Sizing Vacuum Pumps

Pumping speed, or capacity, is measured in terms of gas volume drawn in a length of time. Cubic Feet per Minute (cfm) or Cubic Meters per Hour (m^3/h) are the two standard measurements. The number corresponds to the volume of the suction chamber multiplied by the pump revolutions in the time unit and by a correction coefficient which is usually 0.85.

Conductance

As and example, for a pipe with a constant gas flow of Q, the quantity of conductance, C, can be expressed by:

$$C = \frac{Q}{P_2 - P_1}$$

Where P_2 and P_1 are the pressures at pipe sections 2 and 1 respectively. From a physical standpoint, conductance equates a resistance and expresses the ease which the gas flow Q passes along the pipe itself.

Conductance is a function of two factors: circuit configuration and pressure.
Conductance is relatively high when pump-down begins, and decreases progressively. Its values are particularly low for vacuum levels better than 1 mbar. For a typical straight tube with round sections, having a length (L) much larger than the diameter (D) conductance is calculated by means of the following formulae:

Viscous or Laminar Flow: When P x D > $5x10^{-1}$ torr x cm:

$$C = \frac{135xD^4}{L}xP \qquad [1 \cdot s^{-1}]$$

Molecular flow: When P x D < $1x10^{-2}$ torr x cm

$$C = \frac{12.1xD^3}{L} \qquad [1 \cdot s^{-1}]$$

It is understood that conductance under molecular flow is independent of the pressure P, not included in the second formula. So, the Viscous or Laminar flow is used most of the time when talking about conductance.

Actual Speed

The actual speed at a specific point of the circuit *A* never matches the nominal pumping speed *S* due to the constrictions and pressure fluctuations in the circuit itself. The actual speed looks more like this:

$$\frac{1}{A} = \frac{1}{S} + \frac{1}{C}$$

A refers to the hypothetical point in the circuit where the actual speed is present, where *C* is the conductance of the circuit between the pump inlet and section *A* of the circuit.

Assessing Optimum Pumping Capacity for Evacuating Refrigeration Circuits

Assuming a vacuum pump and standard refrigeration circuit, connected by means of quick release couplers and vacuum hoses to a tube 40 cm long x 1 cm in diameter, the conductance is considered to be 1 mbar.

The conductance is calculated from the Viscous or Laminar Flow formula, by adding the coefficient 3.6 the units l/s are converted to m^3/h

$$C = \frac{135x3.6x1^4}{40}x1 = 12.15m^3/h \text{ (7.2 CFM)}$$

Example 1
A pump having a nominal pumping speed (S) of 100 m^3/h and tube conductance (C) of 12.5 m^3/h, the actual speed, as determined by the formula above, at the service port is:

$$A = \frac{SxC}{S+C} = \frac{100x12.15}{112.15} = 10.8m^3/h \text{ (6.4 CFM)}$$

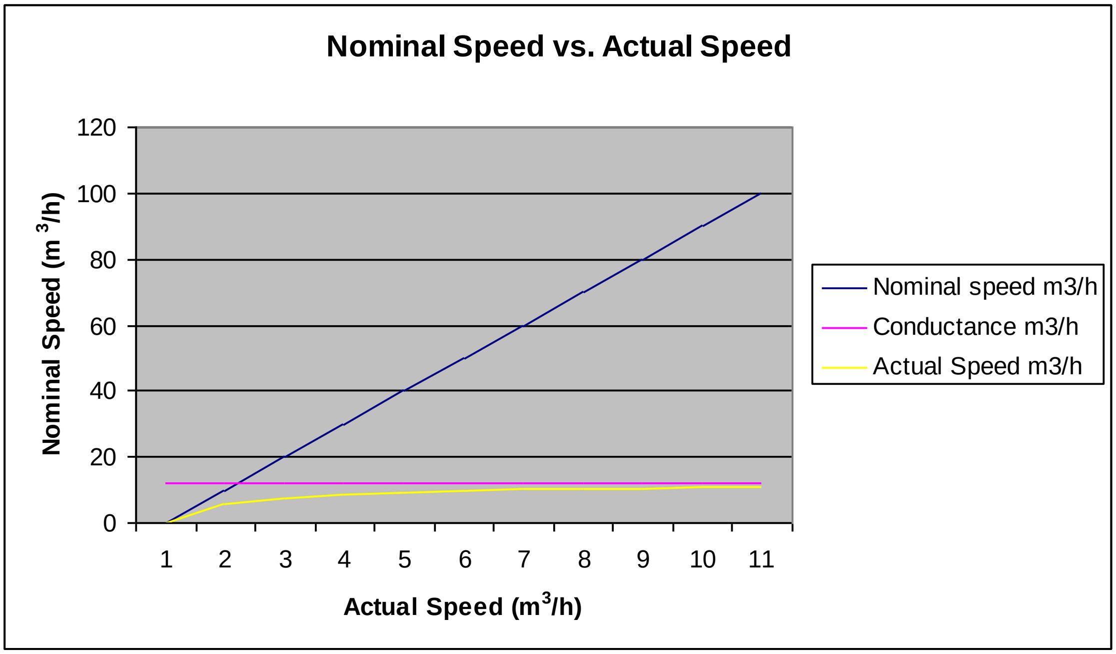
Example 2
A pump having nominal pumping speed (S) of 20 m^3/h and the same tube conductance of 12.15 m^3/h, the actual speed is:

$$A = \frac{20x12.15}{32.15} = 7.56m^3/h \text{ (4.5 CFM)}$$

It is clear to see from these two examples that it is pointless to employ large capacity pumps where smaller ones will suffice. High capacity pumps have other applications, such as those using large vacuum chambers, but in a smaller refrigeration circuit, a 100 m^3/h pump will generate only 30% more pumping capacity at 5 times the size of a 20 m^3/h pump.

In business language, that is a poor return on investment. Conversely, an undersized pump, with a nominal pumping speed less than 10 m^3/h would involve a much longer initial pump-down time to reach the required pressure of 1 mbar from atmospheric pressure.

The optimum capacity is from 10 to 20 m^3/h (5.9 to 11.8 CFM), allowing the desired vacuum level of 1 mbar to be obtained in a reasonable amount of time.



Using pumps that are too large is not only wasteful but may be dangerous as the larger suction capacity during initial pump-down causes an accelerated evaporation of moisture inside the system, causing freezing inside the circuit tubes. The heat involved in vaporizing moisture within the system can only be drawn from its surroundings, namely the water inside the system. Ice crystals thus formed would stay in the circuit throughout the evacuation process and pose a threat to the proper functioning of the refrigeration system.

The good news is that most of this work has been done for you by the manufacturer of the vacuum pump. Today's dual-stage rotary vane pumps are designed to meet the needs of the industry. Most manufacturers carry 5 to 7 sizes of vacuum pumps, ranging between 6.5 m^3/h (3.8 CFM) to 145 m^3/h (85 CFM). Ideally, the small to intermediate sized pumps are best suited (11.5 m^3/h or 6.8 CFM to 18.0 m^3/h or 10.6 CFM for instance).

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