ARC Technical Resources

AUSTRALIAN REFRIGERATION COUNCIL

Evacuation: Stationary Refrigeration and Air Conditioning Systems

The main purpose of evacuating a refrigeration or air conditioning system is to remove moisture and non-condensables which include air and nitrogen from the pipework and components. Non-condensables in the system will cause high discharge pressures and therefore inefficient operation.

Moisture in the system will be picked up by the refrigerant and form ice crystals at the expansion device, resulting in a restriction or blockage until it warms up, melts and allows the refrigerant to flow again. This results in intermittent operation of the system. Moisture mixed with refrigerant creates an acid which results in corrosion of steel and to a lesser extent copper and brass. In hermetic compressors this acid eats through the motor windings' protective lacquer and results in a burnt-out compressor. When this acid mixes with refrigerant oil, fine beads of sludge are formed, which reduces the lubricating ability of the oil and blocks fine strainers and expansion devices.

Therefore, it is vital to ensure that all non-condensables and moisture are removed from refrigeration and air conditioning systems by evacuating the system using a high vacuum pump, before the refrigerant charge is added. Evacuation lowers the pressure in the system so any moisture will boil off and the resulting water vapour and non-condensables will be removed. Refer to the table below to see the effect of lowering pressure on the boiling temperature of water.

For example, at normal atmospheric pressure, water boils at 100°C, but when the pressure is reduced to 17,300 microns (-99 kPa gauge) water will boil at 20°C.

Boiling Temperature of Water at Given Pressures

Temperature °C	Gauge Pressure kPa	Microns of Mercury
100	0	759,968
90	-31.3	525,526
80	-54.0	355,092
70	-70.1	233,680
60	-81.4	149,352
50	**-89.0**	**92,456**
40	-94.0	55,118
30	-97.0	31,750
20	-99.0	17,300
10	-100.0	9,279
0	-100.7	4,572
-10	-101.015	2,315
-20	-101.185	1,065
-29	**-101.255**	**500**
-30	-101.265	460
-40	-101.305	185
-50	-101.315	68
-60	-101.320	23
-70	-101.323	7

What pressure must the system be evacuated to?

This is determined by referring to the following Codes of Practice and Standards which are called up in the of Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995:

- **Australia and New Zealand Refrigerant handling code of practice 2007 – Part 2 Systems other than self-contained low charge systems**

  Section 5 Installation procedures, states the following:

  - 5.2 The installer must ensure that all tools and equipment used during the installation process (including but not limited to vacuum pumps, tools and gauges) are appropriately rated for the refrigerant being used in the installation and are in serviceable condition.

  For example, if the system is to operate on R32, the vacuum pump must be rated as suitable for class A2L Lower Flammability refrigerants and serviced per manufacturer's instructions to ensure its effective operation.

  Section 6 Evacuation, states the following:

  This section refers to evacuation in the field only – not evacuation during the manufacturing process.

  - 6.3 The system must be evacuated to remove moisture and non-condensables after determining that there are no refrigerant leaks when the system is pressurised.
  - 6.4 Evacuation must be either the deep evacuation method, or triple evacuation using dry nitrogen only as the moisture absorber, following the procedures described below.
    - Deep vacuum method:
      Pull a deep vacuum to a pressure of less than 65 Pa absolute (500 microns of mercury). After isolating the vacuum pump, allow the system to stand for 60 minutes to ensure the vacuum is maintained at or below 78 Pa absolute (600 microns of mercury); OR
    - Triple evacuation method:
      Use a vacuum pump to pull a vacuum to a pressure of at least 65 Pa absolute (500 microns of mercury). Break the vacuum with dry nitrogen and allow the system to stand. Re-evacuate the system and repeat the procedure twice more, breaking the vacuum each time with dry nitrogen.
  - 6.5 After the system has been evacuated the vacuum pump should be isolated from the system. As a guide, with constant ambient conditions, the vacuum should not rise more than 13 Pa (100 microns of mercury) in one hour. A greater rate of rise may indicate a leak or the presence of moisture (see also 8.1.17).
  - 6.6 Absolute vacuums must be measured using accurate measuring equipment selected for the specific application.

  That is, the system must be evacuated using either the deep evacuation method, or triple evacuation method to achieve a vacuum of at least 65 Pa absolute (500 microns of mercury) and the vacuum should not rise more than 13 Pa (100 microns of mercury) in one hour once the vacuum pump is isolated from the system and turned off. The vacuum must be measured with an electronic vacuum gauge, not manifold gauges as they are not accurate enough to measure the vacuum.

- **Australian standard AS/NZS 5149.2:2016 Refrigerating systems and heat pumps - Safety and environmental requirements, Part. 2: Design, construction, testing, marking and documentation**

  It states in:
  - 5.2.3.6 Requirements for piping installed at site
    - Connecting pipe joints (e.g. in the case of split systems) shall be made before opening the valves to permit refrigerant to flow between the refrigerating system parts. A valve shall be provided to evacuate the interconnecting pipe and/or any uncharged refrigerating system part.

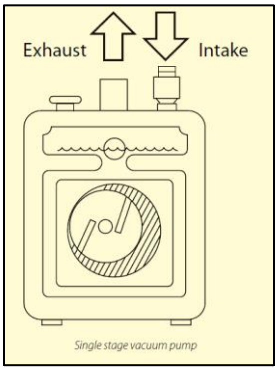
  Australian standard AS/NZS 5149.4:2016 Refrigerating systems and heat pumps - Safety and environmental requirements, Part. 4: Operation, maintenance, repair and recovery

  It states in:
  - 5.4.3 Execution of the change of refrigerant type
    Follow the recommendations of the equipment manufacturer; the compressor manufacturer; the refrigerant supplier or apply the following procedure in accordance with the plan developed according to 5.4.2:
    h) evacuate the system to less than 132 Pa absolute pressure (990 microns);

What type of vacuum pump should be used?

The 2 main types of high vacuum pumps used in the field during installation and service work are:

1. Single Stage Vacuum Pumps

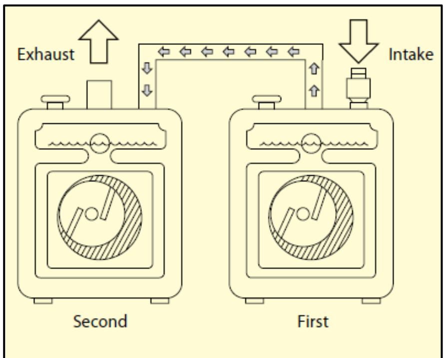


Single stage high vacuum pumps are smaller, lighter in weight and less expensive than two-stage pumps of equal capacity in L/min.

There are single stage vacuum pumps available which can pull down to about 50 microns under ideal laboratory conditions, but this is not achievable in the field as they discharge directly into the atmosphere.

A gas ballast feature helps single stage pumps to keep the oil free of moisture and other contaminants for a longer period of time than similar units without. Most single stage pumps with the gas ballast open will pull down to about 1000 microns. Once this vacuum is achieved the gas ballast can be closed to achieve a lower vacuum.

2. Two Stage Vacuum Pumps



Two stage vacuum pump

Most refrigeration/air conditioning service technicians use a two-stage high-vacuum pump for the bulk of their service jobs as they can achieve a lower vacuum in less time. The exhaust of the first pumping stage is discharged into the intake of the second pumping stage, rather than to atmospheric pressure.

Two-stage high-vacuum pumps with a gas ballast can continuously pull down to 20 microns for prolonged periods of time which will help to ensure that all moisture and non-condensables are removed from a system.

To ensure the required vacuums are achieved by the vacuum pump, regular maintenance including oil changes must be performed as moisture from the system will condense into the pump's oil. If it is allowed to remain inside the pump, this moisture will attack the metal components and result in lock ups or loss of efficiency and/or capacity.

What size high vacuum pump is required?

To determine the size of pump needed, use the following formula:

$$\text{Pump capacity in litres/min} = \frac{\text{Max. System Size (kW)}}{\text{Factor } 1.15}$$

$$\text{Example: } \frac{102.6 \text{ kW}}{1.15} = 118 \text{ litres/min}$$

On systems larger than the pump's capacity, it is recommended to use either a larger pump or two or more pumps to achieve the correct pump rate. However, the vacuum achieved will only be as good as the worst performing pump.

This chart gives a reasonable idea of what capacity pump you need for various applications. These are suggested minimum litres/min. Slightly larger capacity high vacuum pumps can be used on smaller systems. However, oversized pumps on systems containing large amounts of water can actually drop the pressure so fast that ice forms.

The evacuation time can be significantly reduced by using short, large diameter hoses.

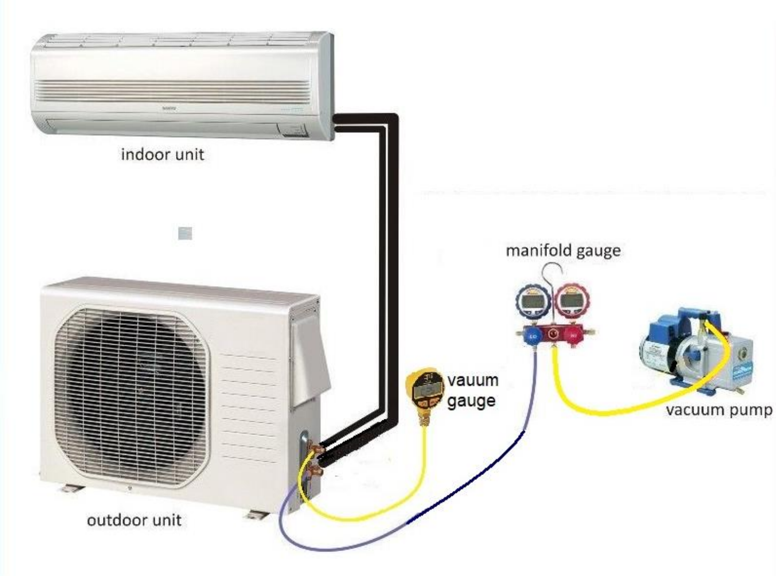
System Capacity	Suggested High Vacuum Pump Size
Up to 30kW	35 litres/min
Up to 75kW	85 litres/min
Up to 123kW	140 litres/min
Up to 246kW	280 litres/min
Up to 370kW	425 litres/min

How must the vacuum be measured?

Manifold gauges are not accurate enough to measure a vacuum. The level of vacuum must be measured with an electronic vacuum gauge as they are specifically designed for use with high vacuum pumps and can be accurately read as low as 1 micron. The output can be a digital display or LED sequence display per the examples below.

Where must the vacuum be measured?

When reading vacuum, the closer to the vacuum pump, the lower will be the reading, so the vacuum gauge should be fitted as far away from the pump as possible to accurately measure the vacuum in the system, not at the pump, per the example below.



When reading the vacuum created in a refrigeration or air conditioning system, isolate the vacuum pump using an isolation valve and allow the pressure in the system time to stablise before taking a final reading.

If the vacuum pressure continues to rise, it is an indication of a leak. If it does stablise at a pressure which is too high, it is an indication of moisture and more pumping time is required.

SUMMARY

- The main purpose of evacuating a refrigeration or air conditioning system is to remove non-condensables and moisture from the pipework and components by lowering the pressure to enable water to boil off at ambient temperature.
- The system must be evacuated using either the deep evacuation method, or triple evacuation method to achieve a vacuum of at least 65 Pa absolute (500 microns of mercury) and the vacuum should not rise more than 13 Pa (100 microns of mercury) in one hour once the vacuum pump is isolated from the system and turned off.
- The vacuum must be measured with a vacuum gauge, not manifold gauges as they are not accurate enough to measure the vacuum.
- The vacuum pump must be rated as suitable for the class of refrigerant, have an appropriate capacity for the system and be serviced per manufactures instructions to ensure its effective operation.
- Two stage vacuum pumps with a gas ballast can achieve lower vacuums than single stage vacuum pumps.
- The vacuum gauge should be fitted to the system as far away from the pump as possible to accurately measure the vacuum in the system, not at the pump.
- The oil in vacuum pumps must be changed regularly as moisture from the system will condense into it and reduce its efficiency.