7. ENERGY PERFORMANCE ASSESSMENT OF WATER PUMPS

7.1 Introduction

Pumping is the process of addition of kinetic and potential energy to a liquid for the purpose of moving it from one point to another. This energy will cause the liquid to do work such as flow through a pipe or rise to a higher level. A centrifugal pump transforms mechanical energy from a rotating impeller into a kinetic and potential energy required by the system.

The most critical aspect of energy efficiency in a pumping system is matching of pumps to loads. Hence even if an efficient pump is selected, but if it is a mismatch to the system then the pump will operate at very poor efficiencies. In addition efficiency drop can also be expected over time due to deposits in the impellers. Performance assessment of pumps would reveal the existing operating efficiencies in order to take corrective action.

7.2 Purpose of the Performance Test

- Determination of the pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of the pump and compare the same with design.

7.3 Performance Terms and Definitions

Pump Capacity, Q = Volume of liquid delivered by pump per unit time,m^3/hr or m^3/sec

Q is proportional to N, where N- rotational speed of the pump

Total developed head, H = The difference of discharge and suction pressure

The pump head represents the net work done on unit weights of a liquid in passing from inlet of the pump to the discharge of the pump.

There are three heads in common use in pumps namely

(i) Static head
(ii) Velocity head
(iii) Friction head.

The frictional head in a system of pipes, valves and fittings varies as a function (roughly as the square) of the capacity flow through the system.

System resistance: The sum of frictional head in resistance & total static head.

Pump Efficiency: Fluid power and useful work done by the pump divided by the power input in the pump shaft.

$$\text{Pump efficiency} = \frac{\text{Hydraulic power, } P_h}{\text{Power input to the pump shaft}} \times 100$$

Where,

Hydraulic power P_h(kW) = $Q \times (h_d - h_s) \times \rho \times g / 1000$

Q = Volume flow rate (m^3 / s), ρ = density of the fluid (kg/m^3), g = acceleration due to gravity (m/s^2), $(h_d - h_s)$ = Total head in metres

7.4 Field Testing for Determination of Pump Efficiency

To determine the pump efficiency, three key parameters are required: Flow, Head and Power. Of these, flow measurement is the most crucial parameter as normally online flow meters are hardly available, in a majority of pumping system. The following methods outlined below can be adopted to measure the flow depending on the availability and site conditions.

7.4.1 Flow Measurement, Q

The following are the methods for flow measurements:

- Tracer method BS5857
- Ultrasonic flow measurement
- Tank filling method
- Installation of an on-line flowmeter

Tracer Method

The Tracer method is particularly suitable for cooling water flow measurement because of their sensitivity and accuracy.

This method is based on injecting a tracer into the cooling water for a few minutes at an accurately measured constant rate. A series of samples is extracted from the system at a point where the tracer has become completely mixed with the cooling water. The mass flow rate is calculated from:

$$q_{cw} = q_1 \times C_1/C_2$$

where q_{cw} = cooling water mass flow rate, kg/s
q_1 = mass flow rate of injected tracer, kg/s
C_1 = concentration of injected tracer, kg/kg

C_2 = concentration of tracer at downstream position during the 'plateau' period of constant concentration, kg/kg

The tracer normally used is sodium chloride.

Ultrasonic Flow meter

Operating under Doppler effect principle these meters are non-invasive, meaning measurements can be taken without disturbing the system. Scales and rust in the pipes are likely to impact the accuracy.

- Ensure measurements are taken in a sufficiently long length of pipe free from flow disturbance due to bends, tees and other fittings.
- The pipe section where measurement is to be taken should be hammered gently to enable scales and rusts to fall out.
- For better accuracy, a section of the pipe can be replaced with new pipe for flow measurements.

Tank filing method

In open flow systems such as water getting pumped to an overhead tank or a sump, the flow can be measured by noting the difference in tank levels for a specified period during which the outlet flow from the tank is stopped. The internal tank dimensions should be preferable taken from the design drawings, in the absence of which direct measurements may be resorted to.

Installation of an on-line flowmeter

If the application to be measured is going to be critical and periodic then the best option would be to install an on-line flowmeter which can get rid of the major problems encountered with other types.

7.4.3 Determination of total head, H

Suction head (h_s)

This is taken from the pump inlet pressure gauge readings and the value to be converted in to meters ($1 kg/cm^2 = 10.$ m). If not the level difference between sump water level to the centerline of the pump is to be measured. This gives the suction head in meters.

Discharge head (h_d)

This is taken from the pump discharge side pressure gauge. Installation of the pressure gauge in the discharge side is a must, if not already available.

7.4.4 Determination of hydraulic power (Liquid horse power),

Hydraulic power $P_h(kW) = Q \times (h_d - h_s) \times \rho \times g / 1000$
Q = Volume flow rate (m^3/s), ρ = density of the fluid (kg/m^3), g = acceleration due to gravity (m/s^2), ($h_d - h_s$) = Total head in metres

7.4.5 Measurement of motor input power

The motor input power P_m can be measured by using a portable power analyser.

7.4.6 Pump shaft power

The pump shaft power Ps is calculated by multiplying the motor input power by motor efficiency at the existing loading.

$$P_s = P_m \times \eta_{Motor}$$

7.4.7 Pump efficiency

This is arrived at by dividing the hydraulic power by pump shaft power

$$\eta_{Pump} = \frac{P_h}{P_s}$$

Example of pump efficiency calculation

Illustration of calculation method outlined

A chemical plant operates a cooling water pump for process cooling and refrigeration applications. During the performance testing the following operating parameters were measured;

Measured Data

Pump flow, Q	0.40 m^3/ s
Power absorbed, P	325 kW
Suction head (Tower basin level), h_1	+1 M
Delivery head, h_2	55 M
Height of cooling tower	5 M
Motor efficiency	88 %
Type of drive	Direct coupled
Density of water	996 kg/ m^3

Pump efficiency

Flow delivered by the pump	0.40 m^3/s
Total head, $h_2 -(+h_1)$	54 M
Hydraulic power	0.40 x 54 x 996 x 9.81/1000 = 211 kW
Actual power consumption	325 kW
Overall system efficiency	(211 x 100) / 325 = 65 %
Pump efficiency	**65/0.88 = 74 %**

7.5 Determining the System resistance and Duty point

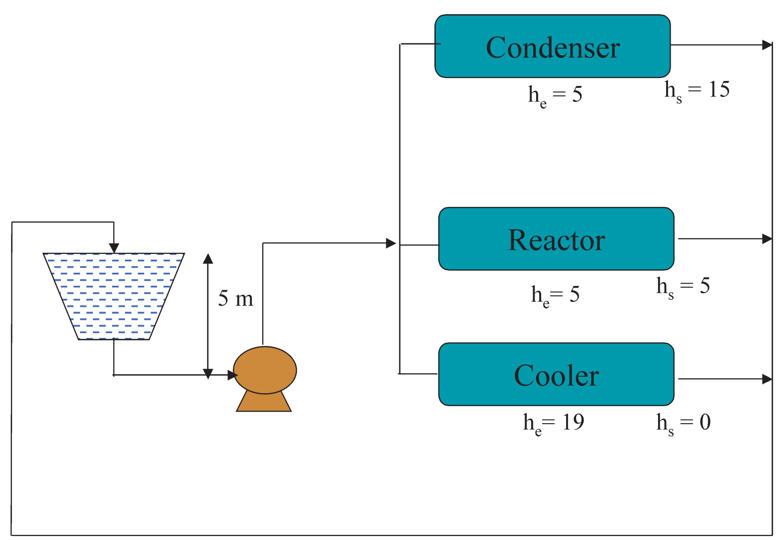
Determination of the system resistance curve and imposing the pump curve over it will give an idea of the operating efficiency of the pump and also the drop in efficiencies when the system curve changes from normal / design. The example following from the earlier example outlines the method of constructing a system curve.

Example:

Location of equipments

The Refrigeration plant is located at +0.00 level and the Process plant condensers are located at +15 M level. One cooler having a design pressure drop of 1.9 kg/cm^2 is located at the 0.00 level (ground level). Other relevant data can be inferred from the earlier section. See schematic in Figure 7.1.

Figure 7.1: Schematic of the System



h_s = Static Head ; h_e = Equipment pressure drop

The step-by-step approach for determining system resistance curve is given below.

Step-1 Divide system resistance into Static and dynamic head

Find static head;

Static head (Condenser floor height) ; 15M

Find dynamic head;

Dynamic Head = Total Head – Static Head

Dynamic head = (54–15) = 39 M

Step-2 Check the maximum resistance circuit

Resistance in the different circuits is as under

S.no	System	Condenser loop resistance, M	Reactor loop resistance, M	Cooler loop resistance, M
1.	Supply line from pump	15	10	15
2.	Static head	15	5	Nil (cooler at ground level)
3.	Equipment	5	5	19
4.	Return line from equipment to CT	15	10	15
5.	Tower head	-	-	5
6.	Total	50	30	54

It can be noted that at full load the condenser and cooler circuits offer the maximum resistance to flow.

Step 3; Draw system resistance curve

Choose the condenser loop as it offers maximum resistance and is also having a static head component

Static head: 15 M

Dynamic head at full load; 39 M

Compute system resistance at different flow rates

S.No.	Flow (%)	Dynamic head = 39x (%flow)^2	Static head M	Total head M
1.	100	39	15	54
2.	75	21.9	15	36.9
3.	50	9.75	15	24.75
4.	25	2.44	15	17.44

Step 4 - Plot the system resistance against flow in the pump efficiency curves (see Figure 7.2) provided by the vendor and compare actual operating duty point and see whether it operates at maximum efficiency. In the example provided it is found that the pump system efficiency is lower by 4 % due to change in operating conditions.

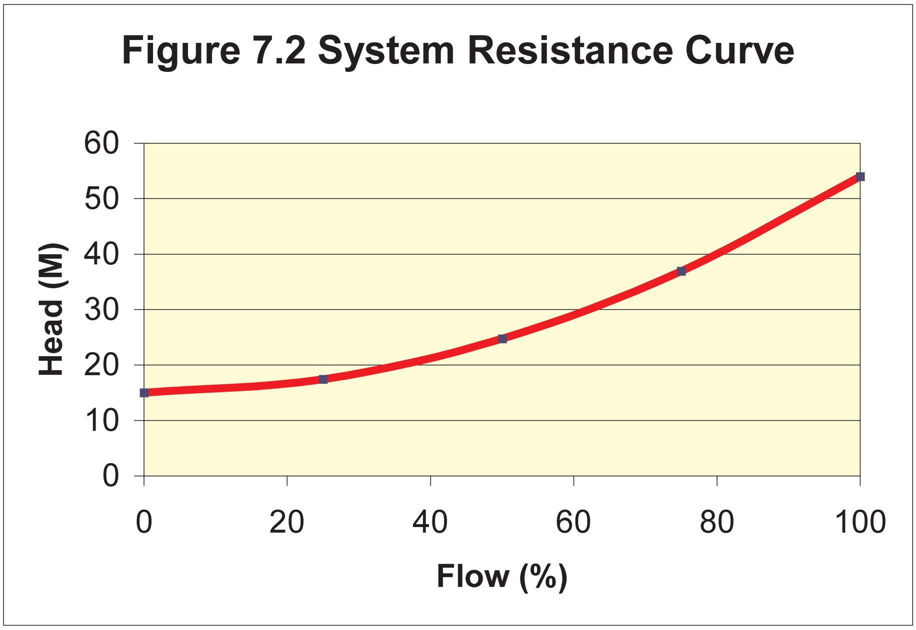


Figure 7.2 System Resistance Curve
Head (M)
60
50
40
30
20
10
0
0
20
40
60
80
100
Flow (%)

QUESTIONS	
1)	How would you measure the flow by using tracer method?
2)	What are the various ways of measuring flow?
3)	A pump motor draws 75 A current. The voltage is 415 V. Assuming a power factor of 0.9. Calculate the power drawn?
4)	The suction head is 1m below the pump centerline. The discharge pressure shows 3 kg/cm^2. The flow is calculated to be 100 m3/hr. Find out the pump efficiency.
5)	The pump efficiency is 70%. The hydraulic power is calculated to be 22 kW. Find out the motor power required to drive the pump.

REFERENCES

1. Pump handbook by Karassik
2. Energy Audit Reports of National Productivity Council