POLITECNICO DI TORINO

Absence of oil in vacuum drying processes using the piston pump by Italvacuum.

A concern regarding the use of oil-lubricated pumps in vacuum drying processes is the possibility of transport of oil from the pump to the dryer with contamination of the final product. As discussed in a report by Politecnico di Torino[1], the phenomenon can be quantitatively estimated, determining if there is contamination and to what extent. This document summarises the main findings of the cited report with reference to Italvacuum Saurus939 vacuum pump.

A schematic diagram of a vacuum drying system is shown in Figure 1. The drying unit is connected to the vacuum pump by a line that contains a filtering unit and a condenser. A flow of gaseous solvent reaches the vacuum pump, whereas some vapours of the lubricating oil may diffuse backwards from the pump to the dryer. We decided to evaluate only the flow rate of oil diffused back to the condenser through line t_3 of Figure 1, as if the vacuum pump was directly connected to the drying unit, hence largely overestimating the amount of oil that reaches the dryer.

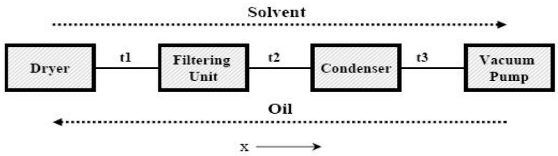

Figure 1: Plant scheme.

We considered for line t_3 a length of 4 m and conditions of fully developed flow. The flow rate of oil is estimated by solving a mass transport equation that takes into account the effect of diffusion, which moves the oil from the pump to the condenser, and of convection, which acts in the opposite way.

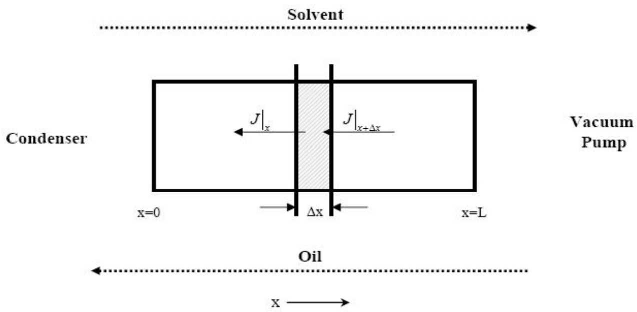

Figure 2: Mass balance in line t_3.

1

Politecnico di Torino – Department of Material Science and Chemical Engineering,
Corso Duca degli Abruzzi, 24 – 10129 Torino Italia

Referring to Figure 2 the oil mass balance in line t_3 can be written as:

$$vS\,c\big|_{x} - vS\,c\big|_{x+\Delta x} + \left(-J\,S\big|_{x}\right) + J\,S\big|_{x+\Delta x} = 0 \tag{1}$$

where *S*, *v* and *c* indicate respectively section of the pipe, velocity and oil concentration. The first two terms of equation (1) represent convective transport, while the latter two diffusive transport, that can be expressed through the following relationship (Fick's relationship):

$$J_A = -D\frac{dc_A}{dx} \tag{2}$$

in which *D* is either molecular or turbulent diffusivity, depending on the flow regime, in a binary system (oil-solvent vapour).

Vacuum dryers can work with different solvents; the study focused on drying processes of products containing water, but results would be similar for other solvents. Because of the lack of information about the chemical composition of the lubricating oil, a hydrocarbon with a vapour pressure of 0.66 mbar at 110°C was chosen for calculation: 0.66 mbar is in fact the maximum vacuum level achievable by the pump Saurus939 (without the use of compressor roots with which it comes up to 0.03 mbar[2]), so the oil is characterized by a vapour pressure of 0,66 mbar or less.

In line t_3 the flow regime varies from laminar to turbulent in connection with pressure variation; low pressures correspond to laminar regime, while turbulent flow is characteristic of higher pressures. As a consequence the diffusive component of transport is calculated using molecular diffusivity in the first case and turbulent diffusivity, calculated with the k-ε model, in the other case.

For the resolution of the mass transport equation (1) two boundary conditions were employed:

a. the oil concentration was set to zero in the condenser: this is the worst condition, as it implies maximum mass transfer level to the condenser
b. the partial oil pressure at the pump is the oil vapour pressure (0.66 mbar).

Three condenser-dryer-vacuum pump configurations were considered in the study, which correspond to the three different Saurus939 vacuum pump models VVB, VVC and VVD, respectively with nominal inlet diameters of 40, 65 and 80 mm.

In addition different vacuum levels were considered, in order to investigate all the range of working conditions, from 1 to 100 mbar. Under these conditions molecular and turbulent oil diffusivities have values around 10^{-3} and 10^{-4} m^2/s.

[2] Even in case of use of compressor roots the evaluation results do not differ from the ones obtained in this study.

Typical times for drying operations are of the order of one day; therefore the mass of oil reaching the condenser in 24 hours was calculated for every vacuum level.

Obtained values are absolutely negligible and below any level of analytical detection.

Table 1 shows values only for p = 1 mbar, which is the worst case among the analysed ones.

DN (mm)	Pressure (mbar)	µg of oil in 24 hours
40	1	$1*10^{-1478}$
65	1	$1*10^{-1379}$
80	1	$1*10^{-1732}$

Table 1: Quantity of oil that reaches the condenser

If we had considered a lower molecular weight component (e.g. propane) and a very short duct (1 m), i.e., two conditions that maximize unrealistically the transport due to counter-diffusion, the transferred mass would have been nevertheless negligible, as evidenced in Table 2. This fact clearly shows that the flow of solvent towards the vacuum pump prevents effectively the counter diffusion of any oil component to the condenser and hence to the dryer, even in presence of very short connection pipes.

DN (mm)	Pressure (mbar)	µg of oil in 24 hours
40	1	$1*10^{-147}$
65	1	$1*10^{-136}$
80	1	$1*10^{-173}$

Table 2: Amount of transported low MW oil in a shorter tube

Based on the obtained results we can observe that **THE QUANTITY OF LUBRICATION OIL THAT REACHES THE CONDENSER, AND CONSEQUENTLY THE DRYER, CAN BE NEGLECTED IN ALL THE CONSIDERED CASES AND IS MUCH BELOW ANY DETECTION THRESHOLD**. Moreover all the hypothesis shown at the beginning of the present summary were conservative, so the obtained oil quantity is overestimated compared to the real one.

Also **THE CHOICE OF THE SOLVENT AND OF THE USED HYDROCARBON DO NOT INFLUENCE SIGNIFICANTLY THE CALCULATION**.