MINIMUM FLOW DUE TO THERMAL CONSIDERATIONS

The factors which determine minimum allowable rate of flow include the following:

- Temperature rise of the liquid as it passes through the pump
- Radial hydraulic thrust on impellers -- This is most serious with single volute pumps and, even at flow rates as high as 50% of BEP could cause reduced bearing life, excessive shaft deflection, seal failures, impeller rubbing and shaft breakage. This has been covered in Pump Clinic 12.
- Flow re-circulation in the pump impeller -- This includes suction and discharge recirculation when operating at flows other than the best efficiency point. This has been covered in Pump Clinic 3.
- Total head characteristic curve -- Some pump curves droop toward shut off, and some curves show a dip in the curve. Operation in such regions should be avoided.

This article considers minimum allowable flows based on temperature rise considerations only. To avoid thermal problems during low flow operation and to prevent a potential hazardous or mechanically damaging temperature rise within the pump, the temperature rise at shut off (i.e. fully closed discharge) and the minimum flow required for thermal protection should be calculated and the required flow be bypassed to dissipate heat generated due to pump inefficiency.

In the majority of cases, considerations other than thermal issues will dictate minimum allowable flow. Thermal considerations are important where liquids are at, or close to, the boiling point e.g. boiler feed pumps.

TEMPERATURE RISE AT SHUT OFF

The rate of temperature rise in the pump at shut off can be calculated by:

$$T_R = \frac{P \times 14.4}{Q \times SH \times SG}$$

where:

T_R= temperature rise per minute, in degrees Centigrade
P = power at shut off in kilowatts
Q = volume of liquid in the pump in litres
SH= specific heat of the liquid in calories/gm. C
SG= specific gravity of the liquid

This calculation disregards any allowance for heat dissipated by radiation from pump casings.

MAXIMUM ALLOWABLE TEMPERATURE RISE

The maximum allowable temperature rise can be determined by $T_2 – T_1$ where:

T_2 = saturation temperature corresponding to the absolute pressure of the pumped liquid at the pump suction flange

T_1 = temperature of the liquid at the pump suction flange

TEMPERATURE RISE AT VARIOUS FLOWRATES

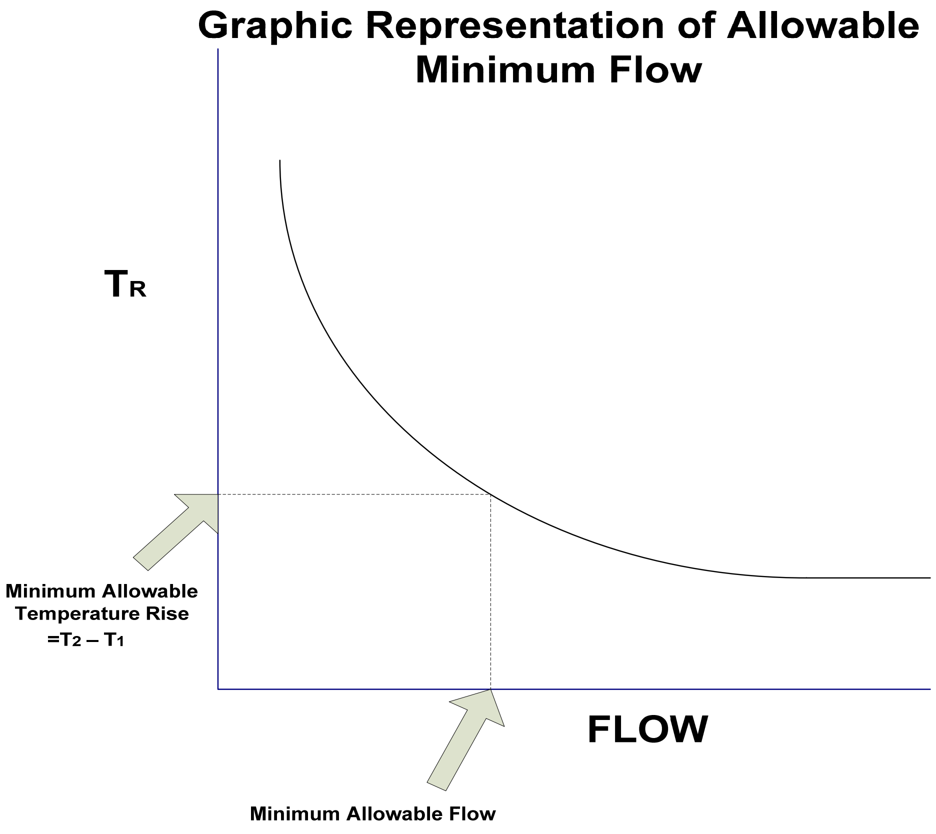
The temperature at the discharge will exceed the suction temperature and this can be calculated for any given flow. This rise is determined by the following formula:

$$T_R = \frac{H}{432.4 \times SH}$$

where:

T_R = temperature rise, in degrees Centigrade
H = total head in metres
SH= specific heat in calories/gm. C
E = pump efficiency in % at the flow involved.

Values of total head at various flows can be read from the pump performance curve and the temperature rise at the various flows can be calculated. The figure below gives a graphical representation of this formula and allows determination of the minimum allowable operating flow once the maximum allowable temperature rise has been selected.



As shown, the temperature rise increases very rapidly with a reduction in flow. This is caused by the fact that the losses at low deliveries are greater when the flow of liquid that must absorb the heat developed in the pump is low.

If the pump is fitted with a balancing device for axial thrust e.g. balance drum or balance disc, a certain portion of the suction capacity known as leakoff is returned either to the pump suction or to the suction supply vessel. In this case, the discharge capacity does not represent the true flow through the pump.

The formula for the temperature rise can still be used, provided a correction is made to take care of the increase in pump flow representing the balancing device leakoff. Balance device leak off information is provided by pump manufacturers.

The formula is modified to:

$$T_R = \frac{H}{432.4 \times SH} \times \frac{Q_d}{Q_d + Q_b}$$

where:

T_R = temperature rise, in degrees Centigrade
H = total head in metres
SH= specific heat in calories/gm. C
E = pump efficiency in % at the flow involved.
Q_d = flow through pump discharge in litres/sec
Q_b = leak off from balance device in litres/sec