# SOLVENT PUMP

## 1. TECHNICAL DESCRIPTION, BACKGROUND

In a chemical industrial plant, a new solvent supply system has been installed. The simplified sketch of the system is shown in **Figure 1.** The solvent – dichlor-methane – is stored in a reservoir. The pressure on the liquid surface is considered as atmospheric, $p_R = 10^5$ Pa. The mean level difference between the liquid surface and suction pipe is $H_R = 1$ m. The suction pipe has a total length of $L_P = 30$ m and inner diameter of $d_P = 56$ mm. A filter is installed in the suction pipe. The centrifugal pump, running at a constant speed of 2920 RPM, provides a liquid volume flow rate of $q_V = 12$ $m^3/h$ toward the technological process. A valve is installed close downstream of the pump. The operational temperature is 20°C.

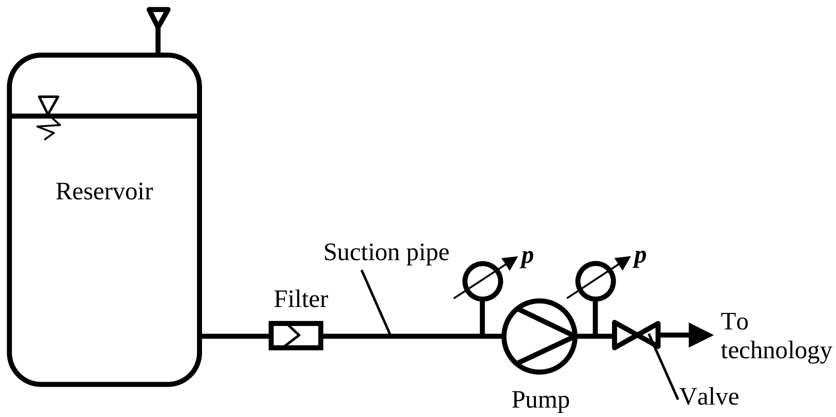


***Figure 1.***

## 2. PROBLEM SETTING

After installation, test operation is initiated. The pump produces an enormous noise and vibration. After not more than five minutes, the pump rotor becomes cracked, the pump bearings become damaged, and the rotor is blocked. The problem is to be eliminated and safe operation is to be guaranteed since the technological process necessitates continuous supply of solvent.

## 3. FIND THE REASON

- **Idea 1:** The pump originally had constructional/mechanical problems, e.g. micro-rupture on the rotor, rotor unbalance etc. (?)

Answer: Since the pump has been delivered under guarantee, the distributor of the pump provided another one. After installation and short test operation, the second pump also became damaged.

- **Idea 2:** Contamination (solid particles, abrasive segments, etc.) being present in the liquid destroyed the pump. (?)

Answer: the filter has been installed in the system just to eliminate such problems.

- **Idea 3:** the operating state is extraordinary, i.e. too high volume flow rate is expected from the pump – it has been designed for a substantially different flow rate (?)

Answer: observing the operational manual of the pump, it has been confirmed that its nominal flow rate is 12 $m^3/h$.

- **Idea 4:** Solvent may have increased inclination to evaporate. Cavitation erosion (!?)

## 4. JUSTIFICATION

- **1: Measurements**

**If a manometer is located at the suction port (as in the figure):**

The characteristics of the liquid can be taken from Perry's Chemical Engineering Handbook, Sixth Edition. McGraw-Hill International Editions, 1984, for temperature of 20°C:

- The density of the solvent is $\rho = 1330\ kg/m^3$.
- The dynamic viscosity of the solvent is $\mu = 4.7 \cdot 10^{-4}\ kg/(ms)$.
- The saturation steam pressure is $p_S = 46\ 570\ Pa$.

Operating the new pump for a very short time, the manometer on the suction port reads approximately - 0.5 *bar*(rel) pressure. (Depression relative to the atmospheric pressure of 1 *bar*.)

This value is close to $p_S$. Considering that the rotor of high circumferential speed has increased inclination to perform cavitation, it is confirmed that the cause of pump damage is cavitation erosion.

- **2: Hydraulic calculation**

(If no manometers are installed)

Hydraulic calculation on the suction side. (The following order of calculation steps can be altered, on the basis of the real-time discussion.)

Mean velocity in the pipe:

$$v = q_V / (d_P^2\ \pi/4) = 1.35\ m/s \qquad (1)$$

Reynolds number:

$$Re = v\ d_P\ \rho / \mu = 2.14 \cdot 10^5 \qquad (2)$$

Pipe wall roughness (drawn steel pipe): $k = 0.05\ mm$

Reciprocal value of relative roughness: $d_P / k = 1120$ (3)

Pipe friction factor, from Moody diagram: $\lambda = 0.021$

The friction coefficient of filter and the connecting hydraulic elements on the suction side, based on data delivered by the manufacturer: $\zeta_F = 40$

The static pressure upstream of the pump $p_{UP}$ can be approximated with use of the following hydraulic relationship ($g = 9.81\ N/kg$):

$$p_R + \rho\ g\ H_R = p_{UP} + \rho\ v^2 /2\ (\zeta_F + \lambda\ L_P / d_P + 1) \qquad (4)$$

This yields $p_{UP} = 49\ 700\ Pa$.

This value is close to $p_S$. Considering that the rotor of high circumferential speed has increased inclination to perform cavitation (see NPSH), it is confirmed that the cause of pump damage is cavitation erosion.

## 5. PROPOSAL FOR SOLUTION OF THE PROBLEM

- **Idea 1:** To reduce the hydraulic losses in the suction pipe. To omit the filter. To place the pump closer to the reservoir.

Answer: The filter cannot be omitted. Once a system is built up, it is not desirable to modify its structure, e.g. to change the location of the pump.

- **Idea 2:** To increase the system pressure by increasing the liquid level in the reservoir, or to provide overpressure in the reservoir.

Answer: this necessitates structural modifications, auxiliary equipments.

- **Idea 3:** Immediate solution: to reduce the volume flow rate (and also the dynamic pressure) below the cavitation limit by throttling the system on the pressure side, with application of the valve.

Answer: this is a reasonable and simple solution if the reduction of flow rate below12 $m^3/h$ is not crucial from the viewpoint of technology. Counter-arguments: i) the system may be overthrottled, i.e. unnecessarily high throttling is applied. But this can be checked by means of a manometer monitoring $p_{UP}$. ii) Throttling is not an energy-efficient solution for control.

- **Idea 4:** To control the pump motor speed by means of a frequency converter. The speed can even be controlled on the basis of measured $p_{UP}$. This solution necessitates remarkable additional investment costs but can be worthwhile in long-term operation.

## LIST OF SYMBOLS

| | | |
|---|---|---|
| d | [m] | diameter |
| g | [N/kg] | gravity field intensity |
| H | [m] | level difference |
| K | [m] | pipe wall roughness |
| L | [m] | pipe length |
| p | [Pa] | static pressure |
| $q_V$ | [$m^3$/s] | volume flow rate |
| Re | [-] | Reynolds number |
| v | [m/s] | fluid velocity |
| ρ | [kg/$m^3$] | fluid density |
| μ | [kg/(ms)] | dynamic viscosity of fluid |
| ζ | [-] | friction coefficient |

## Subscripts and superscripts

| | |
|---|---|
| F | filter |
| P | suction pipe |
| R | in the reservoir |
| S | steam |
| UP | upstream of the pump |