TYPE 742: VARIABLE OR CONSTANT SPEED PUMP, MASS FLOW RATE INPUT, POWER CALCULATED FROM PRESSURE RISE AND PUMP EFFICIENCY

General Description

Type742 models a pump that sets its fluid outlet mass flow rate equal to the user specified inlet mass flow rate. Because mass flow rate is an input (as opposed to a parameter), Type742 can equally well be used to model a constant or a variable speed pump. *Unlike* most pumps and fans in TRNSYS, Type742 passes the inlet mass flow rate through to its output. Type742 sets the downstream flow but does not take either a maximum allowable flow rate or a control signal. The pump's power draw is calculated from pressure rise, overall pump efficiency, motor efficiency, fluid flow rate and fluid characteristics. Pump starting and stopping characteristics are not modeled.

Nomenclature

Δp	[Pa]	Pressure rise across the pump.
ρ_{fluid}	[kg/m^3]	Fluid density
$\dot{m}$	[kg/hr]	Mass flow rate of fluid passing though the pump.
η_{motor}	[-]	Efficiency of the pump motor
$\eta_{overall}$	[-]	Overall pump efficiency (motor efficiency * pumping efficiency)
$\eta_{pumping}$	[-]	Efficiency of pumping the fluid
$\dot{Q}_{fluid}$	[kJ/hr]	Energy transferred from the pump motor to the fluid stream passing through the pump.
$f_{motorloss}$	[0..1]	Fraction of pump motor inefficiencies that contribute to a temperature rise in the fluid stream passing through the pump. The remainder of these inefficiencies contribute to an ambient temperature rise.
$\dot{P}$	[kJ/hr]	Power drawn the pump.
$\dot{P}_{shaft}$	[kJ/hr]	Shaft power required by the pumping process (does not include motor inefficiency)
$\dot{W}_{pumping}$	[kJ/hr]	Shaft work performed in the pumping process (does not include motor or pumping inefficiency). This value is also called the ideal work performed.
$\dot{Q}_{ambient}$	[kJ/hr]	Energy transferred from the pump motor to the ambient air surrounding the pump.
$T_{fluid,out}$	[kJ/kg]	Temperature of fluid exiting the pump
$T_{fluid,in}$	[kJ/kg]	Temperature of fluid entering the pump

Detailed Description

If the pump is determined to be OFF due to it's inlet mass flow rate being set to 0, the pump outlet mass flow rate, power drawn, energy transferred to ambient and energy transferred to the fluid stream are all set to zero. The temperature of fluid exiting the pump under the OFF condition is set to the temperature of fluid at the pump inlet. If, however, the pump is determined to be ON (inlet mass flow rate greater than 0) then the mass flow rate of fluid exiting the pump is set to the current inlet mass flow rate specified in the model's input list. The efficiency of pumping the fluid from its inlet to its outlet pressure is given by equation 742.1

$$\eta_{pumping} = \frac{\eta_{overall}}{\eta_{motor}} \quad \text{(Eq. 742.1)}$$

If it is not specifically listed in available data, the overall efficiency of the pump may be calculated from nameplate values using a consistent set of units as:

$$\eta_{overall} = \frac{\dot{v}_{rated}\ \Delta p_{rated}}{\dot{P}_{rated}} \quad \text{(Eq. 742.2)}$$

The ideal work done in pumping the fluid is given by

$$\dot{W}_{pumping} = \frac{\Delta p\ \dot{m}}{\rho_{fluid}} \quad \text{(Eq. 742.3)}$$

To model a constant speed pump using Type742, the user should insure that the mass flow rate set as an input to the model always has the same value. A variable speed pump is modeled simply by allowing the inlet mass flow rate to vary with time. Care should be taken not to exceed a given pumps operating range, however, since the model is not equipped with a maximum allowable flow rate.

The work done at the pump shaft takes into account the inefficiency of the pumping process as calculated in equation 742.2

$$\dot{P}_{shaft} = \frac{\dot{W}_{pumping}}{\eta_{pumping}} \quad \text{(Eq. 742.4)}$$

The total power drawn by the pump includes the effects of motor inefficiency as shown in equation 742.5.

$$\dot{P} = \frac{\dot{P}_{shaft}}{\eta_{motor}} \quad \text{(Eq. 742.5)}$$

Energy transferred from the pump motor to the fluid stream is calculated as shown in equation 742.6

$$\dot{Q}_{fluid} = \dot{P}_{shaft}\left(1-\eta_{pumping}\right)+\left(\dot{P}-\dot{P}_{shaft}\right)f_{motorloss} \quad \text{(Eq. 742.6)}$$

In which $\eta_{pumping}$ is the pumping process efficiency and $f_{motorloss}$ is a value between 0 and 1 that determines whether the pump motor inefficiencies cause a temperature rise in the fluid stream that passes through the pump or whether they cause a temperature rise in the ambient air surrounding the pump. Through use of the $f_{motorloss}$ fraction, the user can in effect specify whether the pump has an inline motor, in which case all waste heat would impact the fluid stream temperature and $f_{motorloss}$ would have a value of 1, or whether the pump motor is housed outside of the fluid stream such that it's waste heat impacts the ambient and $f_{motorloss}$ would have a value of 0.

The energy transferred from the pump motor to the ambient is given by equation 742.7.

$$\dot{Q}_{ambient} = \left(\dot{P} - \dot{P}_{shaft}\right)\left(1 - f_{motorloss}\right) \quad \text{(Eq. 742.7)}$$

The temperature of fluid exiting the pump can now be calculated as shown in equation 742.8.

$$T_{fluid,out} = T_{fluid,in} + \frac{\dot{Q}_{fluid}}{\dot{m}_{fluid}} \quad \text{(Eq. 742.8)}$$

Type742 does not model pump starting and stopping characteristics; as soon as the inlet mass flow rate indicates that the pump should be ON, the outlet flow of fluid jumps to match the inlet flow rate. The time constants with which pumps react to input changes are much shorter than the typical time steps used in hydronic simulations.