pumps in place of open refrigerant pumps is not always possible due to different inlet pipe layout design and higher speed of rotation.

Background Information

Many types of pumps have been developed for pumping refrigerants, for example gear, concentric rotary, centrifugal, turbine vane and worm type. Most pumps are of the open type, typically either Douglas or Witt designs with open shaft seal and external drive motor.

For many years the slow rotation speed (100 RPM) of the Douglas positive displacement type refrigeration pump gave reliable performance when pumping ammonia but the pump was unsuitable because of its open gland seal construction for use with other modern refrigerants. The open refrigerant pump manufactured by Witt, having a more reliable shaft seal design continues to be suitable for installation in the UK and export refrigeration markets. Both of these designs of pumps, correctly installed, are still in use and continue to have a place in existing refrigerant plants.

Modern refrigeration high speed pumps (2900 RPM) require greater design considerations for all pipe work with special emphasis on the venting and purging, for returning of gas bubbles to the LP receiver or in the case of oil cooler installations using HP liquid in the HP receiver.

The semi-hermetic design of Hermetic Pumpen (Cam Type) and Th. Witt hermetic pumps (HRP Type) have several advantages including avoidance of shaft seal, their higher speed, increased swept volume and pump head.

Cavitation, vapour entrainment and internal recirculation have an effect on the pump's capacity and can cause considerable damage to pump seals, impellers, motors and casing.

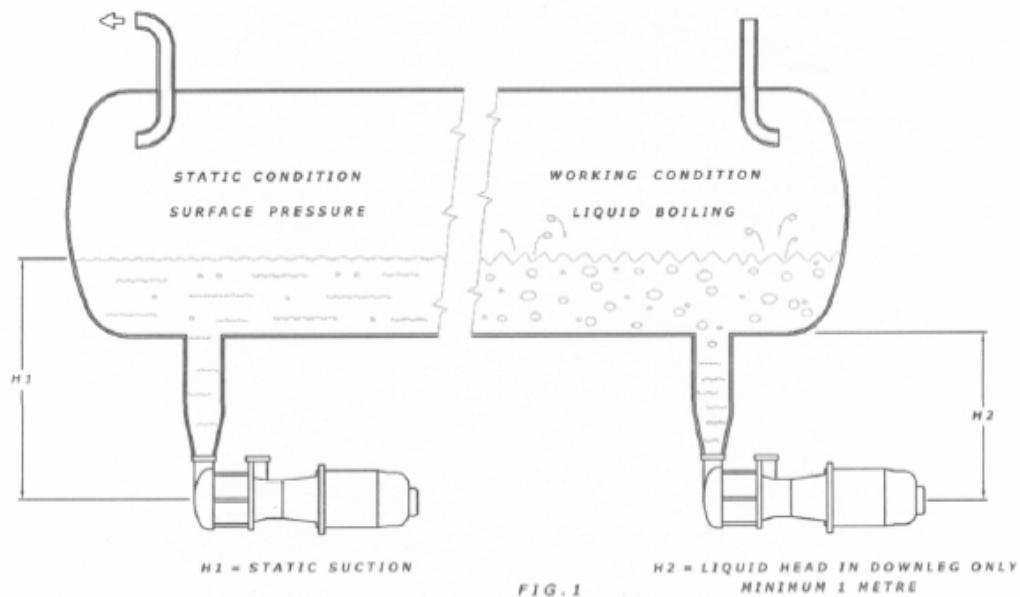
Light Liquids more Sensitive to Cavitation

The lower density refrigerants such as ammonia and propane are more sensitive to cavitation. Also the dilution of the refrigerant by oil and foaming tendencies of oil in halocarbons will contribute to cavitation.

Design Consideration for Refrigerant Pump installation

For refrigerant pumps the Net Positive Suction Head, as understood when pumping non volatile liquids, is not relevant as the fluid in the pump is in a boiling condition.

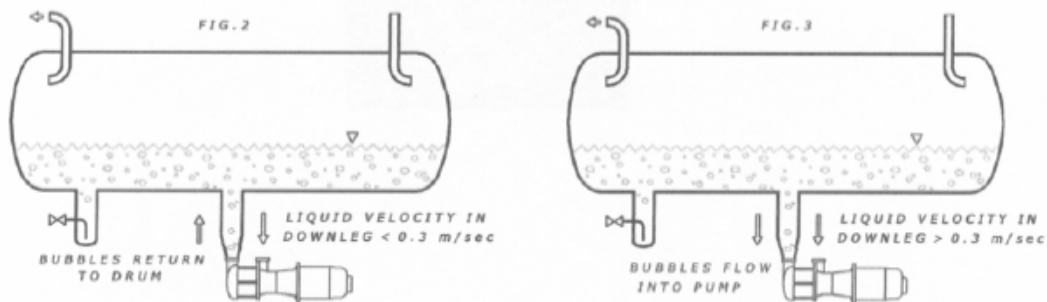
NPSH is misleading as the liquid head in the surge drum can be reduced to zero by the effect of the mass of bubbles in the boiling refrigerant. The only true head of liquid (h_2) is in the liquid down leg from the bottom of the surge drum to the centre line of the refrigerant pump.



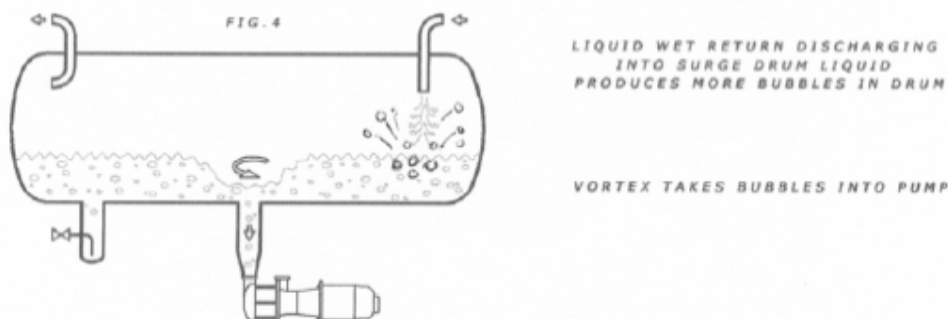
The problem can largely be minimised by the use of fully modulating liquid feed injection system and smooth compressor capacity control. For reciprocating compressors with 33/66/100% steps of capacity control it is not possible to maintain a steady drum pressure.

The pump suction line should be sized to give a velocity of less than 0.3m/sec in the down leg.

When pressure in the drum falls rapidly, the gas bubbles first rise, counter to the downwards liquid flow. Through laboratory observation of an ammonia system it has been seen that when the velocity increases above a value of 0.35m/sec the gas bubbles changed direction. Fig 2 and Fig 3. This is supported by theoretical analysis using the FROUD parameter.



Vapour entrainment may be induced by the wet return splashing into the down leg, or by the formation of a vortex in the down leg and pump suction line. Fig 4. It can also result when starting the pump from standstill after it has been allowed to warm up. The cold liquid should be introduced to the stationary pump with the vent line open before the pump has started.



Pump Head

The Discharge head of the refrigerant pump should be sufficient to overcome the required height lift, the pressure drop in the liquid lines and valves and the calculated pressure drop at the throttling valve or orifices at the evaporators.

Refrigerants

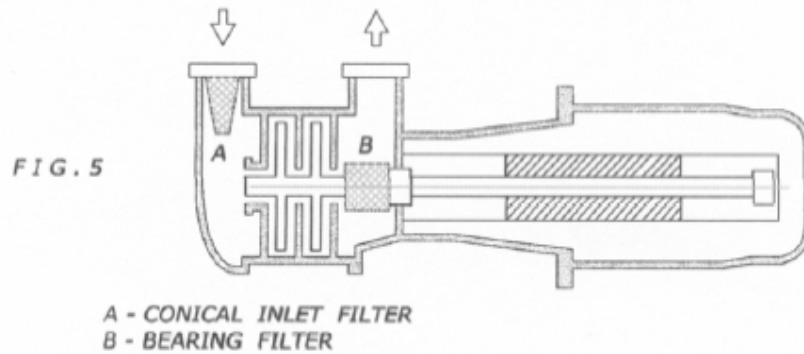
Care should be taken to use fluids of refrigerant quality.

CO₂, which is now being used as a low temperature refrigerant in cascade systems must be certified free of all moisture; below 20 ppm is recommended.

Pump Internal Design

It is important when designing installations using refrigerant pumps that the individual internal design and protection devices are understood. Each pump should have a suitably sized cleanable suction filter in front of the pump inlet. This filter should be easily accessible and inspected regularly. During the commissioning period the filter should be opened up and cleaned after a short running time.

Lubrication and cooling the of back bearing is dependant on a good quality supply of refrigerant through the shaft. To ensure the refrigerant is clean an additional internal filter should be installed around the shaft inside the pump. Fig 5.



Lack of good maintenance often accounts for poor delivery head and high-absorbed power. This can be attributable to blocked filters. In addition to the usual shot blasting sand and welding spelter materials produced during fabrication of the refrigeration plant; other foreign materials inside the refrigeration circuit can include paper, flakes of paint, string, wire gauze from burst filters and steel mill scale.

Poor Pump Performance

Pump performance and pump inlet design is based on receiving good quality refrigerant without bubbles or oil mixture contamination. Causes of poor performance can be identified as: -

Design

- Poor pipe work design
- Incorrect design or size of down leg to pump
- Lack of pipe work anti-cavitation devices

Operation

- Incorrect pump lead/lag change over procedure
- Fast pull down of refrigerant system

Maintenance

- Oil contamination in system
- Filter Blockages

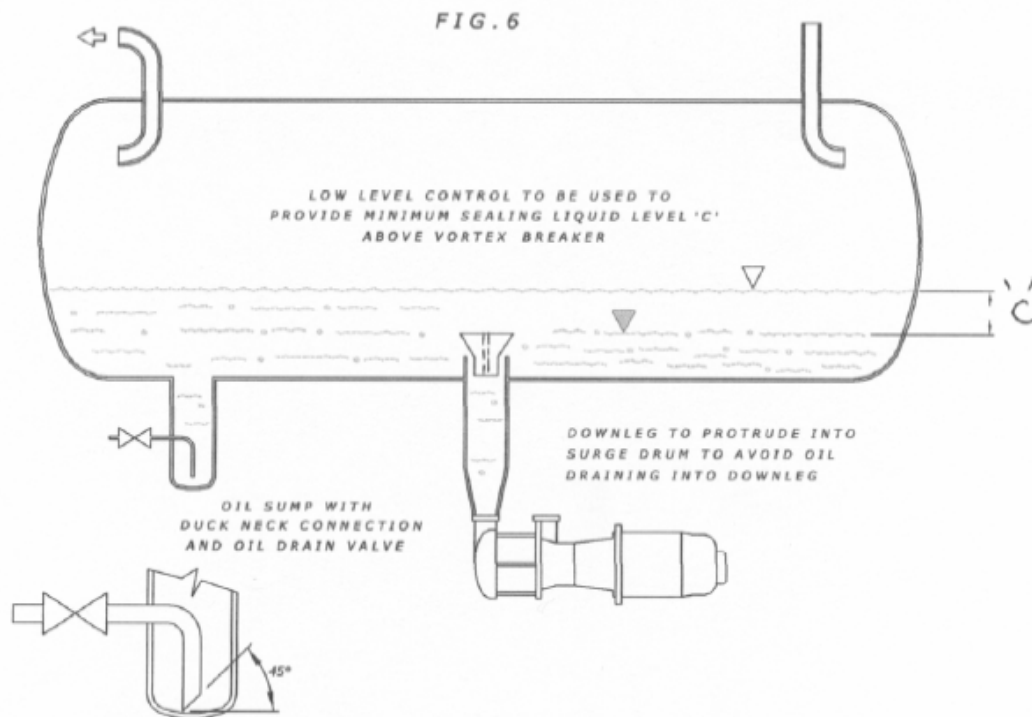
Surge Drum Design, Low Pressure Systems

The shape and size of the surge drum, position of connections, and design of oil drain all have an influence on the performance of the pump installation.

Each pump should be connected to the surge drum individually to avoid interaction with other pumps. The use of a Vortex breaker is most important to avoid cavitation in the liquid down legs to the pumps.

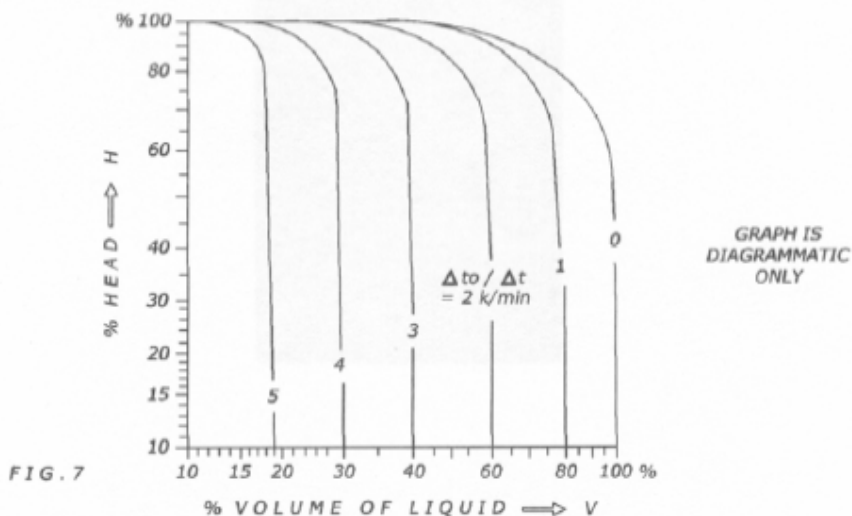
A horizontal type surge drum is preferred to provide sufficient surface for the settlement of oil in the drum and to enable stable suction head conditions.

When sizing the refrigerant sealing charge for the surge drum it is important to ensure a good sealing level with a minimum level indicated to avoid draw down of bubbles or cavitation into the liquid down leg. Fig 6.



Pull Down Conditions inside Drum

The adverse effect of fast system pull down is illustrated by Fig 7, which shows that when the evaporation temperature drops in pull down conditions, large quantities of vapour bubbles are formed in the surge drum, temporarily reducing the mass flow of liquid.



This graph is a very valuable tool to understanding what effect a fast pull down will have on the quality of refrigerant inside the surge drum.

The horizontal axis (V) illustrates the reduction of liquid refrigerant per specific evaporation temperature drop K/min. From the graph it can be seen at

5 K/min the amount of liquid is approx 18% with approx. 82% vapour. When the pull down is reduced to 2 K/min the percentage liquid increases to 60% while the vapour reduces to 40%.

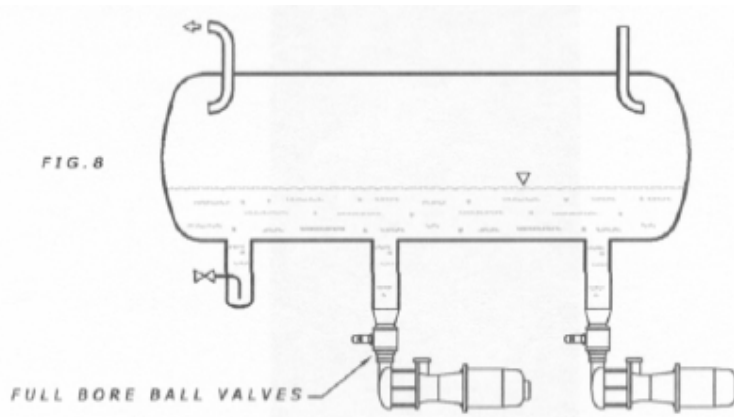
The vertical axis (H) illustrates the percentage loss of pumping head at the different conditions.

Down Leg Design

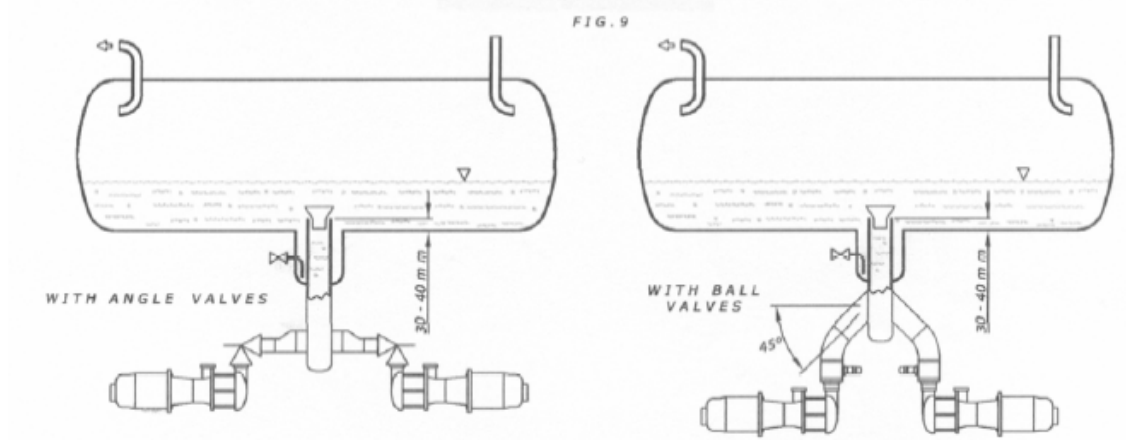
The pressure at the top of the suction down leg is equal to the system saturation pressure in that part of the refrigeration circuit. When the pressure is reduced by compressor start up or increased capacity, boiling of the refrigerant occurs throughout the liquid in the surge drum/low pressure receiver.

All the gas bubbles formed in the liquid column above the pump will collapse and condense on entering the pump. When this occurs it will cause cavitation inside the pump. The effect of cavitation is to reduce pump delivery mass flow and possibly damage pump internal parts. Design of the down leg and determination of the correct diameter is of great importance.

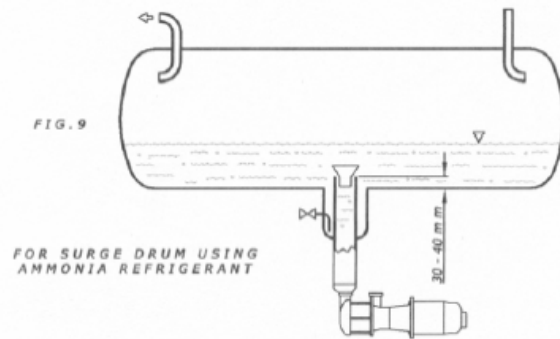
To prevent interference between pumps it is advised that each pump be connected individually to the separator, fig 8.



When a stand-by pump is to be used, an installation according to fig 9 is recommended.

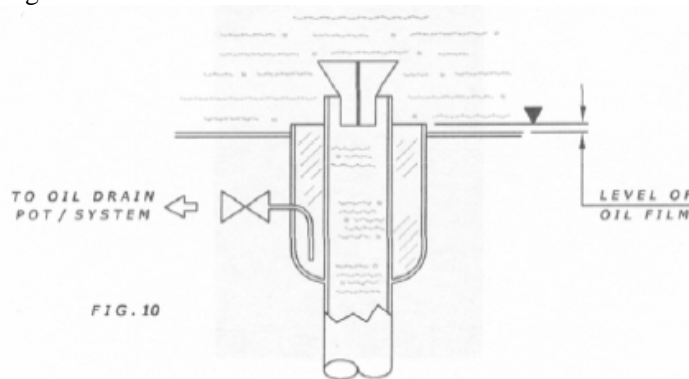


The down leg should protrude (30 – 40 mm) into the surge drum and be fitted with anti vortexing device.



Oil Draining

For ammonia systems an oil drainage dome can be installed around the down leg to the pump. This will ensure that any oil in the surge drum can be collected and drained separately before entering the refrigerant pump/s fig. 10.

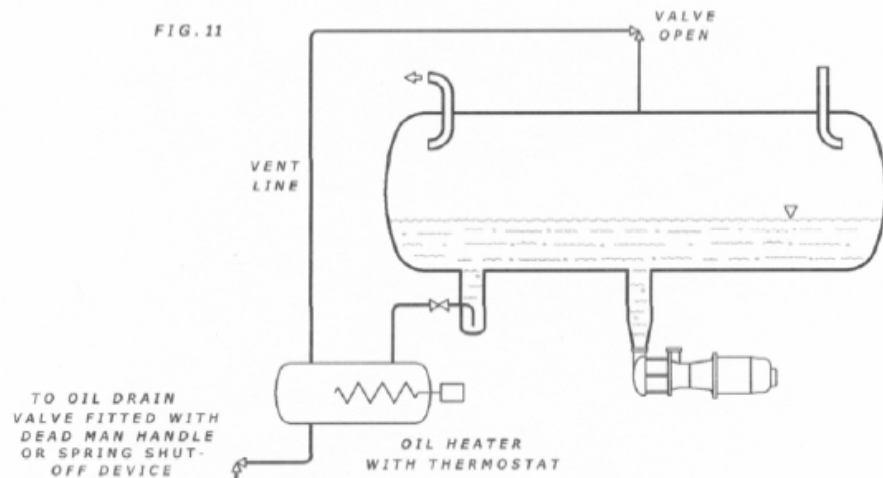


When designing the vertical down leg care must be taken to ensure that oil does not drain into the running pump or stand by pump connections.

Oil Purging and Oil Return

For ammonia systems the pump line connection should be made a few centimetres above the bottom of the surge drum in order to prevent entrainment of oil.

Oil can also be drained into a separate small uninsulated oil pot positioned below the surge drum. This oil pot may be fitted with a small heater and safety controls to facilitate oil removal. Fig 11.



Down Leg Liquid Velocity

The diameter of the down leg has to be sufficient to keep the liquid velocity to below 0.3m/sec; at this velocity gas bubbles in the liquid refrigerant can rise and return to the surge drum. Fig 4.

Any gas accumulation in the suction line and particularly in valves attached to the pump must be avoided. Gas bubbles should be able to flow back to the separator unhindered, counter to the liquid flow. This is important when the pump is not in operation.

To ensure the pump will operate at a low pressure difference resulting in maximum capacity, the diameter of the downleg to the pump should be sized as detailed in the table below.

Guide Sizes for Down Leg to Pump

Approx. Pump flow rate	5m ³ /hr	12m ³ /hr	15 m ³ /hr	35 m ³ /hr	70m ³ /hr
Pump suction size	32 mm	50 mm	50 mm	80 mm	100mm
Down leg	80 mm	100 mm	125mm	150 mm	250 mm

The Pump Suction Connection

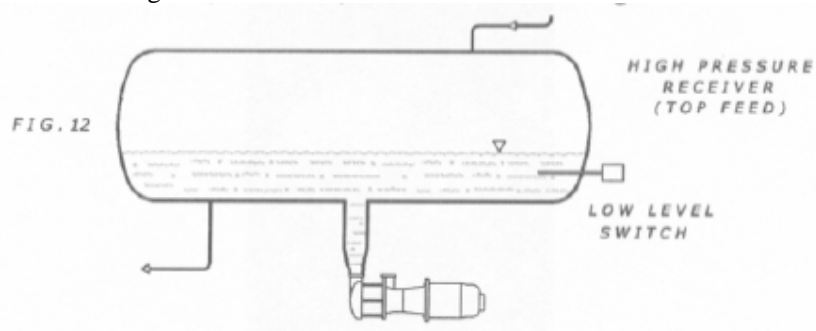
Horizontal pipework connections must be avoided.

Shut off valves in the suction line shall be sized generously and without reducers to enable purging. Installation of full-bore ball valves is recommended in the suction line to the pump. If straight through shut off valves are used these must be installed with the stem in the horizontal position; ball valves should not have a reduced bore on the pump side connection. It is recommended the design engineer installs any additional line filters or driers in the pipe work in front of the pump.

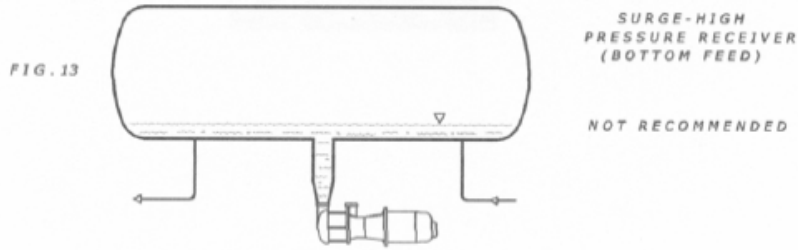
Pump re-circulation for Compressor Oil Cooling

When hermetic pumps are used for pumping high temperature liquid at condensing pressure and temperature the cooling capacity of the liquid is reduced and the temperature difference available is smaller.

It is important where the liquid supply is taken from the main high-pressure receiver that the receiver is fitted with a low level switch alarm. This low level alarm should be in circuit to stop the pumps if the liquid level is too low. Fig 12.

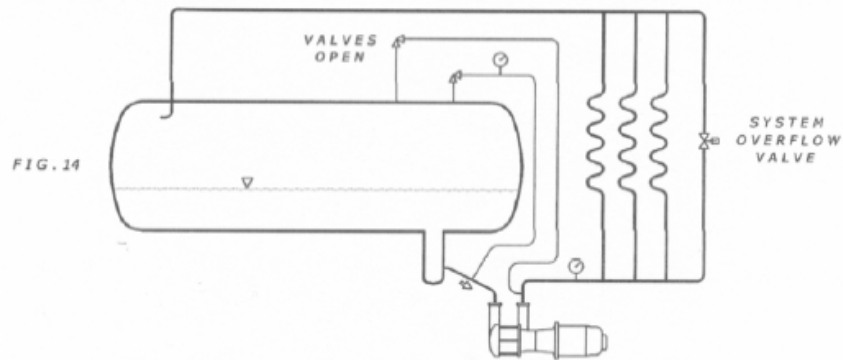


A surge receiver or horizontal liquid main feeding the surge receiver should not be used to feed the pumps because the surge receiver might not contain any liquid. Fig 13.



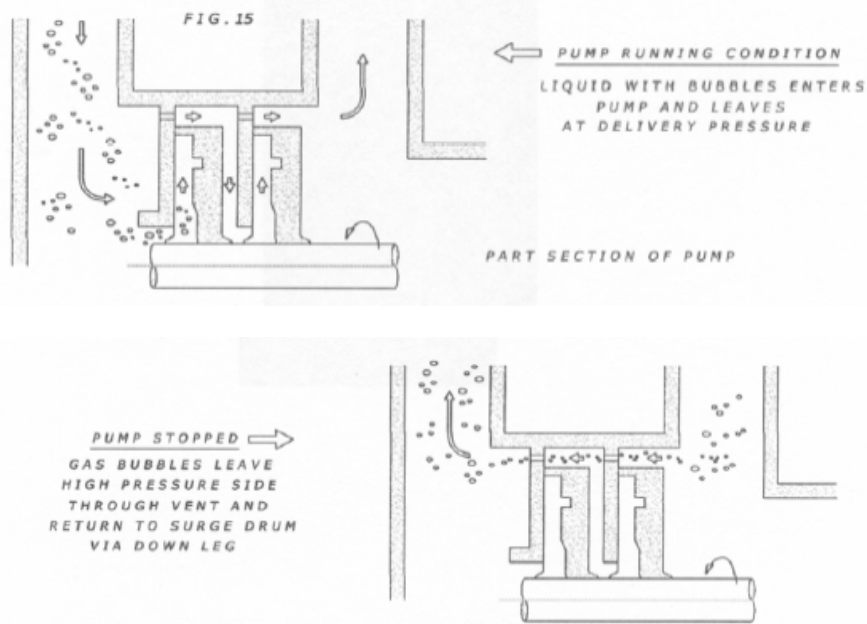
Self Venting of Hermetic Pumps

The traditional method of externally venting or purging of refrigerant pumps was to install a separate connection under the discharge valve inlet. This connection could be used for installing a vent line and pressure gauge connection. Fig 14.



The modern self venting refrigerant pump is designed with special designed intermediate pieces. On top of each intermediate piece there is a small by-pass hole connecting the discharge side to the suction side.

When gas has collected in the pump discharge chamber it can escape through these vent holes into the suction chamber and then return to the surge drum. Fig 15.



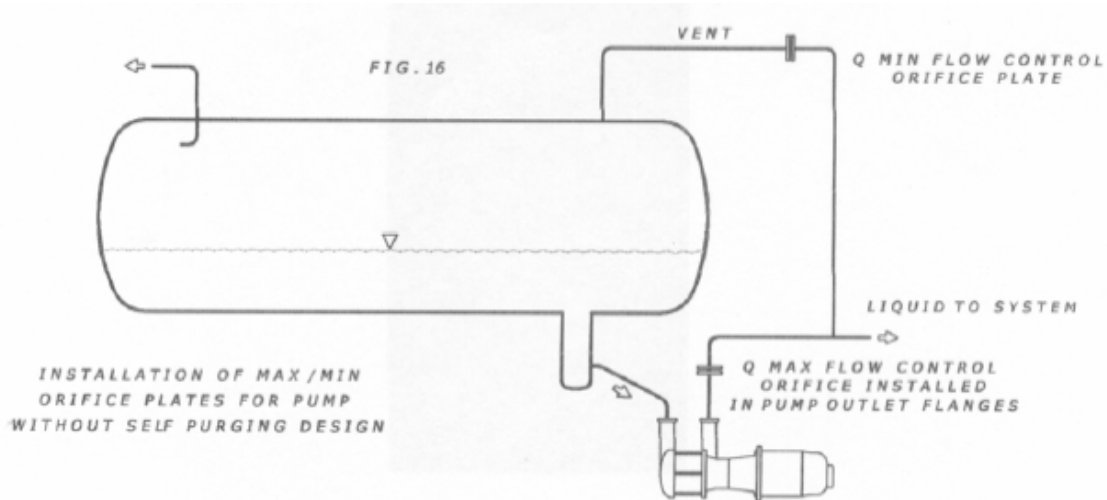
For pumps without a self purging design correct venting should be made as shown in fig.14. If more than one pump is installed each pump must have its own venting arrangement.

Depending on the design of the hermetic pump correct venting of a pump to cope with the effects of vapour entrainment and internal recirculation is essential. Vapour entrainment can lead to the collection of vapour at the impeller reducing the pump capacity (effective flow rate) for pumps which are not self purging (cam type).

When required the vent line should be taken off the top of the pump to minimise the possibility of vapour collecting in the pump.

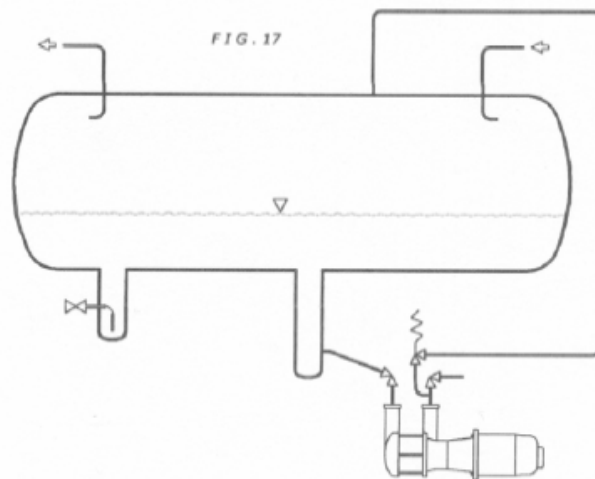
Discharge Pipe work

The discharge pipe work should be designed to ensure a liquid velocity of 1.5m/s or less. The pipe work from each pump should be fitted with a suitable stop check valve when two or more pumps are connected to one discharge manifold to avoid reverse running of refrigerant pump while not in use. Some types of centrifugal hermetic pumps have to be fitted with external minimum and maximum orifice plates. These are installed in small-bore pipe work around the pump and in the discharge pipe work respectively. Fig 16.



Hydraulic Lock

Small relief valves around the pumps are required to avoid hydraulic locking if it is possible for both the pump isolating valves to be closed at the same time. Fig 17.



Hermetic pumps should not be run against a closed head, which can cause premature wear on the impellers and intermediate parts.

The correct method of safely relieving the pump pressure is to install at the end of the liquid main a differential pressure regulating valve to act as an overflow valve. Fig 14.

Pump Suction Filter

The need for suction filters is particularly related to pumps where dirt can cause wear or jamming as in gear, turbine and canned pumps. These filters need regular inspection during commissioning and after major system overhauls.

Oil in ammonia systems may clog screen filters.

Trapped Liquid

Precautions have to be taken to avoid trapped liquid in pumps, particularly between non return valves and solenoid valves.

If subcooled liquid contained in the pump is allowed to warm up the pressure will increase rapidly to an unacceptable level which may cause the pump or pipe work to fracture. At all times pumps containing subcooled liquid should have the suction valve open.

Adequate precautions must be taken at all times by the design engineer to prevent any liquid from becoming trapped inside a pump.

Guide to Flow Rates

The evaporators have to be supplied with sufficient liquid refrigerant, so that the surfaces of the evaporators are fully used, and a sufficient supply of liquid to evaporators in different locations or with different duties is obtained.

The required refrigerant flow is calculated from the refrigerant evaporation rate in the low side evaporators times the re-circulation rate (pump ratio).

The re-circulation rate depends on the type of evaporator equipment and operation conditions.

Typical re-circulation rates are given in the following table

Application	Refrigerant		
	CO ₂	NH ₃	R22
Air Coolers	1.2 – 2	3 – 4	2 - 3
Plate Freezers	5 – 10	7 – 14	5 - 12
Liquid Chillers	1.2 – 1.5	1.2 – 1.5	1.2 – 1.5

Pump Arrangement

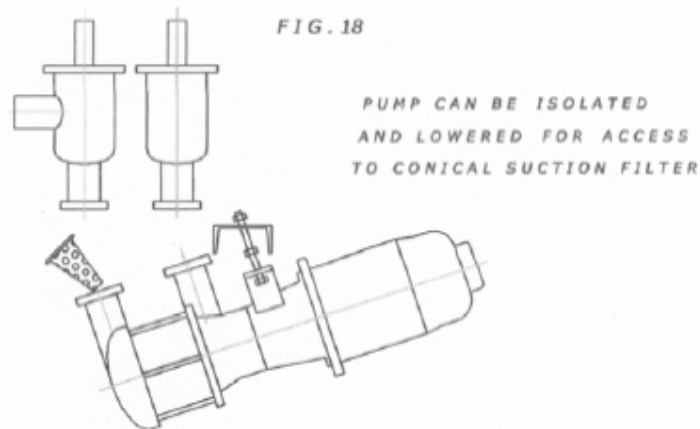
To ensure trouble free operation some basic rules need to be applied to the installation of the hermetic type refrigeration pump.

The pumps and pipe work should be arranged under the low pressure receiver allowing sufficient access space around the pumps for removing or replacing, servicing valves, setting the pressure

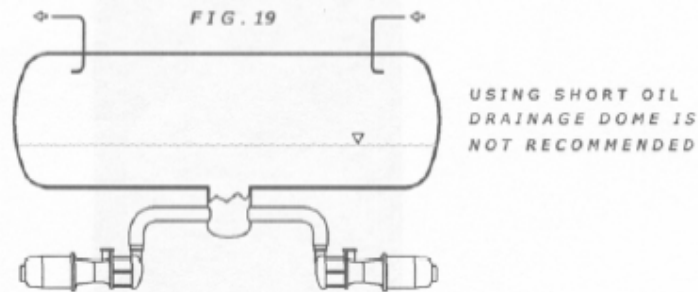
difference control, inspection and cleaning of the inlet filter. Also allow space for normal ice accumulation around the pump.

The vertical distance between bottom of the separator to the pump centre (h_2) shall be at least 1m. Greater distance is an advantage as the pump will be less sensitive to system pressure fluctuations. Fig 1.

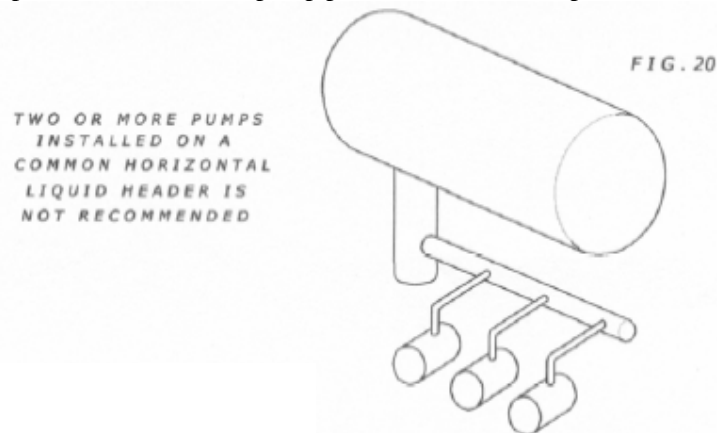
The use of top support feet has several advantages for refrigerant pumps. This reduces stress in the pump body and pipe work when the temperature is very low, (-40°C), gives good access to the pump suction filter and facilitates the mounting and cleaning of condensate drip tray. Fig 18.



A standard short oil drainage dome is not suitable for connecting a pump suction down leg. Fig 19.



Do not connect two or more pumps in operation by a single common pump suction line liquid horizontal header, as the gas bubbles in the liquid are not able to return to the surge drum and will be drawn into the pump inlet and reduce the pump performance or cause premature failure. Fig 20.



Safety and Electrical Information

To prevent damage to the pump shaft bearings, the pumps must not be allowed to run dry. The following electrical equipment should be installed:

- overload protection switch, maximum setting to be lower than value on name plate.
- thermal cut out device, which interrupts the control voltage to the motor relay when the motor temperature exceeds a critical set value.

The pumps should not be restarted until the cause has been investigated. Restarting of the pump should not be allowed more than six times per hour.

Various safety equipment should be used to protect the pump including pressure differential switch, flow switch, minimum level cut out switch mounted on the drum and a differential pressure regulating valve.

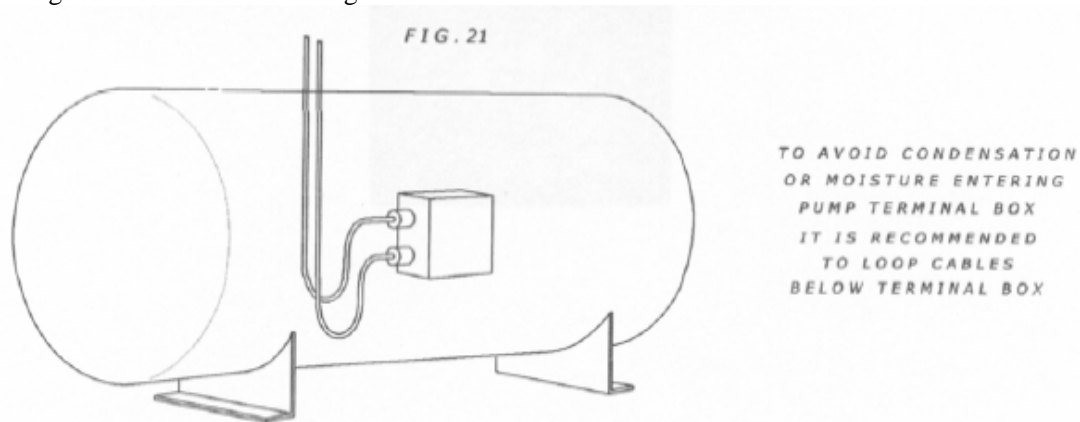
Direction of Pump Rotation

This can be determined by marks on the pump and by the examination of the terminal box wiring.

Electric Cable

It is important that all electrical cables are connected with a loop to the terminal box to allow movement of the pump.

By using a small loop in the cable, any condensate that may run along the cable is prevented from running into the terminal box. Fig 21.



To prevent accidental touching of the electrical connections and dirt or moisture entering the terminal box the sealing top must be fitted at all times.

Oil compatibility with system

Factory tests are sometimes carried out using mineral refrigerant machine oil. If the pump is to be used in systems where contamination with mineral oil is not allowed for example in cases with ester oil in the system, the residual oil must be removed and the pump cleaned by use of solvents.

Prior to Commissioning – some recommendations

- The refrigeration system must be pressure tested, vacuum tested and be fully charged with refrigerant
- The suction and discharge valves must be fully open

- The valves of the pressure differential control, if fitted must be fully open
- The pressure differential switch, if fitted, must be set at a difference of at least 20 kPa above the system static height. (Static height equals liquid column plus pressure difference between the cooler inlet and the separator)
- A sufficient volume of refrigerant must be present in the separator or low-pressure receiver for a minimum running time of approximately 2-3 minutes
- The electrical control system including all safety controls must be pre-tested prior to starting the pump
- Check wiring for the correct rotation of the motor

Commissioning Procedure

- It is easier to prime the pump by starting it before starting the compressor
- Check and record the pressures in the system
- If the system pressure difference is smaller than expected, the pump may be rotating in the wrong direction. The pump rotation should be checked by measuring phase sequence. If this is necessary, switch off electrical system; change over two connecting cables and test pressure difference again.
- If you hear unusual, or unfamiliar sounds from the pump, switch off the pump immediately and investigate the cause.
- When the pump operates normally, check the pressure difference after 2 hours, after 8 hours and occasionally thereafter, and record the measured values.

Preventative Maintenance

After a period of trouble free operation, (one/two weeks) the pump filter should be inspected for dirt and contamination. Depending the degree of contamination the pump inlet should be regularly inspected until the system is clean.

The following items should be checked frequently:

- suction filter for contamination
- pump re-circulation pipework for oil contamination
- the pressure differential of the pump
- the bearing wear indicator (Witt type pump)
- listen to the running sound of the pump. Crackling noise indicates oil contamination
- Once a year, or as dictated by the classification rules, the pump operation, settings and all safety provisions should be checked.
- The date, time and results of each inspection should be recorded together with the serial number

Stand-by Pump

During periods of pump standstill, only one main valve should be closed, preferably the discharge valve to avoid trapping cold liquid in the pump.

If the stand-by pump is contaminated by oil, the oil must be drained before restarting the pump. Failure to ensure the pump is clear of oil can lead to failure of the pump. Oil prevents sufficient cooling of the bearings resulting in an unacceptable overheating of the pump.

When the pump oil is to be drained while the pump housing is still under pressure, a self-closing valve must be used in addition to the drain valve. Oil from the discharge chamber or in between the intermediate pieces can only be partly removed from the pump. At low temperatures when oil removal is slow the pump may be warmed up with hot water to lower the viscosity of the oil making it flow more easily. The oil return system from the surge drum should be checked or modified to prevent further oil contamination of the pump.

Lead/Lag pump change over procedure

When two or more pumps are installed one of the pumps may be used as a lead pump with the other pump/s on stand-by.

Problems can occur due to oil accumulating in the down leg due to the down leg acting as a still with the refrigerant boiling off. This oil accumulation can lead to pump failing to start or to pump damage.

A suitable lead/lag change over procedure should be designed into the control system so that the lead pump is switched over periodically to act as the lag machine.

A change over frequency of 2 to 3 days is recommended. For a heavy oil contaminated system a daily change over may be necessary.

Service and Maintenance

Only trained refrigeration engineers should carry out any work on the refrigeration plant.

Only a qualified electrician should carry out any work on electrical equipment or controls.

Removing a pump

Follow all national and local safety requirements when removing the pump. Particular care must be taken of the following: -

- wear the correct protective safety clothing, as minimum use of safety goggles and gloves, in case of ammonia, have a respirator within easy reach
- check the plant room layout and exit doors so you can evacuate the area quickly in case of an emergency
- seek assistance to handle and remove the pump
- stop valves should be labelled when closed

Isolate the pump by switching off and locking off the electrical supply and the electrical controls. A label should be fixed to control panel to indicate pumps are switched off and are being worked on. Note the sequence of electrical connections and disconnect the wiring.

Before moving or tilting the pump e.g. to access or to clean the inlet filter, the refrigerant must be discharged. It is recommended that the refrigerant is purged to the dry gas side of the surge drum. Warm water may be used on the outside of the pump to accelerate the boiling off of the liquid refrigerant.

Never use naked flame or open fire to warm up the pump.

When there is no liquid refrigerant left in the pump, carefully depressurise the pump. Be aware of any trapped liquid or leaking valve seats. Particular care must be taken in draining ammonia pumps, where subcooled liquid ammonia can remain in low parts of the system even when they are opened to atmosphere.

Damaged rotor can

You cannot automatically detect whether the rotor can is damaged or is leaking since the stator housing is designed for the same allowable pressure. To find out whether refrigerant has penetrated into the stator housing loosen carefully the screw plug on the motor cover.

Use a leak detector or if NH₃ is used you can use litmus to check whether refrigerant is present in the transformer oil.

Warnings

For hermetic pumps all rotating parts, including bearings and motor rotor are in direct contact with the refrigerant.

Any unusual running conditions other than stable operation will have an influence on moving parts particularly the bearings. Dirt, oil and large pressure fluctuations may shorten the life of the bearings.

The suction side pipe work of the refrigerant pump is a critical area of design where valve economies or too small sizes can cause considerable site running problems.

Stated temperature and pressure limits should not be exceeded.

Pump should not be removed unless the system has been drained and evacuated.

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TROUBLE SHOOTING

No.	Symptom	Possible causes
1	Pump makes Scratching noise	<ul style="list-style-type: none"> - noise comes from outside - foreign material in pump - lack of refrigerant - conical filter is blocked - too fast decrease of the evaporating temperature - impellers or intermediate pieces worn out - bearings worn out - rotor in contact with can
2	Capacity too low (valves on pump open)	<ul style="list-style-type: none"> - direction of rotation wrong - frequency of the pump too low - stop valves behind the pumps closed - too much gas in liquid - liquid level in separator too low - valves on cooler closed - regulating valve not opened far enough - overflow valve closed or pressure set too low - contamination is blocking the piping system - non return valve of another pump leaks - dirt in pump strainer or at the coolers - power supply not right, working on only 2 phases - impellers worn out - oil in pump at low temperature - not sufficient suction head
3	Switched off on pressure switch	<ul style="list-style-type: none"> - see number 2 - set value of pressure control not right - hand control valves in system opened too much - too quick start up or capacity steps of compressor(s) - too quick switch off of big capacities
4	Switched off on flow switch	<ul style="list-style-type: none"> - see number 2 - set value of flow switch not right - suction side or discharge side closed - too quick start up or capacity steps of compressor(s)
5	Switched off by too high temperature	<ul style="list-style-type: none"> - motor overloaded - switching too frequently on/off (> 6/hr) - dirt on strainer around shaft - bearings worn out, especially the tail bearing - rotor in contact with can - too much oil in refrigerant
6	Switched off by too high power consumption	<ul style="list-style-type: none"> - rotor in contact with can - too much dirt in refrigerant - flow too large - too much oil in low temperature refrigerant
7	Life time of bearings too short	<ul style="list-style-type: none"> - see above points - set value pressure diff. control too low - too much dirt in system - too much gas in liquid - small particles in system
8	Motor protection/fuses trip the pump	<ul style="list-style-type: none"> - moisture in the terminal box: check the connections and seal the terminal box - pump is blocked (see above)