

**101
SOLVED
MECHANICAL
ENGINEERING
PROBLEMS**

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*PROFESSIONAL PUBLICATIONS, INC.
Belmont, CA 94002*

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HYDRAULICS/ PNEUMATICS

HYDRAULICS-1

The line between a low-pressure booster pump and a high-pressure boiler feed pump contains a running length of 65 ft of 6-in schedule-40 steel pipe, four long radius 90° elbows, a swing check valve, and a fully open gate valve. The feed pump is 12 ft higher than the booster pump in elevation. The flow rate is 740 gpm of 250°F water. The known pressures are

pressure before booster pump	37 psia
pressure before boiler feed pump	95 psia
pressure after boiler feed pump	1350 psia

- What is the pressure at the discharge of the booster pump?
- What is the brake horsepower requirement of the motor for the boiler feed pump if the pump's efficiency is 62%?

HYDRAULICS-2

A centrifugal pump has the following operating characteristics based on operation at 1800 rpm, 14.7 psia, and 85°F water.

Q (gpm)	H (ft)	NPSHR (ft)
550	50.0	8.0
600	47.5	9.5
650	45.0	11.1
700	42.1	13.0
750	39.1	15.0
800	36.0	17.2

- Tabulate the H and NPSHR characteristics as a function of Q if the pump is turned at 2000 rpm.
- Will the pump operate satisfactorily at 1800 rpm under the following conditions?
 - 5000 ft altitude
 - 90°F water
 - 9-ft static discharge head
 - 7-ft suction lift
 - 650-gpm flow rate
 - 10-ft friction loss in suction line

HYDRAULICS-3

In order to maintain the original appearances of a historic building, it has been decided to renovate the original hot-water radiator heating system. The building has a design heating load of 400,000 Btu/hr, which is satisfied by convective heat transfer from radiators throughout the building. Water leaves the boiler at 220°F saturated liquid and returns at 190°F. The hot water system has the following characteristics.

pipes

- 2½-in steel, schedule-40
- 225 linear feet (exclusive of minor losses)

minor losses (all fittings are screwed)

- 8 90° regular elbows
- 1 swing check valve
- 2 gate valves (normally open)
- boiler heating coils head loss: 12 ft

pump

- pump efficiency: 55%
- motor efficiency: 75%

- What hydraulic horsepower is required?
- What is the motor's nameplate rating (in watts)?

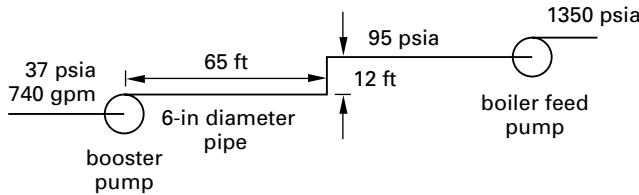
HYDRAULICS-4

A pump was originally chosen based on an NPSHR of 21 ft for a given flow rate of 850 gpm of hot water. The water was to flow through 90 ft of 6.00-in (inside diameter) pipe (Darcy friction factor of 0.02) prior to entering the pump. Water entering the pump is currently at 180°F and 14.1 psia, and cavitation in the pump inlet is being experienced.

It has been proposed to enclose the inlet pipe with a larger diameter pipe for its entire 90 ft of run, and cold water circulated countercurrently through the outside pipe. The temperature at the pump inlet would be

HYDRAULICS/PNEUMATICS

1. (a)



For 6-in pipe,

$$D = 0.5054 \text{ ft}$$

$$A = 0.2006 \text{ ft}^2$$

$$Q = (740) \left(0.002228 \frac{\frac{\text{ft}^3}{\text{sec}}}{\frac{\text{gal}}{\text{min}}} \right)$$

$$= 1.649 \text{ ft}^3/\text{sec}$$

$$v = \frac{Q}{A} = \frac{1.649}{0.2006} = 8.22 \text{ ft/sec}$$

For water at 250°F,

$$\nu = 0.269 \times 10^{-5} \text{ ft}^2/\text{sec}$$

$$\rho = 58.8 \text{ lbm/ft}^3$$

The equivalent length of pipe is

$$L_e = 65 + (4)(5.7) + 3.2 + 63 = 154 \text{ ft}$$

For the steel pipe,

$$\epsilon = 0.0002$$

$$\frac{\epsilon}{D} = \frac{0.0002}{0.5054} \approx 0.0004$$

$$N_{Re} = \frac{vD}{\nu} = \frac{(8.22)(0.5054)}{0.269 \times 10^{-5}} = 1.54 \times 10^6$$

$$f = 0.016$$

The friction loss is

$$h_f = \frac{fLv^2}{2Dg} = \frac{(0.016)(154)(8.22)^2}{(2)(0.5054)(32.2)}$$

$$= 5.12 \text{ ft}$$

The booster pump discharge pressure is

$$p = 95 + \frac{(12 + 5.12)(58.8)}{144} = \boxed{102.0 \text{ psia}}$$

(b) $P = \dot{m}\Delta h$

$$= \frac{(1.649)(58.8) \left(\frac{1350 - 95}{58.8} \right) (144)}{(0.62)(550)}$$

$$= \boxed{874 \text{ hp}}$$

2. From affinity laws,

(a) $Q \propto n$

$$H \propto n^2$$

$$\text{NPSHR} \propto n^2$$

The ratio of speeds is

$$\frac{n_{\text{new}}}{n_{\text{old}}} = \frac{2000}{1800} = 1.11$$

$(1.11)(Q)$	$(1.11)^2(H)$	$(1.11)^2(\text{NPSHR})$
611	61.6	9.9
666	58.5	11.7
722	55.4	13.7
777	51.9	16.0
833	48.2	18.5
888	44.4	21.2

These values can be graphed if necessary.

(b) For water at 90°F,

$$\rho = 62.11 \text{ lbm/ft}^3$$

$$h_{vp} = 1.61 \text{ ft}$$

At 5000 ft,

$$p_a = 12.225 \text{ psia}$$

$$h_a = \frac{(12.225)(144)}{62.11} = 28.34 \text{ ft}$$

The net positive suction head is

$$\text{NPSHA} = 28.34 + (-7) - 1.61 - 10$$

$$= 9.73 \text{ ft}$$

Since $9.73 < 11.1$,

Operation is not ok.

Notice that the discharge head is not considered.