A 3.5 Hp Pump Delivers 1145 Lbf Of Ethylene Glycol At 20C In 12 Seconds Against A Head Of 17 Ft. Calculate

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Understanding the performance characteristics of pumps is crucial in engineering applications, especially when dealing with the transfer of fluids like ethylene glycol. In this article, we delve into the details of a pump with a power rating of 3.5 horsepower (Hp), which delivers a specific force (1145 Lbf) of ethylene glycol at a temperature of 20°C within a 12-second timeframe, against a head of 17 feet. We will explore how to analyze such a pump's performance, calculate key parameters such as flow rate, efficiency, and power, and understand the practical implications of these calculations.

Fundamental Concepts in Pump Performance Analysis

Before diving into calculations, it's essential to grasp the basic principles governing pump operation:

Flow Rate

The volume of fluid moved per unit time, typically expressed in liters per second (L/s) or gallons per minute (GPM). It is a key indicator of pump capacity.

Flow Velocity

The speed at which fluid moves through the pump's discharge outlet, affecting flow rate and system performance.

Head

The height (in feet or meters) to which a pump can lift or pressurize fluid, representing the energy imparted to the fluid per unit weight.

Power and Efficiency

The input power supplied to the pump versus the useful work done on the fluid. Efficiency measures how well the pump converts electrical power into fluid energy.

Given Data and Its Significance

Let’s review the provided parameters:

- Pump Power (Hp): 3.5 Hp
- Force (Lbf): 1145 Lbf
- Fluid Temperature: 20°C
- Time to deliver force: 12 seconds
- Head: 17 ft

Understanding these parameters helps us determine the flow rate, the volume of fluid moved, and other performance metrics.

Converting Force to Work Done

The initial step involves understanding the work performed by the pump. The force exerted on the fluid and the distance over which it acts contribute to the work done.

Calculating Work Done

Work (W) can be calculated using the relation:

$$ W = \text{Force} \times \text{Distance} $$

However, since the problem provides force and time, and we want to find flow rate, it’s more effective to relate force to pressure and then link it to flow.

Alternatively, considering the force applied over a certain area produces pressure, which in turn influences flow.

Calculating the Flow Rate

Given the force (1145 Lbf) and the time (12 seconds), we can determine the volume flow rate.

Step 1: Find the Pressure

Pressure (P) is related to force (F) and area (A):

$$ P = \frac{F}{A} $$

But since the area isn't directly given, an easier approach is to relate force to fluid velocity and flow rate.

Step 2: Relate Force to Flow Rate

The force exerted on the fluid relates to the change in momentum:

$$ F = \dot{m} \times v $$

Where:
- $\dot{m}$ = mass flow rate (kg/s)
- v = velocity of fluid (m/s)

Mass flow rate:

$$ \dot{m} = \rho \times Q $$

Where:
- ρ = density of ethylene glycol (~1.11 g/cm^3 or 1110 kg/m^3 at 20°C)
- Q = volumetric flow rate (m^3/s)

Given that:

$$ F = \rho \times Q \times v $$

But since $v = \frac{Q}{A}$, and the force is provided, we can proceed to estimate the flow rate assuming typical pump parameters.

Alternatively, considering the pump delivers a certain force over 12 seconds, the total work done is:

$$ W = F \times d $$

Where d is the distance the fluid moves in 12 seconds. To find d, we need to relate force to pressure and flow rate.

Calculating the Volume of Ethylene Glycol Delivered

Given the force (1145 Lbf) and the duration (12 seconds), the work done in lifting or moving the fluid can be calculated as:

$$ \text{Work} = \text{Force} \times \text{Distance} $$

But since the problem involves fluid flow, a more straightforward approach is to compute the flow rate directly:

Step 1: Convert Force to Power

Power (W) can be calculated from force and velocity:

$$ P = F \times v $$

But since we have force and time, perhaps it’s better to find the flow rate based on the force and head.

Step 2: Use the Hydraulic Power Equation

Hydraulic power delivered by a pump is given by:

$$ P_{hydraulic} = \rho \times g \times H \times Q $$

Where:
- ρ = density of fluid (~1110 kg/m^3)
- g = acceleration due to gravity (~9.81 m/s^2)
- H = head in meters
- Q = flow rate in m^3/s

Rearranged:

$$ Q = \frac{P_{hydraulic}}{\rho \times g \times H} $$

To proceed, we need to estimate the hydraulic power from the given data.

Calculating Hydraulic Power and Flow Rate

Given that the pump power is 3.5 Hp, convert this to watts:

$$ 1\, \text{Hp} = 746\, \text{W} $$

Thus,

$$ P_{input} = 3.5 \times 746 = 2611\, \text{W} $$

Assuming the pump operates at high efficiency, the hydraulic power output is roughly similar. Therefore:

$$ P_{hydraulic} \approx 2611\, \text{W} $$

Now, compute flow rate:

$$ Q = \frac{2611}{1110 \times 9.81 \times 17 \times 0.3048} $$

Note: Convert head from feet to meters:

$$ H = 17\, \text{ft} \times 0.3048 = 5.18\, \text{m} $$

Putting it all together:

$$ Q = \frac{2611}{1110 \times 9.81 \times 5.18} $$

Calculate denominator:

$$ 1110 \times 9.81 = 10886.1 $$

$$ 10886.1 \times 5.18 \approx 56,423.4 $$

Finally:

$$ Q \approx \frac{2611}{56,423.4} \approx 0.0462\, \text{m}^3/\text{s} $$

Convert to liters per second:

$$ 0.0462\, \text{m}^3/\text{s} \times 1000 = 46.2\, \text{L/s} $$

So, the approximate flow rate is 46.2 liters per second.

Determining the Total Volume Delivered in 12 Seconds

Total volume:

$$ V = Q \times t $$

$$ V = 46.2\, \text{L/s} \times 12\, \text{s} = 554.4\, \text{L} $$

Thus, the pump delivers approximately 554.4 liters of ethylene glycol in 12 seconds.

Additional Calculations: Pump Efficiency and Power

Given the power input and the flow rate, it's beneficial to evaluate the pump's efficiency:

Step 1: Calculate Theoretical Power

Theoretical hydraulic power:

$$ P_{theoretical} = \rho \times g \times H \times Q $$

Using previous values:

$$ P_{theoretical} = 1110\, \text{kg/m}^3 \times 9.81\, \text{m/s}^2 \times 5.18\, \text{m} \times 0.0462\, \text{m}^3/\text{s} $$

$$ P_{theoretical} \approx 2611\, \text{W} $$

Step 2: Compare with Actual Power

Since the pump consumes 2611 W (3.5 Hp), the efficiency is approximately:

$$\eta = \frac{P_{hydraulic}}{P_{input}} \times 100\%$$

$$\eta \approx \frac{2611}{2611} \times 100\% = 100\%$$

In reality, some energy losses occur, so actual efficiency is slightly less, typically around 80-90%.

Practical Implications and Applications

Understanding how these calculations translate into real-world usage is vital:

- Designing Pump Systems: Ensuring the pump can deliver the required volume within specified timeframes.
- Energy Consumption: Estimating power needs for operational planning.

Frequently Asked Questions

What is the significance of the 3.5 Hp pump delivering 1145 Lbf of ethylene glycol at 20°C in 12 seconds against a head of 17 ft?

This indicates the pump's power capacity (3.5 Hp), the flow rate (based on weight delivered in a specific time), and the pressure head (17 ft), which are essential for assessing its performance in moving ethylene glycol efficiently in a system.

How do you calculate the flow rate of ethylene glycol in gallons per minute (GPM) from the given data?

First, convert the weight (Lbf) to mass flow rate using the specific weight of ethylene glycol, then convert the mass flow rate to volume flow rate by dividing by its density, and finally convert to GPM for practical understanding.

What is the relationship between the head of 17 ft and the pump's power of 3.5 Hp in terms of pump efficiency?

The head indicates the height the pump can lift the fluid, while power relates to the energy input; their relationship depends on flow rate and efficiency. A higher head at given power suggests the pump is operating efficiently for the specified flow against the head.

How can you determine the flow rate in liters per second (L/s) based on the given data?

Convert the 1145 Lbf of ethylene glycol delivered in 12 seconds to mass flow rate, then divide by the fluid's density to find volumetric flow rate in liters per second (L/s). This provides a clear measure of how much fluid the pump moves per second.

What are the key steps to calculate the total work done by the pump in moving the ethylene glycol against the head?

Calculate the work using the formula: Work = weight of fluid lifted (Lbf) × head height (ft) / gravitational acceleration, then convert to energy units (e.g., Joules) to understand the total energy transferred during the process.

Additional Resources

A 3.5 Hp Pump Delivers 1145 Lbf Of Ethylene Glycol At 20°C In 12 Seconds Against A Head Of 17 Ft: An In-Depth Analysis

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Introduction

Pumping systems are fundamental in various industrial and commercial applications, particularly when handling fluids like ethylene glycol, which is widely used as a coolant in automotive and HVAC systems. Understanding the performance characteristics of a pump—specifically its power, flow rate, and head—is crucial for designing efficient and reliable systems. This review dissects the scenario where a 3.5 Hp pump delivers 1145 pounds-force (Lbf) of ethylene glycol at 20°C within 12 seconds, against a 17-foot head.

Understanding the Core Parameters

Before diving into calculations and implications, it’s essential to clarify each parameter:

- Power (3.5 Hp): The pump's mechanical energy input, which influences flow capacity and head.
- Flow rate (implied): The volume of fluid moved within a specific time frame.
- Force (1145 Lbf): The force exerted by the fluid, indicating the flow's impact and energy transfer.
- Time (12 seconds): Duration over which the fluid is delivered.
- Head (17 ft): The height the pump can lift the fluid, representing the energy per unit weight needed to overcome system resistance.

Converting Power to SI Units

To accurately analyze the system, it's helpful to convert horsepower to watts:

$$
1\, \text{Hp} = 745.7\, \text{W}
$$

Thus,

$$
\text{Power} = 3.5\, \text{Hp} \times 745.7\, \text{W/Hp} \approx 2610\, \text{W}
$$

This represents the input energy available for moving the fluid.

Calculating the Volume of Ethylene Glycol Delivered

Given that 1145 Lbf of ethylene glycol is delivered in 12 seconds, the key is to determine the volume flow rate and mass flow rate.

Step 1: Convert Force to Weight and Mass

- The force (Lbf) relates to the weight of the fluid:

$$
W = \text{Force} = 1145\, \text{Lbf}
$$

- Since weight W is related to mass m via gravity:

$$
W = m \times g
$$

where g is acceleration due to gravity ($32.2\, \text{ft/sec}^2$).

Rearranged:

$$
m = \frac{W}{g} = \frac{1145\, \text{Lbf}}{32.2\, \text{ft/sec}^2} \approx 35.6\, \text{slug}
$$

Note: The slug is a mass unit in Imperial units.

Step 2: Determine the Volume of Ethylene Glycol

The density ρ of ethylene glycol at 20°C is approximately 1.113 g/cm^3 or 1113 kg/m^3.

- Convert mass to volume:

$$
V = \frac{m}{\rho}
$$

Expressed in SI units:

$$
m = 35.6\, \text{slug} \times 14.5939\, \text{kg/slug} \approx 520\, \text{kg}
$$

Then:

$$
V = \frac{520\, \text{kg}}{1113\, \text{kg/m}^3} \approx 0.467\, \text{m}^3
$$

- Convert cubic meters to liters:

$$
0.467\, \text{m}^3 \times 1000\, \text{L/m}^3 \approx 467\, \text{L}
$$

Conclusion: The pump moves approximately 467 liters of ethylene glycol in 12 seconds.

Calculating Flow Rate

Flow rate Q:

\[

$$
Q = \frac{\text{Volume}}{\text{Time}} = \frac{467\, \text{L}}{12\, \text{s}} \approx 38.9\, \text{L/sec}
$$

Expressed in more conventional units:

$$
Q \approx 2.33\, \text{m}^3/\text{min}
$$

or

$$
Q \approx 138.9\, \text{m}^3/\text{hr}
$$

This high volumetric flow rate indicates a robust pumping capability.

Head and Power Relationship

The 17-ft head signifies the height the pump can lift the fluid against gravity, correlating with the energy per unit weight.

Step 1: Convert head to energy per unit weight

$$
H = 17\, \text{ft}
$$

The potential energy per unit weight:

$$
E = g \times H
$$

In SI units:

$$
H\, (\text{m}) = 17\, \text{ft} \times 0.3048\, \text{m/ft} \approx 5.18\, \text{m}
$$

The energy per unit weight:

$$
E_{w} = g \times H
$$

But since g in SI is $9.81\, \text{m/sec}^2$, the energy per unit weight (J/kg):

$$
E_{w} = 9.81\, \text{m/sec}^2 \times 5.18\, \text{m} \approx 50.8\, \text{J/kg}
$$

Step 2: Calculate the power required to deliver this head

Power P:

$$
P = \text{Weight flow rate} \times \text{Head energy}
$$

- The weight flow rate:

$$
\text{Weight flow} = \text{mass flow rate} \times g
$$

- From previous calculation:

$$
\text{Mass flow rate} = \frac{520\, \text{kg}}{12\, \text{s}} \approx 43.3\, \text{kg/sec}
$$

- Therefore,

$$
\text{Weight flow rate} = 43.3\, \text{kg/sec} \times 9.81\, \text{m/sec}^2 \approx 425\, \text{N/sec}
$$

- The power:

$$
P = \text{Force} \times \text{Velocity} = \text{Weight flow rate} \times \frac{H}{\text{time}}
$$

Alternatively, the theoretical hydraulic power:

$$
P_{hyd} = \rho \times g \times Q \times H
$$

Where:

- $\rho = 1113\, \text{kg/m}^3$
- $Q = 2.33\, \text{m}^3/\text{min} = 0.0389\, \text{m}^3/\text{s}$
- $H = 5.18\, \text{m}$

Calculating:

$$
P_{hyd} = 1113\, \text{kg/m}^3 \times 9.81\, \text{m/sec}^2 \times 0.0389\, \text{m}^3/\text{s} \times 5.18\, \text{m}
$$

$$
P_{hyd} \approx 1113 \times 9.81 \times 0.0389 \times 5.18 \approx 2230\, \text{W}
$$

Implication: The hydraulic power required is approximately 2.23 kW (~3 Hp), aligning with the pump's 3.5 Hp power rating, considering efficiencies and losses.

Efficiency and Practical Considerations

- Efficiency estimates: Typically, pump efficiencies range from 70% to 85%. Given the calculated hydraulic power (~2.23 kW) and the pump's input power (~2.61 kW), the efficiency:

$$
\eta = \frac{P_{hyd}}{P_{input}} \approx \frac{2230}{2610} \approx 85\%
$$

This indicates a high-efficiency pump operation, which is desirable in industrial settings.

- Temperature effects: Ethylene glycol's viscosity slightly varies with temperature; at 20°C, it flows relatively easily, contributing to the pump's performance.

- Material compatibility: Since ethylene glycol is corrosive, pumps used must be constructed from compatible materials like stainless steel or certain plastics.

System Implications and Design Considerations

Flow rate and head are interconnected; high flow rates against moderate head require appropriately rated pumps. The calculation highlights several critical design considerations:

1. Pump Capacity: A 3.5 Hp motor provides sufficient power to handle nearly 38.9 L/sec flow against a 17 ft head, suitable for large-scale cooling or fluid transfer applications.

2. Pipe Sizing: To sustain the flow rate without excessive pressure drops, piping must be adequately sized, considering Darcy-Weisbach or Hazen-Williams equations.

3. Energy Efficiency: Maintaining high efficiency minimizes operational costs and energy consumption, especially important in continuous or frequent operation.

4. Control Systems: Incorporating flow and pressure sensors ensures the

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