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Preventing Back-Streaming And Back-Migration Of Rotary And Diffusion Pumps Oil Vapour In An Evacuation System

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ABSTRACT

Back-streaming and back-migration of the working fluid into the vessel can be largely avoided by the use of a baffle. It can be reduced by suitable design of the pump jet arrangement and is usually less in diffusion pumps of the self-fractionating and self-purifying types. The effect of back-streaming and back-migration is that a film of oil can collect on structures undergoing evacuation by an oil diffusion pump, and this may cause difficulties. In many processes this may be unimportant, but some circumstances (e.g. mass spectrometers, ion accelerators and photoelectric cell production) require a clean, oil free environment. Many kinds of scientific instruments such as thin film coaters which have a large bell jar containing evaporating materials presenting a large gas load require a clean high vacuum and must be evacuated from atmospheric pressure to a high vacuum in a short time cycle. To achieve this, back-streaming and back- migration of oil vapour of the vacuum pumps should be avoided.

Keywords: Back-streaming, Back-migration, Rotary pump, Evacuation, Oil vapour, Diffusion pump.

INTRODUCTION

A vacuum can be defined as a space that is empty of matter. Achieving such an empty space is however experimentally impossible. In view of this, vacuum is best described as a space with gaseous pressure that is less than atmosphere pressure. This lack of perfect vacuum in man made chambers is best described as partial pressure or partial vacuum. A high vacuum is one with little matter remaining in it and the quality of a vacuum is indicated by the amount of matter remaining in the system [7]. In a typical evacuation system one should ascertain that the desired high vacuum pressure in the chamber is achieved within a specified evacuation time.

Pumping down characteristics

When a chamber of volume V is evacuated by a pumping speed S

Then $P = V/Se\ (dD/dt)$ ………………… (1)

$\text{Log}\ [P_2]/\ P_1 = -1/2.3\ Se/V\ (t_2\text{-}t_1)$ ………………… (2)

Where

P = Pressure , Se = effective pumping speed, t = time of evacuation.

Effective pumping speed, Se

$$1/Se = 1/Sp + 1/C \quad \text{………………….} (3)$$

Where Sp is the pumping speed of the pump and C is the conductance of the evacuation pipe.

Steady-State Evacuation

The pressure P at an equilibrium state is given as

$$P = Q/Se \quad \text{………..…… } (4)$$

Where (Q) is the net outgassing rate of the chamber under high evacuation.

The net pumping speed and the net outgassing rate of the chamber (Q) vary with pressure. Mathematically the pressure distribution along an outgoing pipe is given as

$$P_k = Q/S + K(I - K/2)\, Q/C \quad \text{…………………} (5)$$

Where K is the fraction showing the position and Q is the net outgassing rate of the whole pipe.[8]

Back-streaming and Back-migration

Vapour pumps suffer from two defects whereby the pump fluid enters the vacuum tank. The first of these is back-streaming. This phenomenon is due to a small fraction of the molecules of the working fluid (oil or mercury) travelling from the first stage jet in the wrong direction, i.e towards the fine-side region instead of towards the fore-vacuum region. This undesired direction of travel is either imparted to the molecule initially as they issue from the jet, or, more likely, it is acquired after impacts with gas molecules or with other vapour molecules in the stream. To this is added the effect of evaporation of pump fluid from the nozzle itself [15].

The second defect is back migration. This is due to re-evaporation of the working fluid from baffles, the walls of the pump and the connecting tube to the vessel.

Back-streaming of the working fluid into the vessel can be largely avoided by the use of a baffle. It can be reduced by suitable design of the pump jet arrangement and is usually less in diffusion pumps of the self-fractionating and self-purifying types.

The effect of back-streaming and back-migration is that a film of oil can collect on structures undergoing evacuation by an oil diffusion pump, and this may cause difficulties. In many processes this may be unimportant, but some circumstances (e.g. mass spectrometers, ion accelerators and photoelectric cell production) require a clean, oil free environment.

LITERATURE REVIEW

Kumagai (1961) examined the diffusion pump (DP) system having two fractionating pumps in series and a specially designed backing pipe of the DP "If the system, impurities of the oil in the DP oil boiler are quickly removed , oil-vapor back streaming is much suppressed".

Dennis et al (1982) investigated the effect of DP-valve opening speed upon the oil-vapour back streaming rate. "Opening the DP-valve slowly is very important for suppressing the pressure-rise in the fore-vacuum side"

Hablanian and Maliakal (1973) reviewed the advance of DP technology. They emphasized that the use of polyphenylether makes a DP achieve a clean vacuum.
Holand et al (1972) obtained a clean high vacuum using a perfluo-ropolyether. They reported the basic characteristics of a DP, such as the pumping chamber, when using a perfluoropolyether. They described that the system using a perfluropolyether tolerates a considerably high backing-pressure. Lawson (1970) reported the chemical features of perfluoropoly fluids in detail. "These fluids do not polymerise when irradiated with electrons".
Laurenson(1982) reported the technology and application of typical pumping fluids. "The chemical and physical properties of the fluids employed in vacuum were given and the suitability of these fluids for various vacuum applications in relation to their properties were discussed.
Rettinghaus and Huber (1974) in an article, "Back-streaming in diffusion pump systems" explained that back-streaming phenomena are measures which are not due to mere evaporation but to molecular scattering within the baffle. The influence of a number of parameters were studied (among others the type of the pump and the pressure). The contribution of back-streaming to system contamination appeared negligible, except at higher pressures in the 10-^{4} Torr range where special precautions were recommended to meet exceptional high requirements for cleanliness.
Harris (1977) in an article, "Diffusion pump back-streaming", dealt exclusively with contamination which can be attributed to back-streaming of diffusion pump working fluid. It discussed the origins of this type of contamination, surveys methods used to prevent and control it and showed that it is possible to produce a clean vacuum using diffusion pumps.

METHOD OF PREVENTING BACK-STREAMING AND BACK- MIGRATION OF OIL VAPOUR

In diffusion pumps, the back-streaming rate can be sufficiently reduced by the use of cold caps surrounding the top nozzle. All diffusion pumps have a certain amount of back-stream but this device intercepts a large amount of back-streaming molecules without significantly reducing the pumping speed. The best pumps have a back-streaming rate of about 0.015mg/min per cm^2 of inlet area as such auxiliary device such as baffles or cold traps surroundings the top nozzle become very imperative to reduce the back streaming.
To prevent back-streaming of rotary pump oil vapour, isolation valve should be installed just above the rotary pump besides the roughing valve positioned at the port of chamber in order to prevent the oil vapour back-streaming into the roughing pipe line [5]. For a roughing pipe of 1m length and 20mm inner diameter roughing should be switched to fine pumping at about 13 pa in order to minimize the back-streaming rate of the oil vapour. The pumping speed of the rotary pump should be selected to reach 13 pa in a specified roughing time as in equation (2) [2]. To strictly revert the back-streaming of oil vapour, absorption trap containing porous alumina should be installed. Porous alumina balls sorb much water vapour during pumping down cycles from atmospheric pressure. To keep a speedy roughing, the alumina balls should be replaced with fresh degassed ones.

CONCLUSION

Many kinds of scientific instruments such as thin film coaters which has a large bell jar containing evaporating materials presenting a large gas load require a clean high vacuum and must be evacuated from atmospheric pressure to a high vacuum in a short time cycle. To achieve this, back-streaming and back- migration of oil vapour of the vacuum pumps should be avoided.

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