# TYPE 743: VARIABLE OR CONSTANT SPEED PUMP, MASS FLOW RATE INPUT, POWER CALCULATED FROM POWER CURVE POLYNOMIAL

## General Description

Type743 models a pump that sets its outlet mass flow rate equal to a user specified inlet mass flow rate. Because mass flow rate is an input (as opposed to a parameter), Type743 can equally well be used to model a constant or a variable speed pump. *Unlike* most pumps and fans in TRNSYS, Type743 passes the inlet mass flow rate of fluid through to its output. Type743 sets the downstream flow but does not take a control signal. The pump's power draw is calculated based upon a user specified polynomial. Pump starting and stopping characteristics are not modeled.

## Nomenclature

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| $\dot{m}$ | [kg/hr] | Mass flow rate of fluid passing though the pump. |
| $\dot{m}_{rated}$ | [kg/hr] | Maximum mass flow rate of fluid that can pass though the pump. |
| $a_0, a_1, a_2 \ldots$ | [ - ] | Polynomial coefficients in the pump power curve |
| $\eta_{motor}$ | [ - ] | Efficiency of the pump motor |
| $\eta_{overall}$ | [0..1] | Overall pump efficiency (motor efficiency * pumping efficiency) |
| $\eta_{pumping}$ | [0..1] | 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) |
| $\dot{Q}_{ambient}$ | [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 Type743 pump is determined to be OFF due to it's inlet mass flow rate being set to 0, the 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 power drawn by the pump when ON is given by equation 743.1.

$$\dot{P} = a_0 + a_1\left(\frac{\dot{m}}{\dot{m}_{rated}}\right) + a_2\left(\frac{\dot{m}}{\dot{m}_{rated}}\right)^2 + a_3\left(\frac{\dot{m}}{\dot{m}_{rated}}\right)^3 + \ldots \qquad \text{(Eq. 743.1)}$$

To model a constant speed pump using Type743, 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.

The power required at the pump shaft excludes the effects of the pump motor inefficiency and is calculated using equation 743.2.

$$\dot{P}_{shaft} = \eta_{motor}\ \dot{P} \qquad \text{(Eq. 743.2)}$$

The efficiency of the pumping process can be calculated from user supplied values of the motor and overall pump efficiency as shown in equation 743.2.

$$\eta_{pumping} = \frac{\eta_{overall}}{\eta_{motor}} \qquad \text{(Eq. 743.2)}$$

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:

$$\eta_{overall} = \frac{\dot{v}_{rated}\ \Delta p_{rated}}{\dot{P}_{rated}} \qquad \text{(Eq. 743.3)}$$

Energy transferred from the pump motor to the fluid stream is calculated as shown in equation 743.4

$$\dot{Q}_{fluid} = \dot{P}_{shaft}\left(1-\eta_{pumping}\right)+\left(\dot{P}-\dot{P}_{shaft}\right)f_{motorloss} \qquad \text{(Eq. 743.4)}$$

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 743.5.

$$\dot{Q}_{ambient} = \left(\dot{P}-\dot{P}_{shaft}\right)\left(1-f_{motorloss}\right) \qquad \text{(Eq. 743.5)}$$

The temperature of fluid exiting the pump can now be calculated as shown in equation 743.6.

$$T_{fluid,out} = T_{fluid,in} + \frac{\dot{Q}_{fluid}}{\dot{m}} \qquad \text{(Eq. 743.6)}$$

Type743 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.