پمپ

تهیه کننده :
رحمت اله یوسفی
0912-3365261


بسم الله الرحمن الرحيم

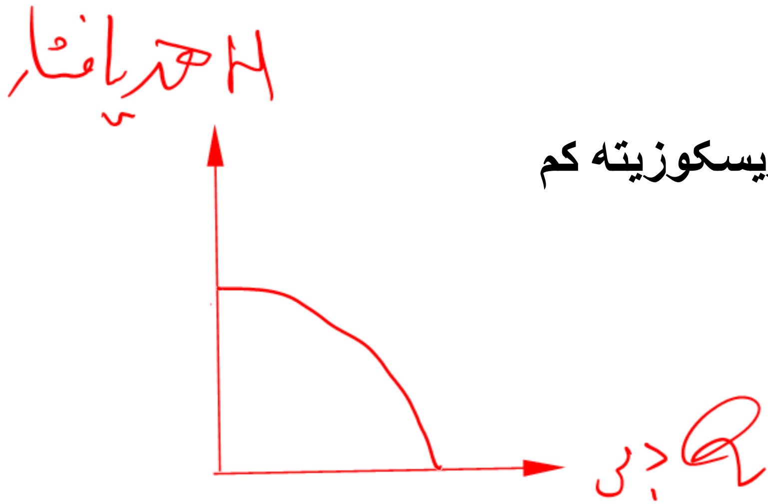
فهرست منابع :

- مبحث چهاردهم
- Carrier
- Ashrae
- HVAC -Capitoline
- نشریات سازمان مدیریت وبرنامه برنامه ریزی(128و172و...)
- نشریات داخلی(طباطبایی - تهرانی – کاشانی حصار – خستو – عماد سادات- نائینیان - ...)
- پمپ و پمپاژ دکتر نوربخش

فهرست مطالب دوره :

- انواع پمپ ها
- مشخصه پمپ ها
- مشخصه مسیر
- بهم بستن پمپ ها
- توان پمپ
- NPSH
- ماگزیمم عمق مکش

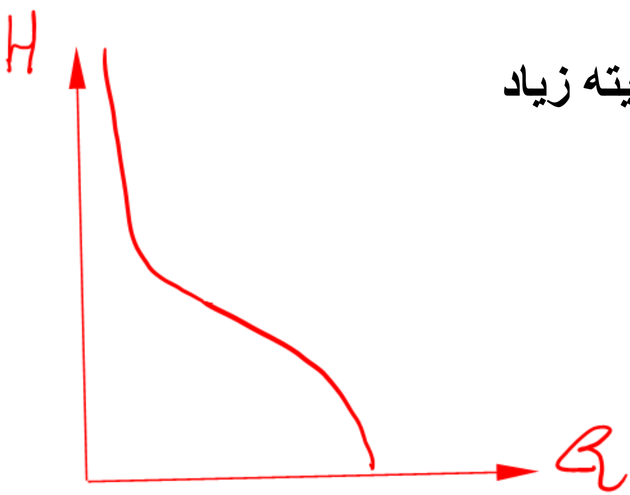
انواع پمپها (انرژی)



1- پمپهای دینامیکی(فشار منفی)– دبی های متوسط تا زیاد و ویسکوزیته کم

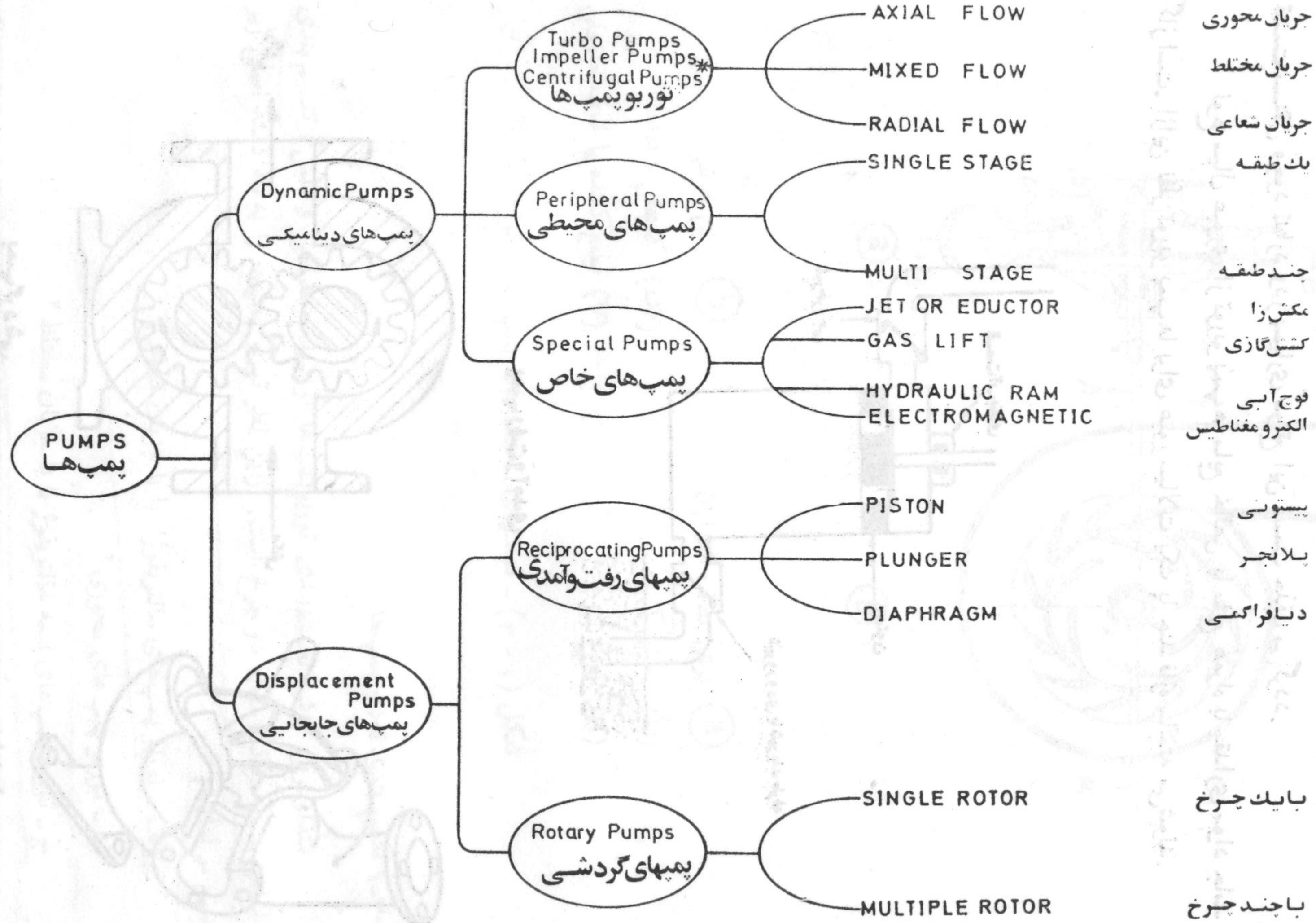
- سانتریفوژ:

- **سیرکولاسیون**
- **کندانس**
- **تغذیه دیگ**
- **خطی**
- **لجن کش**



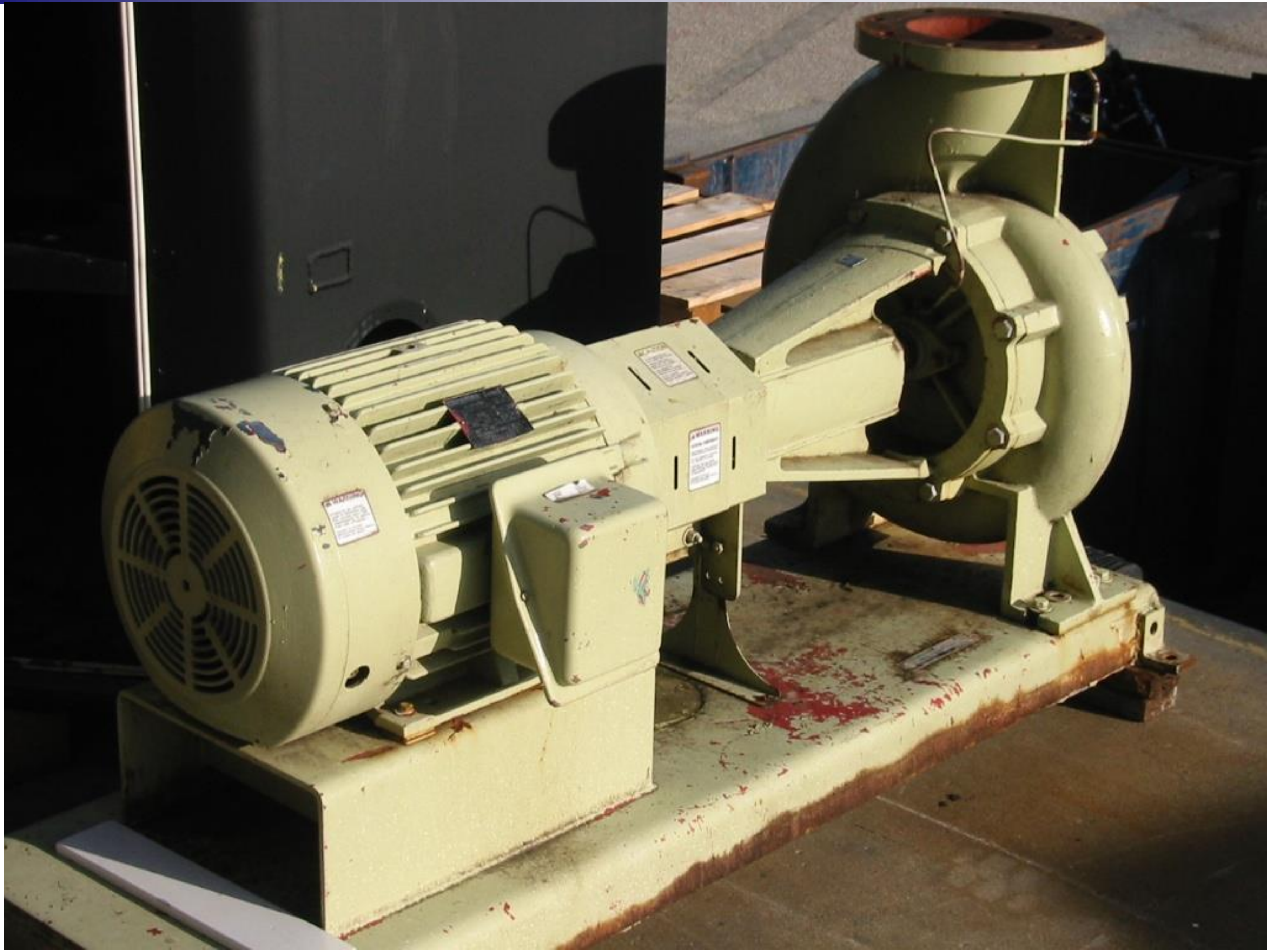
2- پمپهای جابجایی (فشار مثبت)– فشارهای زیاد و ویسکوزیته زیاد

- **پیستونی**
- **دنده ای – پمپ سوخت**
- **دیافراگمی**
- **اسکرو**
- **پره ای**



* - در بعضی کتب کلمه پمپ‌های سانتریفوژ بجای توربوپمپ‌ها بکار رفته است.

شکل (۱ - ۱) - تقسیم بندی پمپ‌ها



close couple کوپل کوتاه

انواع کوپل پمپ

Long couple کوپل بلند

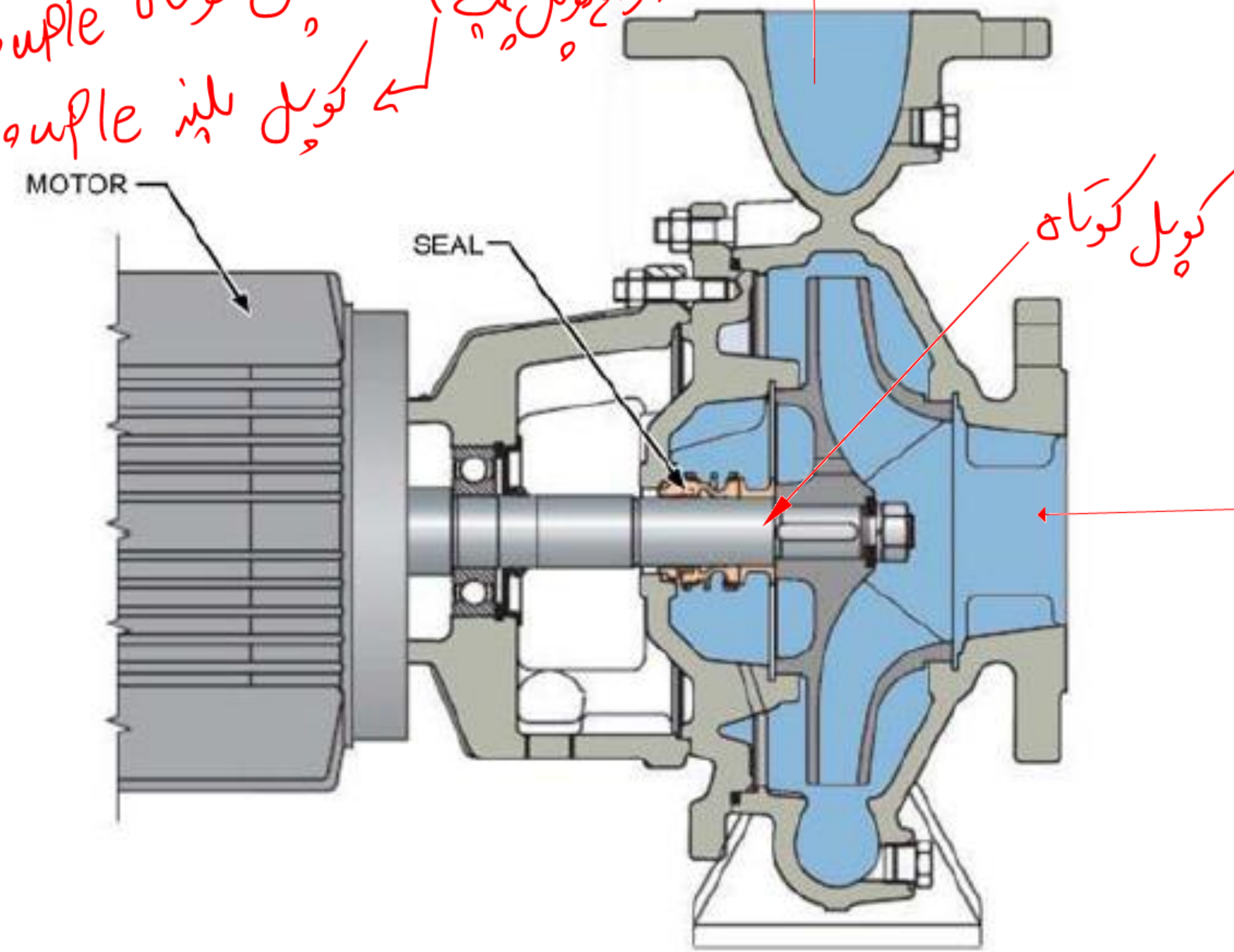
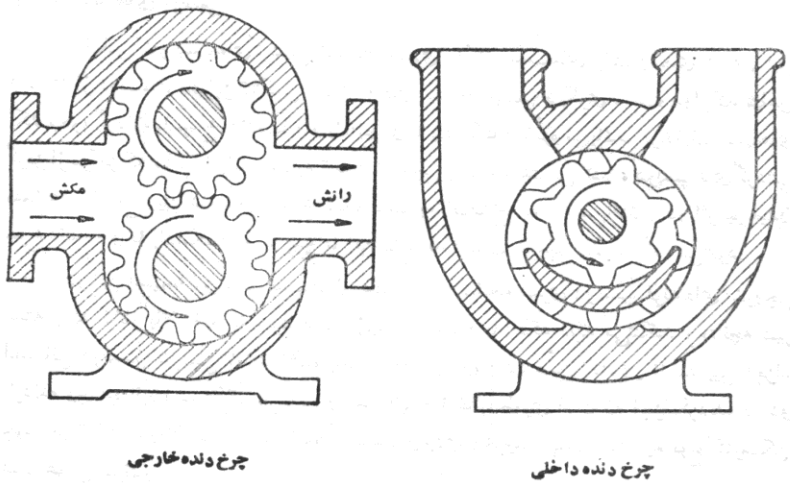
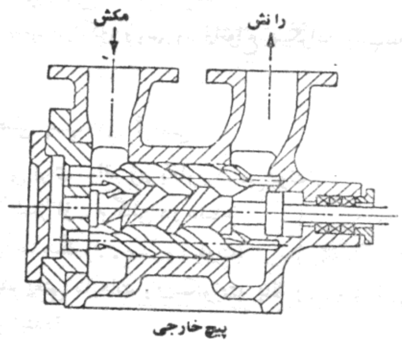
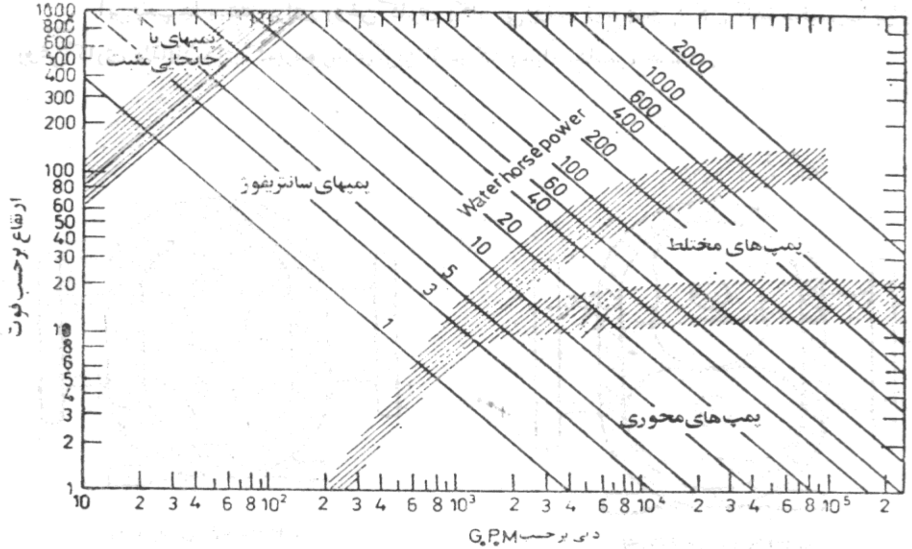


Fig. 4 Close-Coupled Single-Stage End-Suction Pump

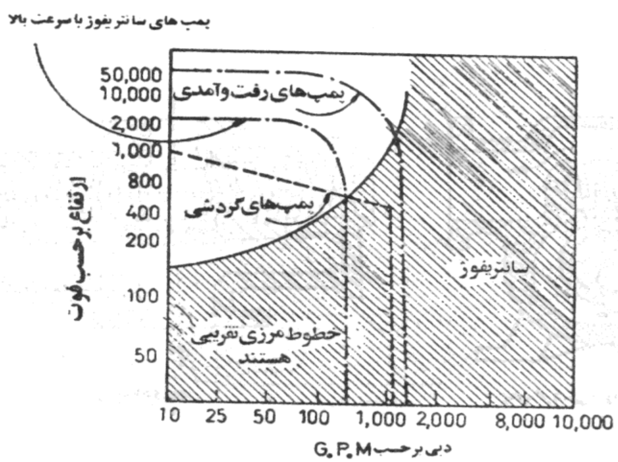




شکل شماره (۱-۱۸)- مهمترین انواع پمپ‌های گردشی



شکل (۱-۲-۰ - الف) - مقایسه دامنه کاربرد پمپ‌ها



شکل (۱-۲-۰ - ب) - مقایسه دامنه کاربرد پمپ‌ها

مشخصات فنی پمپها:

1- منحنی های مشخصه پمپ ها

2- توان پمپ

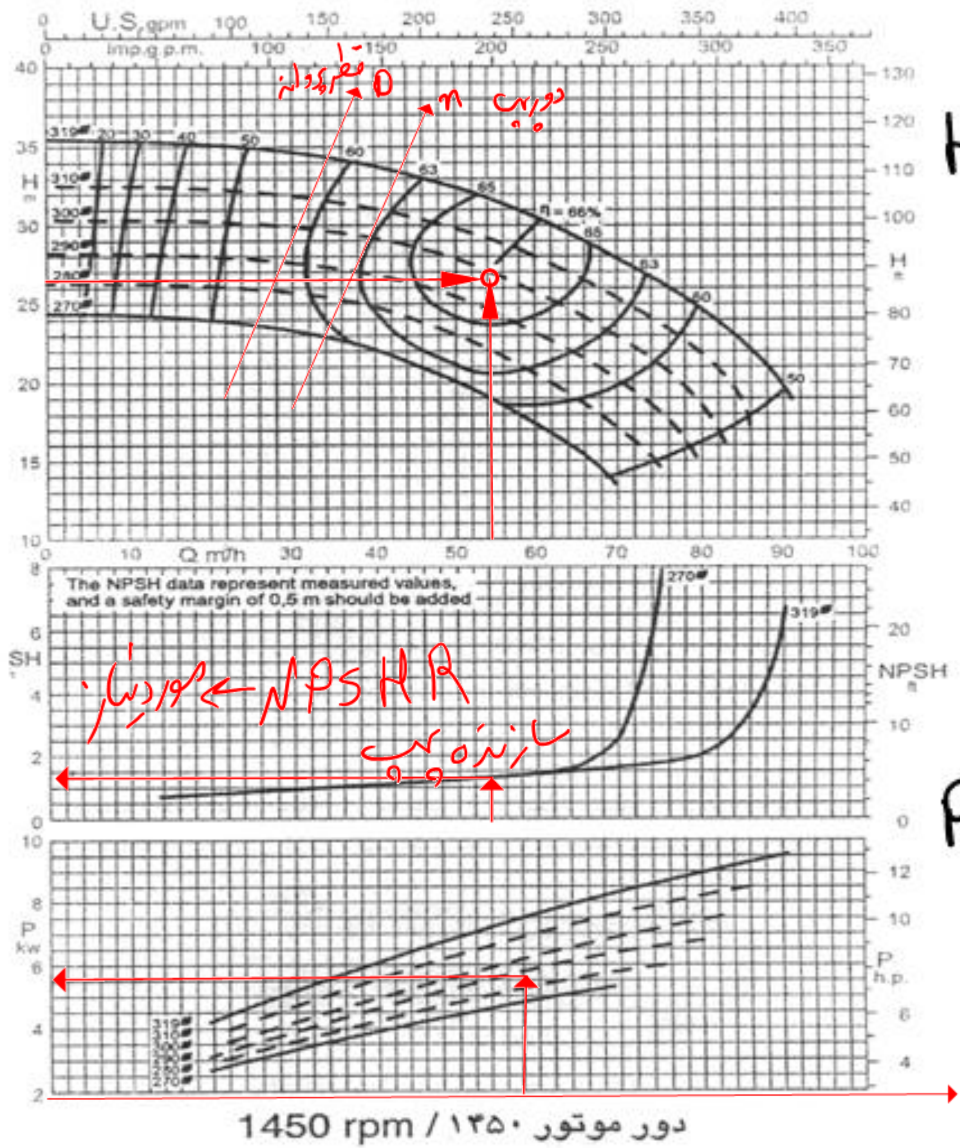
3- NPSH

4- منحنی مشخصه سیستم

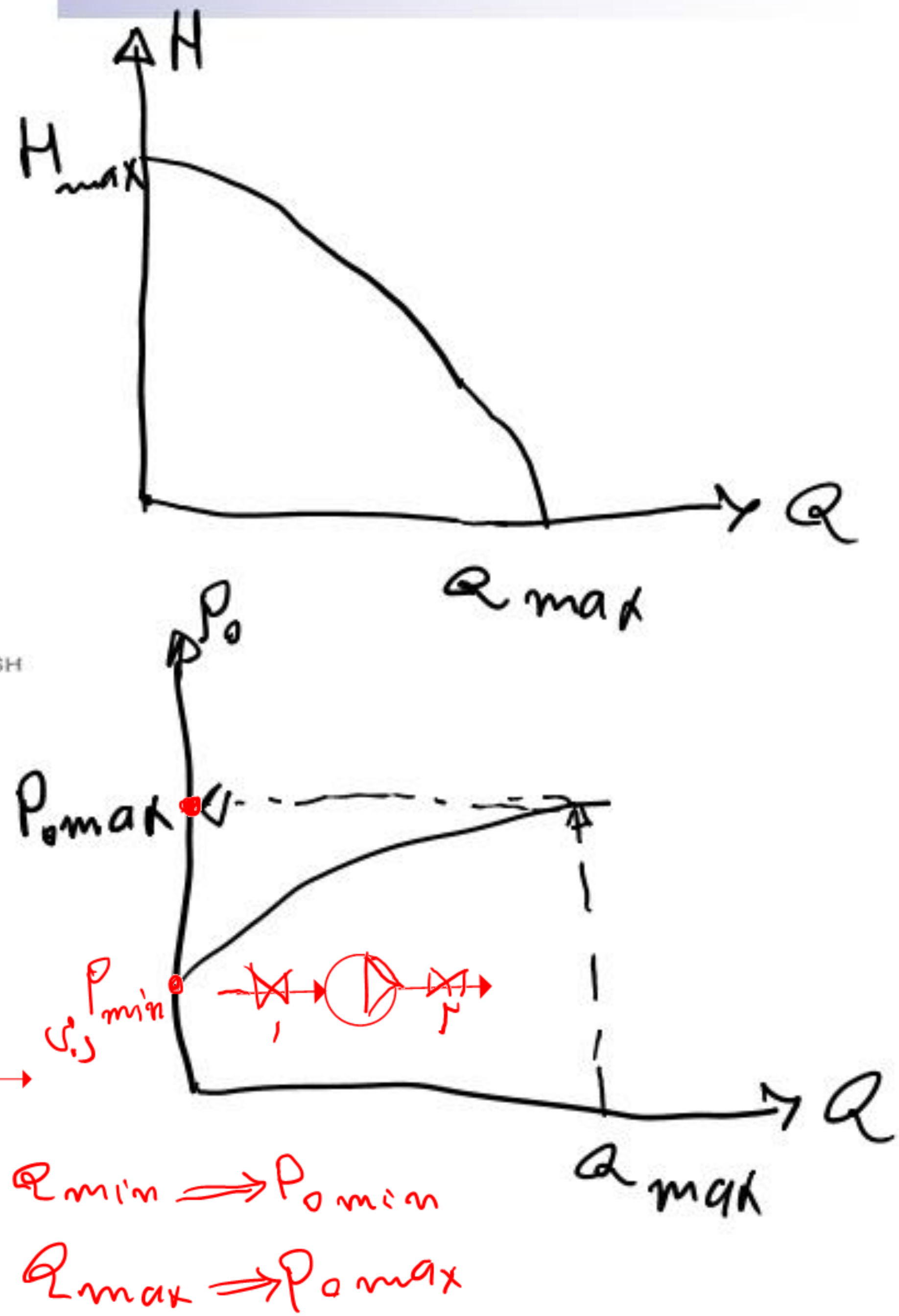
5- بهم بستن پمپ ها

6- ماکزیمم عمق مکش

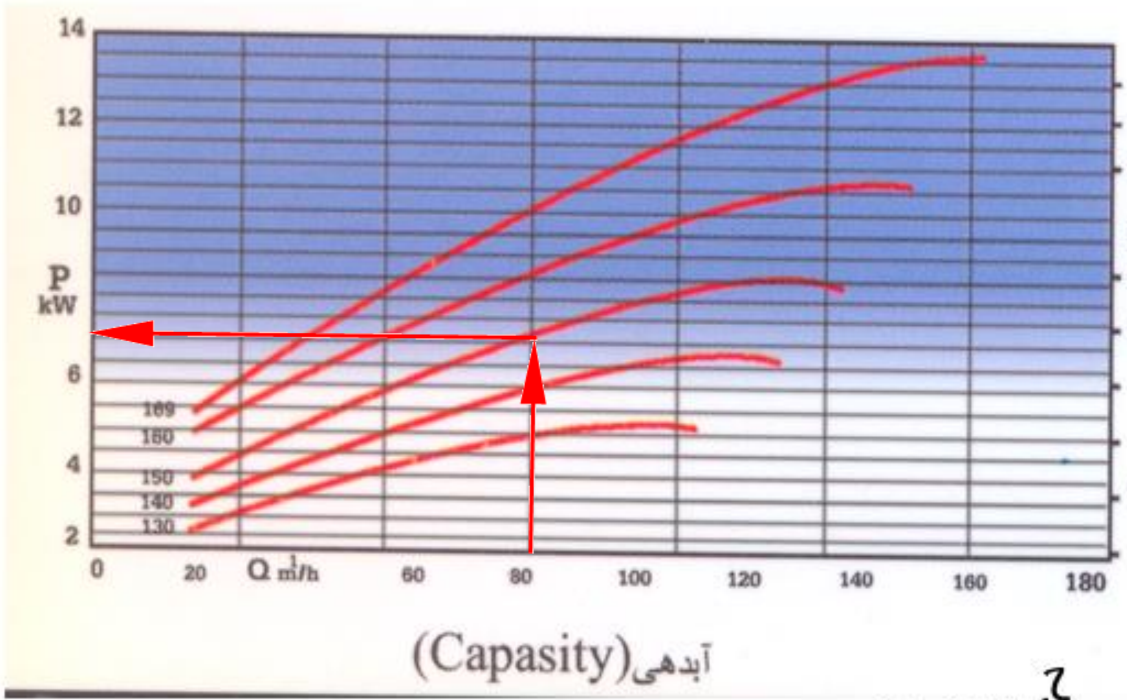
7- روابط پمپ ها



شکل (۹-۴) منحنی مشخصات پمپ ۶۵-۳۱۵



2- منحنی توان پمپ



$$P = \rho \cdot g \cdot H$$

$$P_o(W) = \frac{\rho \cdot g \cdot H \cdot Q}{\eta} \times 1.2$$

$\rho = 1000\ kg/m^3$, $g = 9.81\ m/s^2$, H [m], Q [m^3/s]

$$P_o(hp) = \frac{gpm \times H(ft)}{3960 \times \eta}$$

$$P_o(hp) = \frac{P(psi) \times gpm}{1714 \times \eta}$$

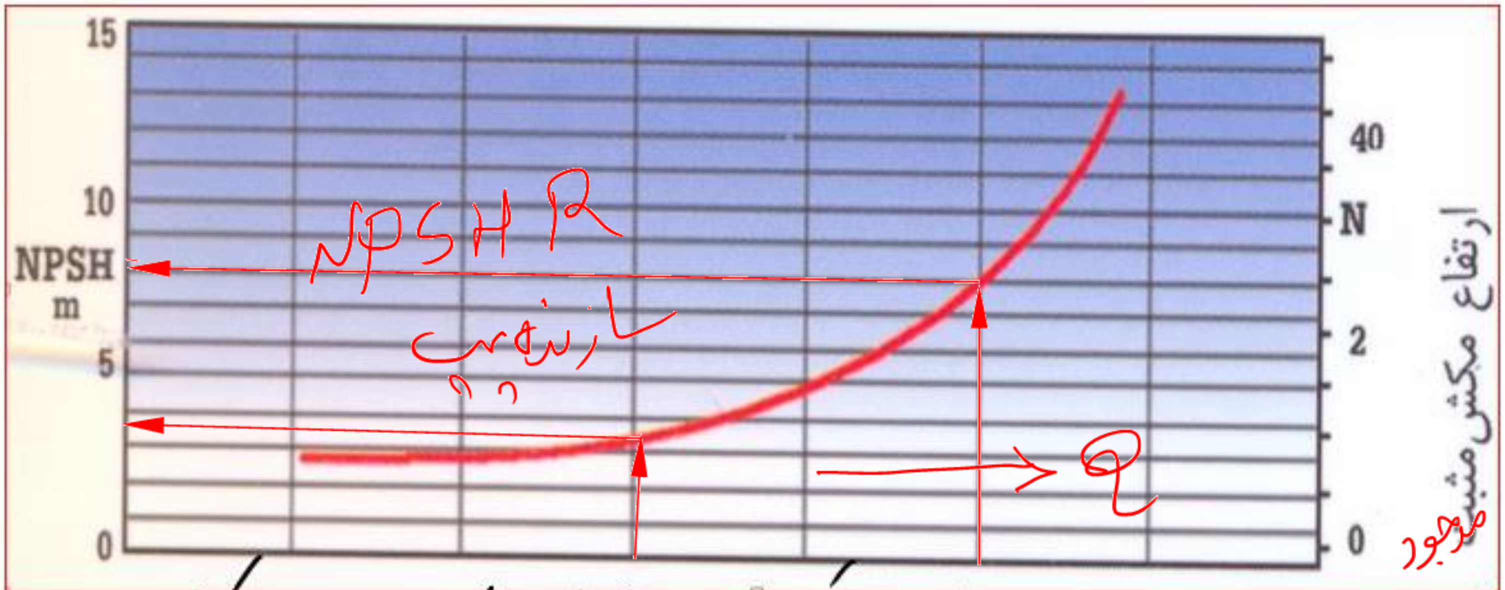
$$P_o(hp) = \frac{P(bar) \times Q(lit/min)}{442 \times \eta}$$

1 kw=1.341 HP

$hp = 745\ W = 0.745\ kW$

3- ارتفاع مکش خالص مثبت(NPSH):

عبارت است از فشار کل سیال در دهانه مکش پمپ که نسبت به فشار تبخیر(اشباع) سیال در درجه حرارت پمپاژ سنجیده می شود.(متر یا فوت)



N = Net

P = Positive

S = Suction

H = Head

واقعی، موجود — مورد نیاز پمپ

$NPSHA > NPSHR$

فشار استاتیک سیال در دهانه مکش پمپ (مطلق) — سرعت سیال در دهانه مکش پمپ — فشار بخار اشباع

$$NPSHA = \frac{P_1}{\rho \cdot g} + \frac{v_1^2}{2g} - \frac{P_v}{\rho \cdot g}$$

$$NPSHA = H_{st_1} + \frac{v_1^2}{2g} - H_v$$

$T = 5^{\circ}C \rightarrow P_v = 870\,Pa$

$T = 55^{\circ}C \rightarrow P_v = 15758\,Pa$

$T = 95^{\circ}C \rightarrow P_v = 84550\,Pa$

$T = 100^{\circ}C \rightarrow P_v = 100{,}000\,Pa$

NET POSITIVE SUCTION CHARACTERISTICS

Particular attention must be given to the pressure and temperature of the water as it enters the pump, especially in condenser towers, steam condensate returns, and steam boiler feeds. If the absolute pressure at the suction nozzle approaches the vapor pressure of the liquid, vapor pockets form in the impeller passages. The collapse of the vapor pockets (**cavitation**) is noisy and can be destructive to the pump impeller (Figure 30).

The amount of pressure in excess of the vapor pressure required to prevent vapor pockets from forming is known as the net positive suction pressure required (NPSR). NPSR is a characteristic of a given pump and varies with pump speed and flow. It is determined by the manufacturer and is included on the pump performance curve.

NPSR is particularly important when a pump is operating with hot liquids or is applied to a circuit having a suction lift. The vapor pressure increases with water temperature and reduces the net positive suction pressure available (NPSA). Each pump has its NPSR, and the installation has its NPSA, which is the total useful energy above the vapor pressure at the pump inlet.

The following equation may be used to determine the NPSA in a proposed design (Figure 31):

$$\text{NPSA} = p_p + p_z - p_{vpa} - p_f \qquad (5)$$

where

p_p = absolute pressure on surface of liquid that enters pump, Pa
p_z = static pressure of liquid above center line of pump (p_z is negative if liquid level is below pump center line), Pa
p_{vpa} = absolute vapor pressure at pumping temperature, Pa
p_f = friction losses in suction piping, Pa

To determine the NPSA in an existing installation, the following equation may be used (see Figure 29):

$$\text{NPSA} = p_a + p_s + \frac{V^2\rho}{2} - p_{vpa} \qquad (6)$$

where

p_a = atmospheric pressure for elevation of installation, Pa
p_s = pressure at inlet flange corrected to center line of pump (p_s is negative if below atmospheric pressure), Pa
$V^2\rho/2$ = velocity pressure at point of measurement of h_s, Pa
ρ = density of fluid, kg/m^3

If the NPSA is less than the pump's NPSR, cavitation, noise, inadequate pumping, and mechanical problems will result. **For trouble-free design, the NPSA must always be greater than the pump's NPSR.** In closed hot and chilled water systems where sufficient system fill pressure is exerted on the pump suction, NPSR is normally not a factor. Figure 32 shows pump curves and NPSR curves. Cooling towers and other open systems require calculations of NPSA.

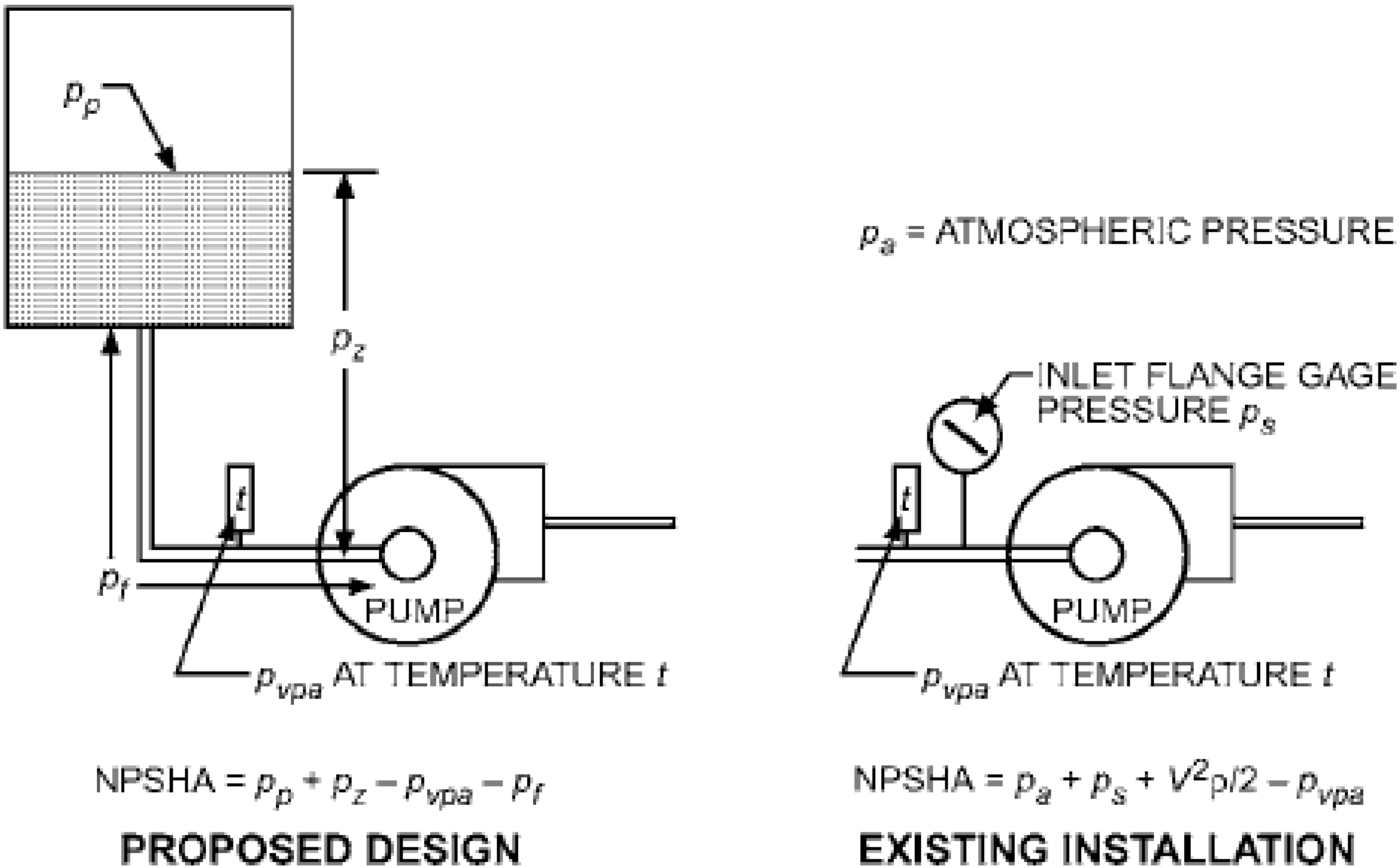
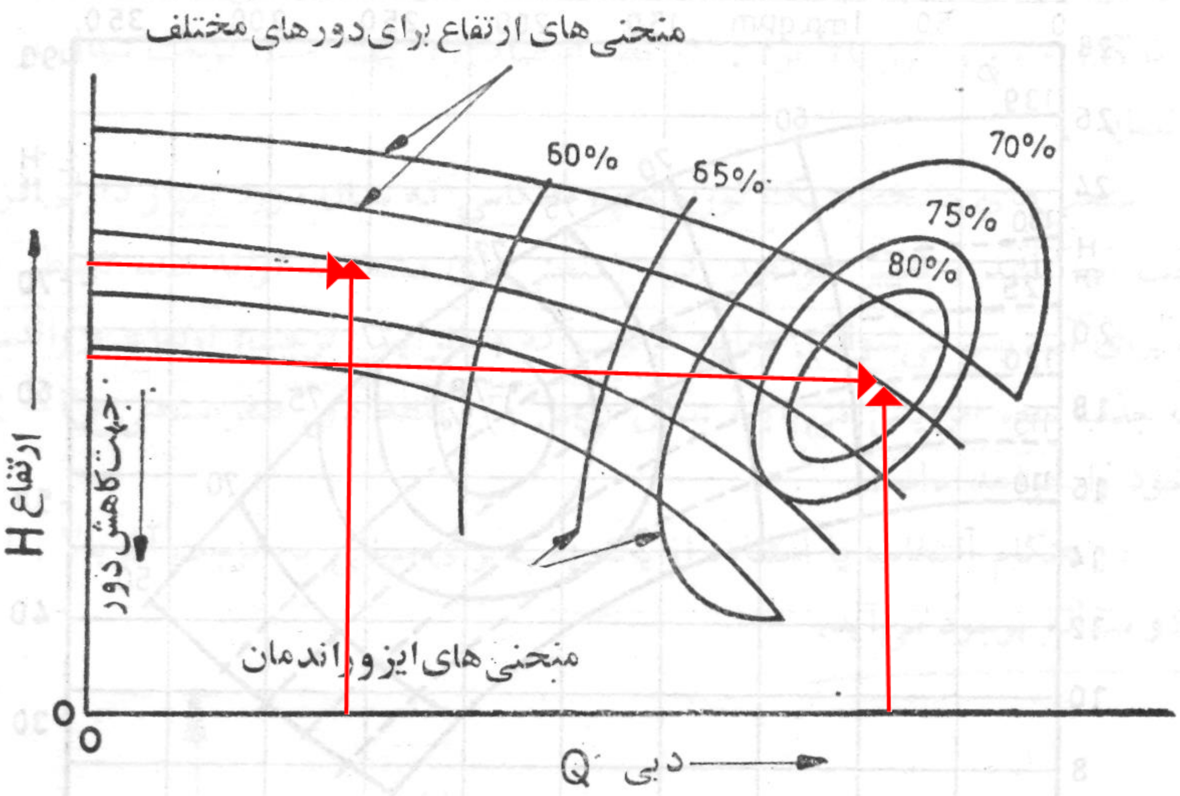


Fig. 31 Net Positive Suction Pressure Available

4- منحنی راندمان:



شکل (٤-٨) - نمونه‌ای از منحنی مشخصه یک پمپ سانتریفوژ
با تغییر سرعت دورانی

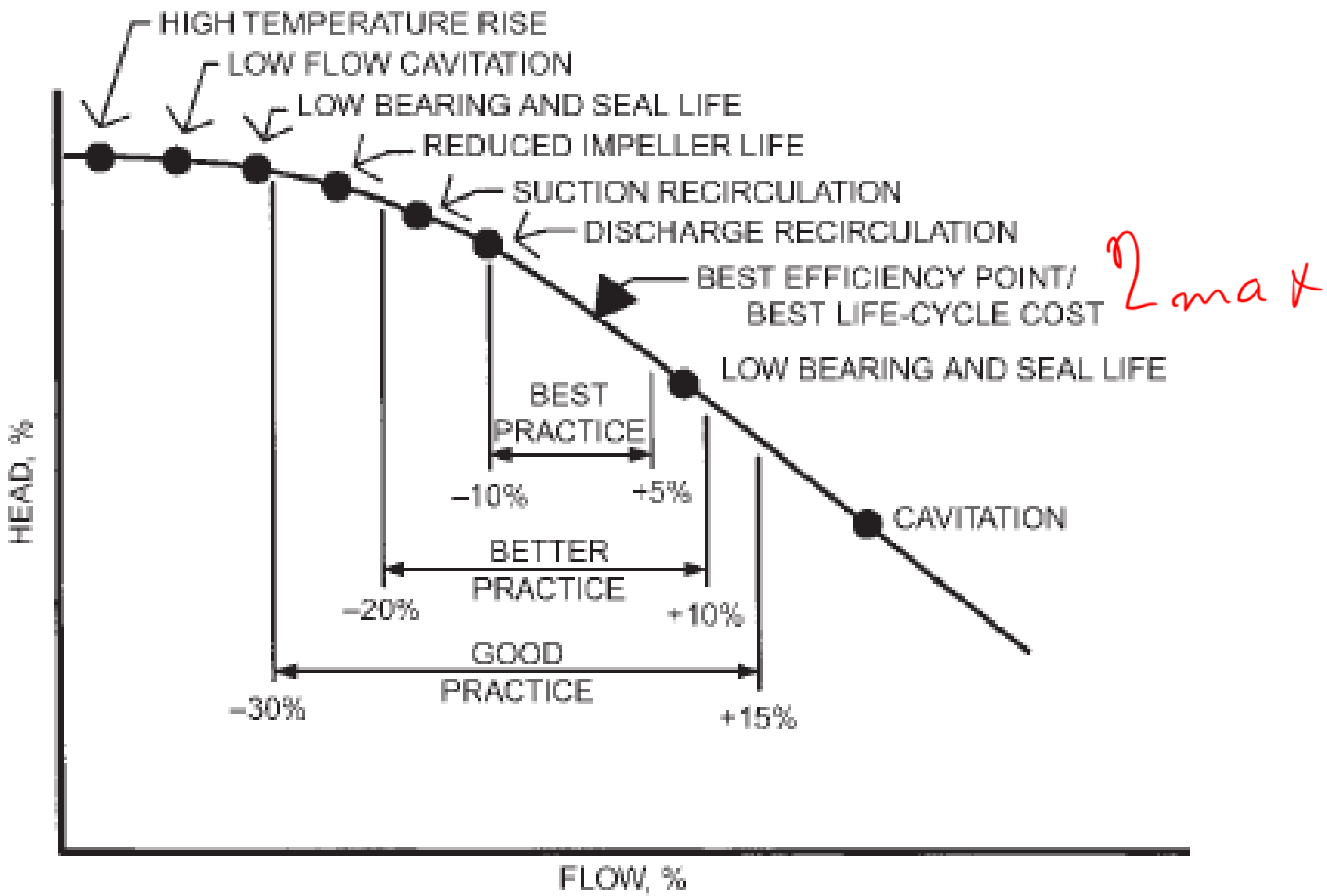


Fig. 7 General Pump Operating Condition Effects

(Hydraulic Institute)

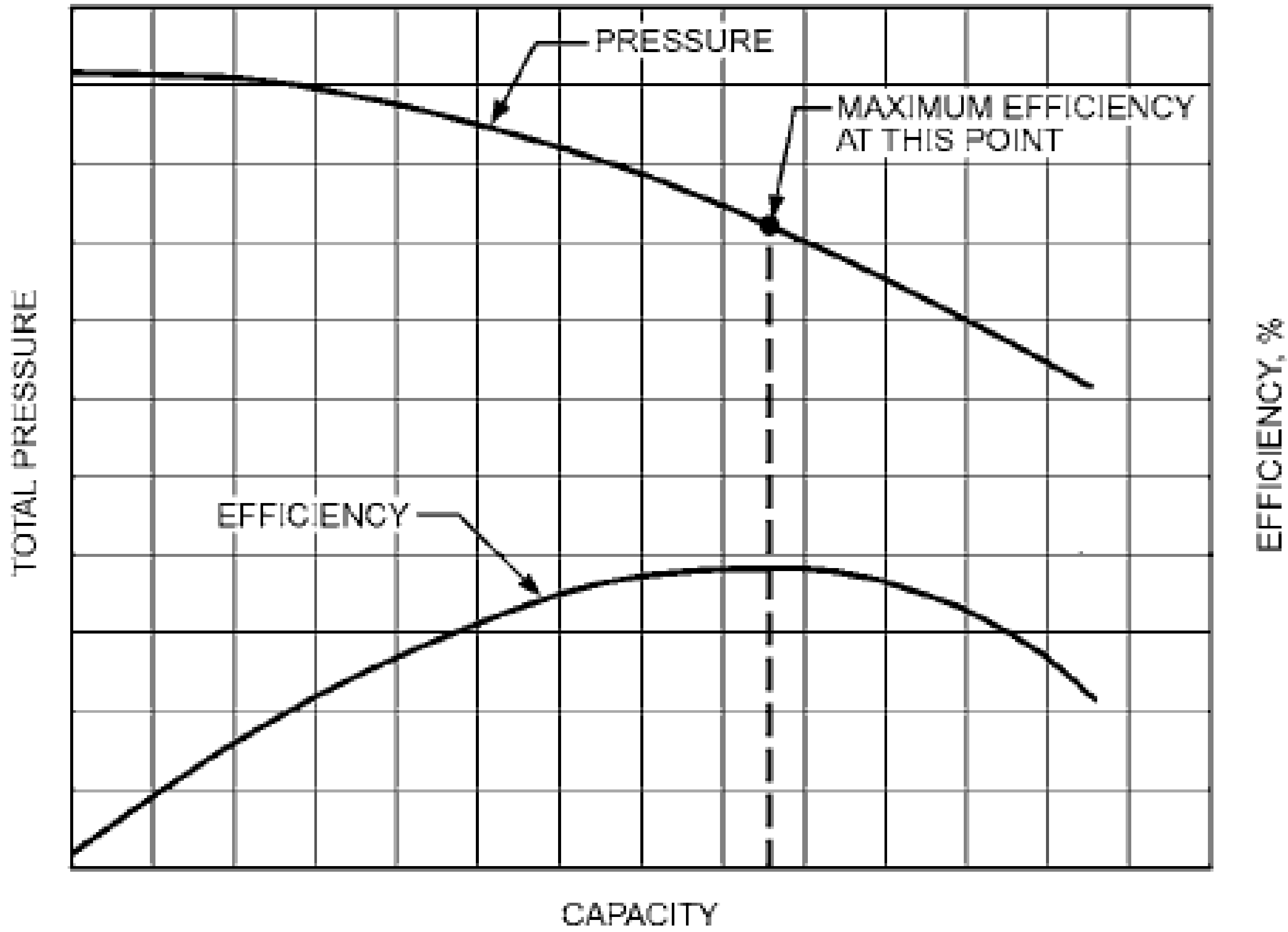


Fig. 22 Pump Efficiency Versus Flow

PUMP EFFICIENCY

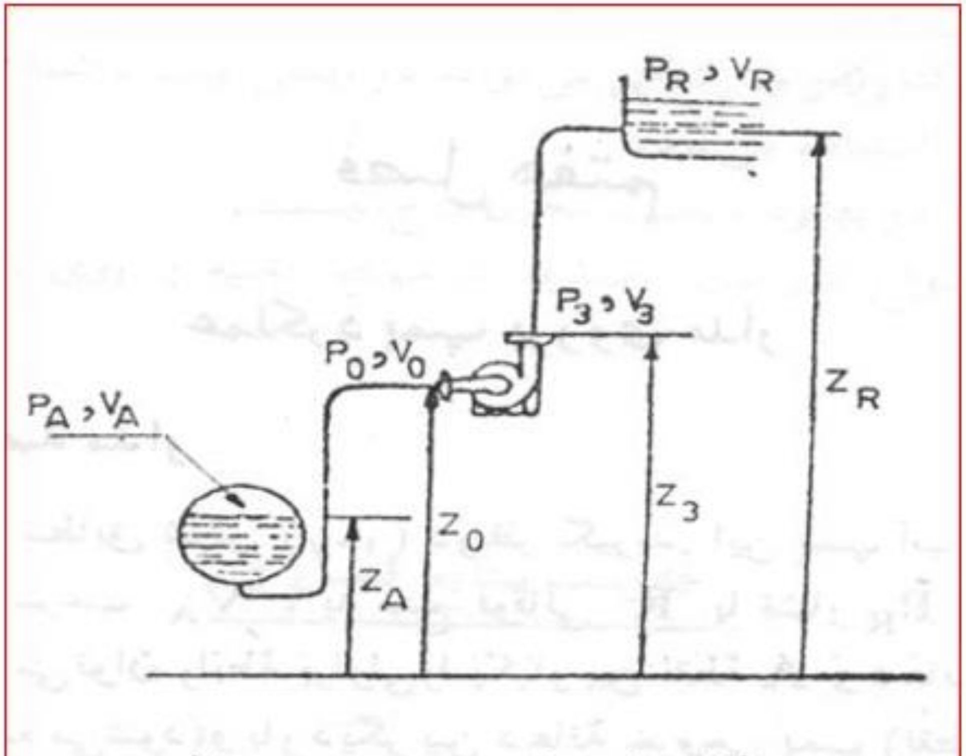
Pump efficiency is determined by comparing the output power to the input power:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{P_w}{P_t} \times 100\% \qquad (4)$$

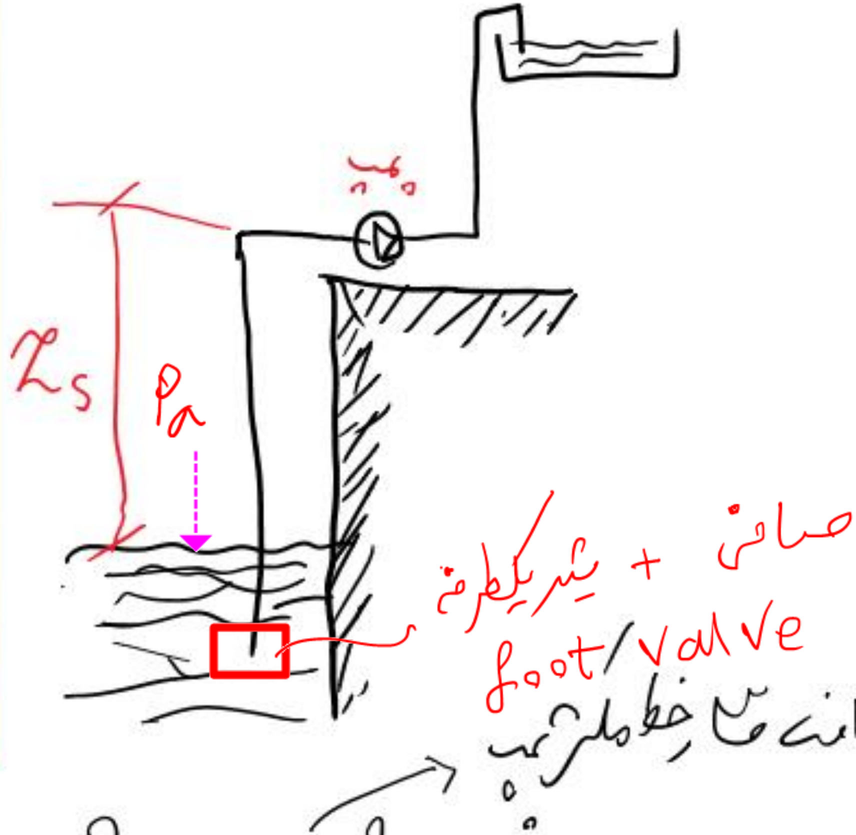
Figure 22 shows a typical efficiency versus flow curve.

The pump manufacturer usually plots the efficiencies for a given volute and impeller size on the pump curve to help the designer select the proper pump (Figure 23). The best efficiency point (BEP) is the optimum efficiency for this pump; operation above and below this point is less efficient. The locus of all the BEPs for each impeller size lies on a system curve that passes through the origin (Figure 24).

۵- ارتفاع مکش ماگزیمم :



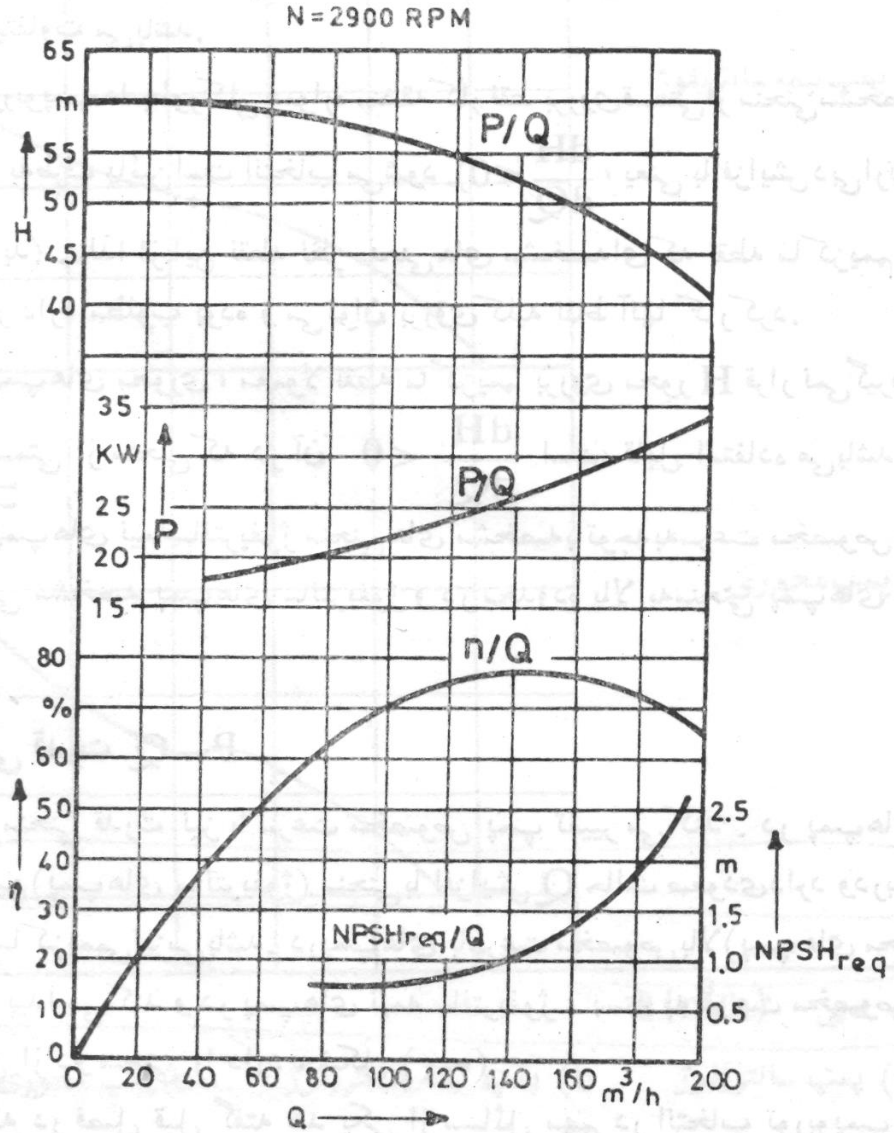
شکل (۱-۷) - پمپ روی مدار



مورد نیاز

$$Z_{s\,max} = \frac{P_a}{\rho \cdot g} - \left\{ NPSHR + \frac{P_v}{\rho \cdot g} + H_l \right\}$$

$$Z_{s\,max} = H_a - (NPSHR + H_v + H_L)$$



شکل (٤-١) ـ نمونه‌ای از منحنی‌های مشخصه یک پمپ سانتریفوژ

سرعت مخصوص پمپ (N_s):

$$N_s = 0.2108\,\frac{n \times \sqrt{Q}}{H^{3/4}}$$

- N_s ← سرعت مخصوص
- n ← rpm
- Q ← دبی پمپ lit/min
- H ← هد پمپ m

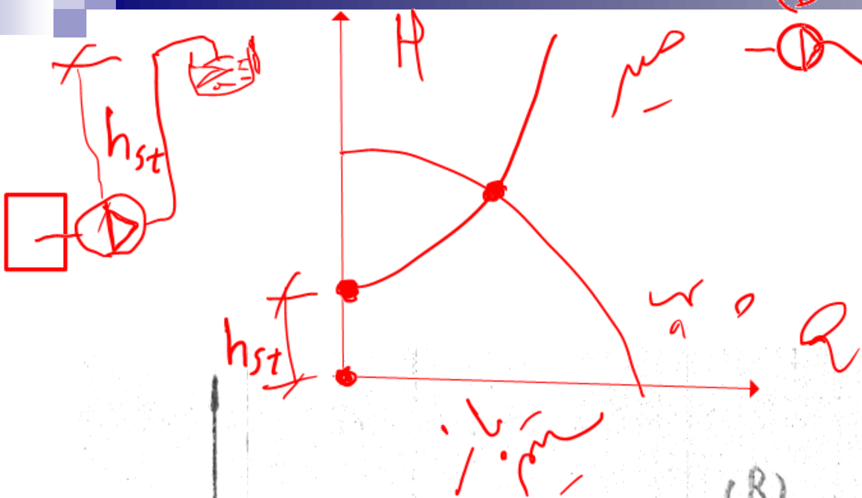
$$N_s = 0.2108\, n \left(\frac{Q}{H^{0.75}}\right)^{0.5}$$

- N_s: سرعت مخصوص پمپ
- n: دور پمپ RPM
- Q: دبی پمپ lit/min
- H: هد پمپ (m)

مثال:

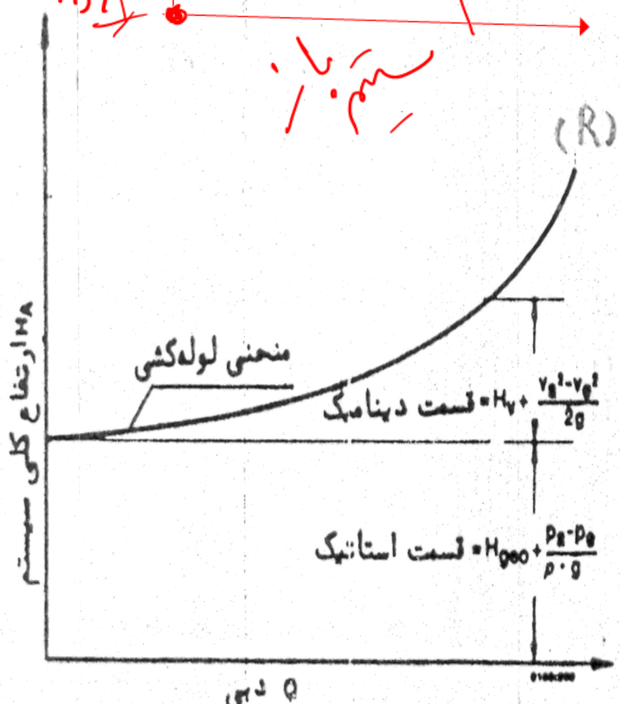
- پمپ گریز از مرکز سانتریفوژ ← 50-3000
- 〃 توربینی ← 3000-6000
- 〃 پروانه‌دار ← 6000-10,000

منحنی مشخصه سیستم (مسیر):

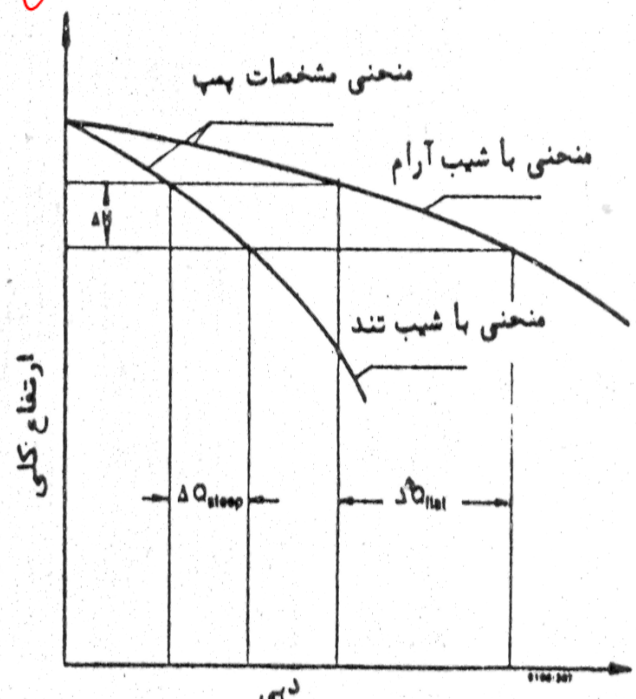


1- سیستم باز

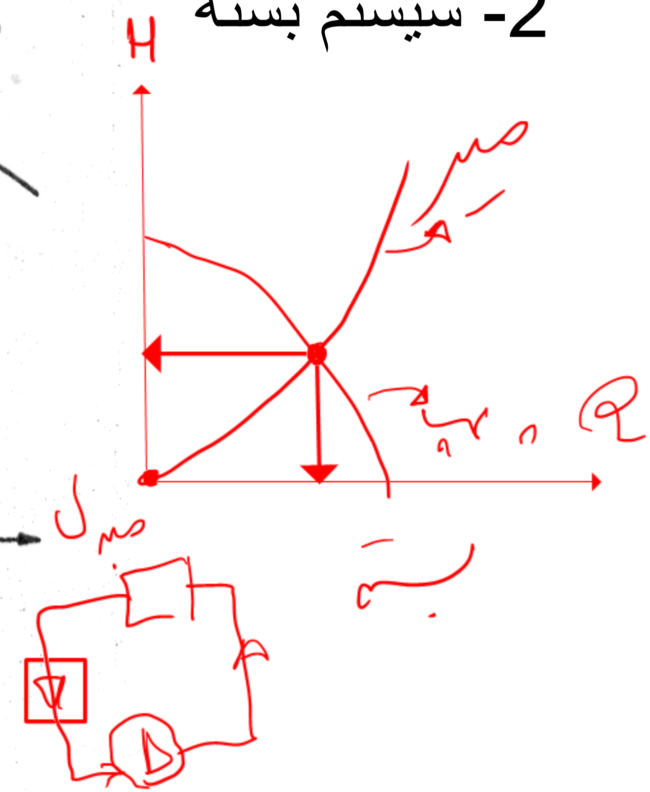
2- سیستم بسته



شکل ۵ ـ منحنی مشخصات لوله‌کشی (سیستم)



شکل ۴ـ منحنی مشخصات با شیب تند و آرام



HYDRONIC SYSTEM CURVES

Pressure drop caused by the friction of a fluid flowing in a pipe may be described by the Darcy-Weisbach equation:

$$\Delta p = f\,\frac{L}{D}\rho\,\frac{V^2}{2} \qquad (1)$$

Equation (1) shows that pressure drop in a hydronic system (pipe, fittings, and equipment) is proportional to the square of the flow (V^2 or Q^2 where Q is the flow). Experiments show that pressure drop is more nearly proportional to between $V^{1.85}$ and $V^{1.9}$, or a nearly parabolic curve as shown in Figures 15 and 18. The design of the system (including the number of terminals and flows, the fittings and valves, and the length of pipe mains and branches) affects the shape of this curve.

Equation (1) may also be expressed in specific energy form:

$$\Delta h = \Delta h = \frac{\Delta p}{\rho g} = f\,\frac{L}{D}\frac{V^2}{2g} \qquad (2)$$

where

Δh = loss through friction, m (of fluid flowing)

Δp = pressure drop, Pa

ρ = fluid density, kg/m^3

f = friction factor, dimensionless

L = pipe length, m

D = inside diameter of pipe, m

V = fluid average velocity, m/s

g = gravitational acceleration, 9.8 m/s^2

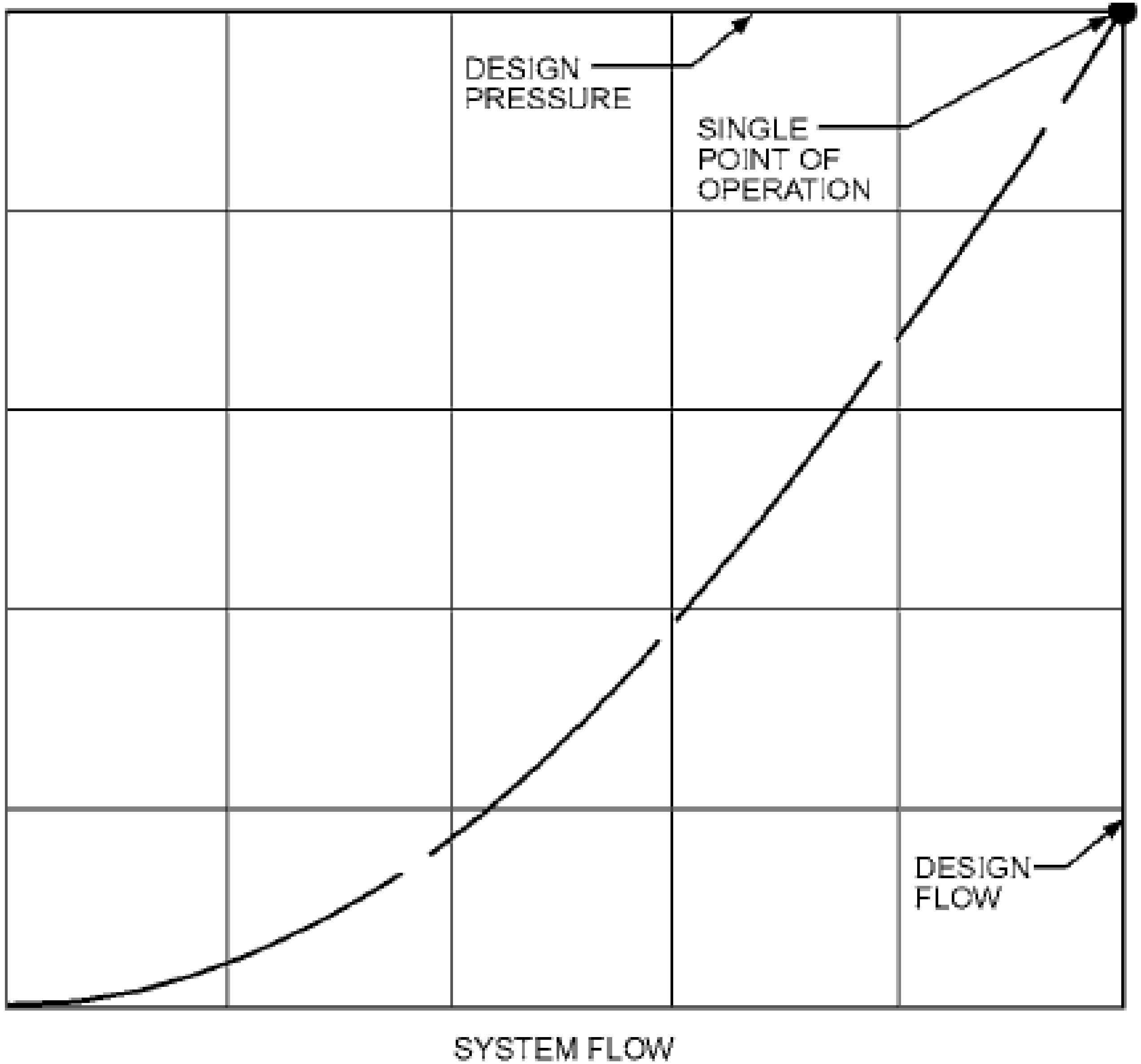


Fig. 15 Typical System Curve

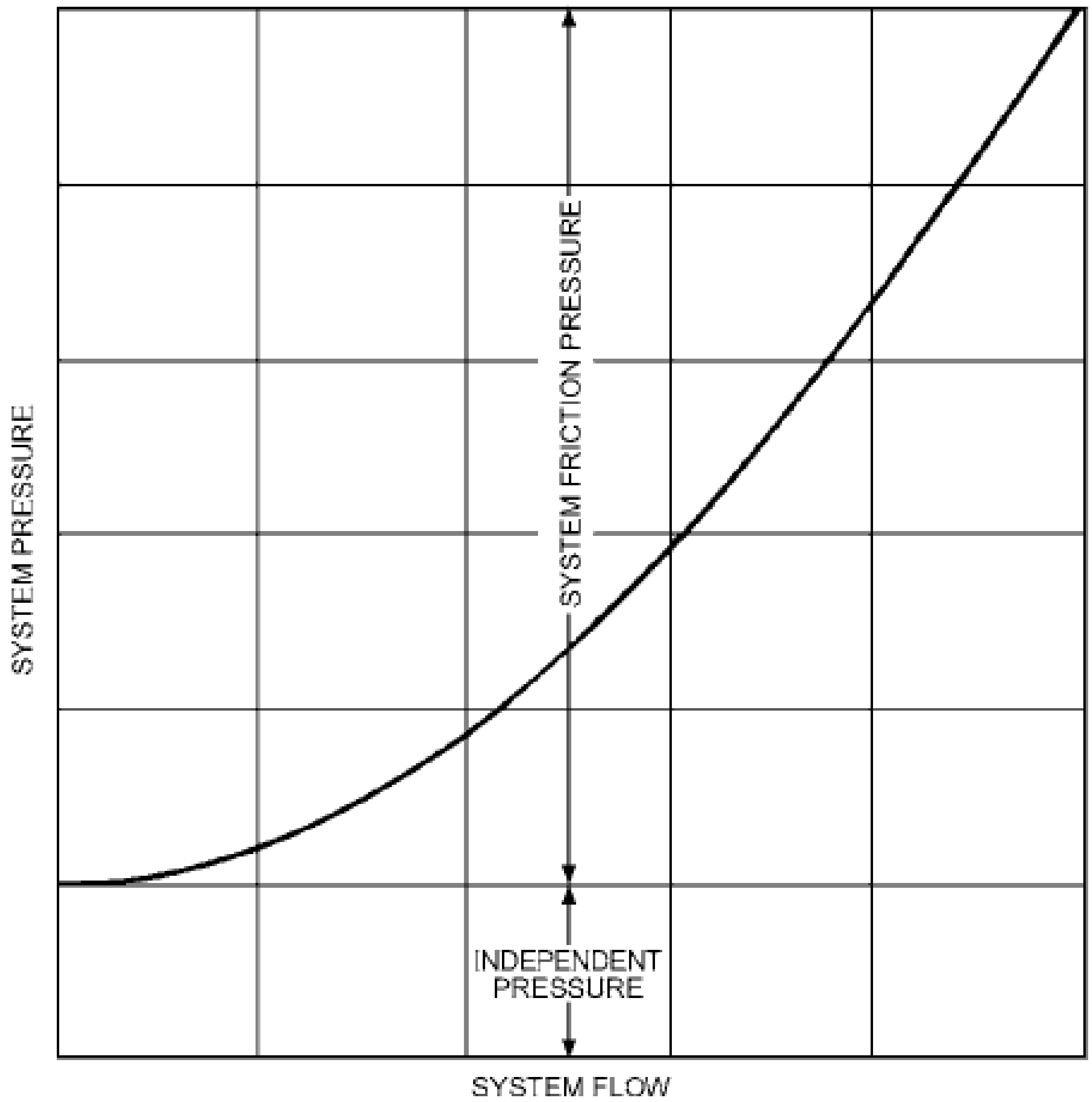


Fig. 16 Typical System Curve with Independent Pressure

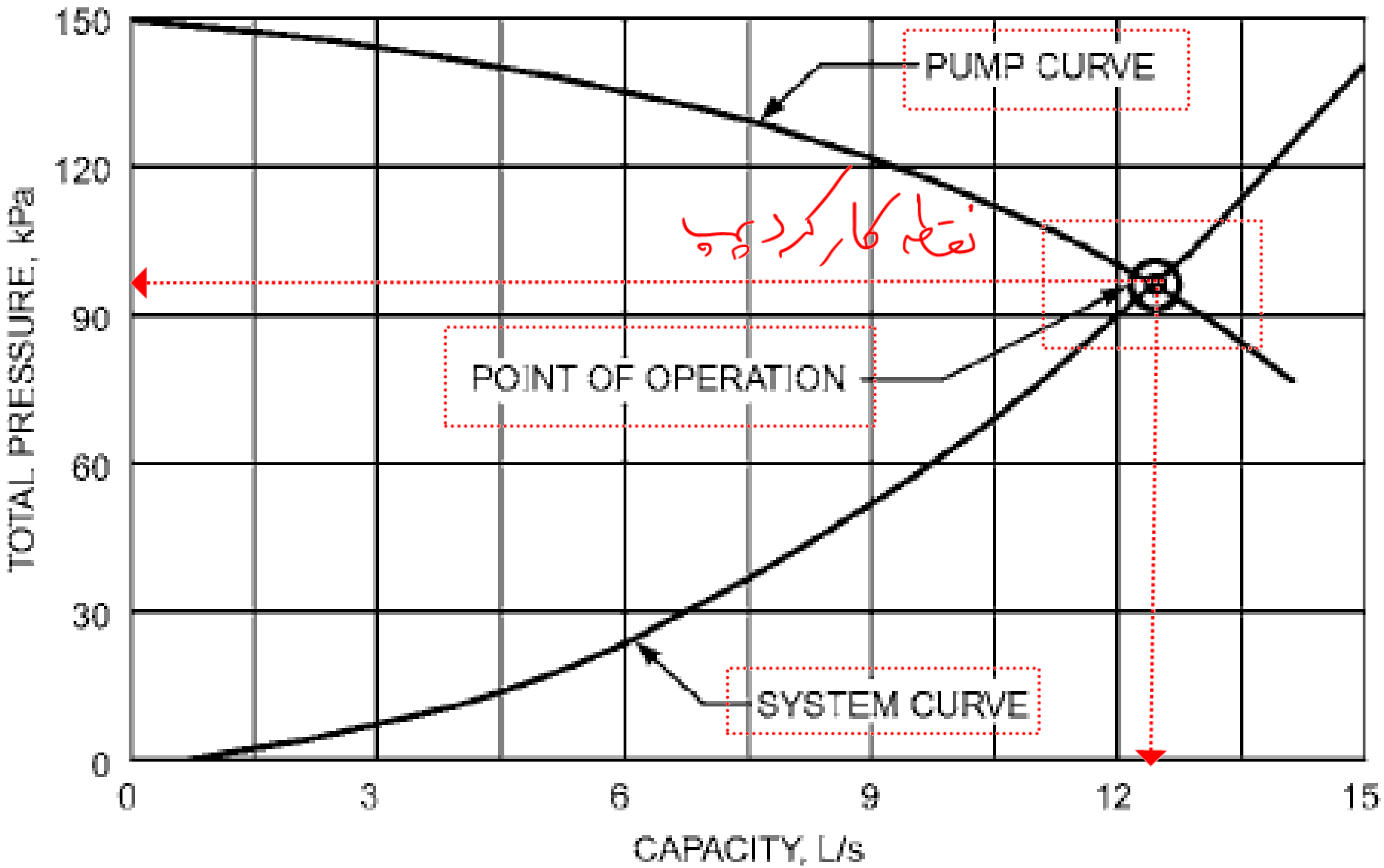
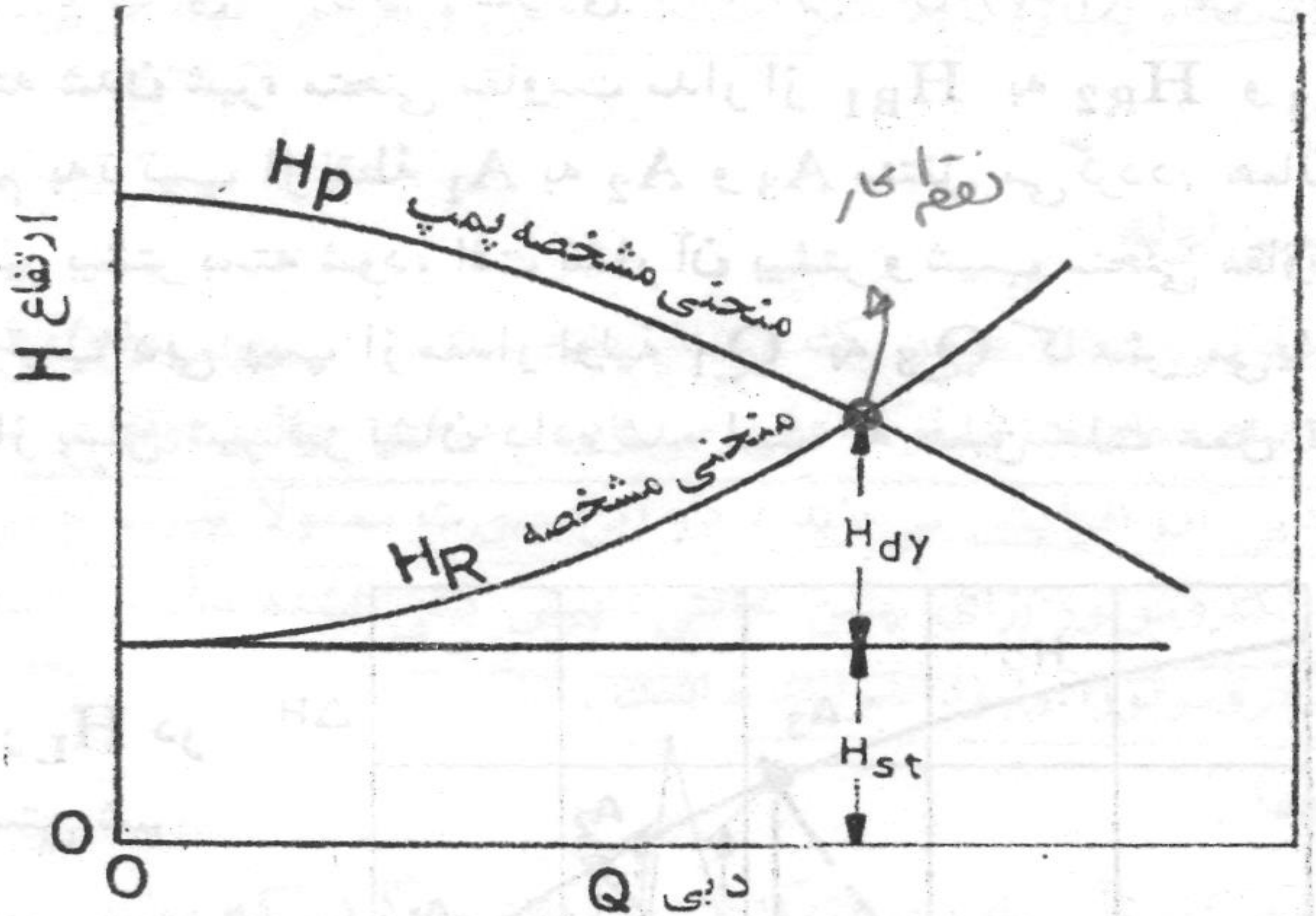


Fig. 17 System and Pump Curves



شکل (۷-۲) - نقطه کار یک توربو پمپ

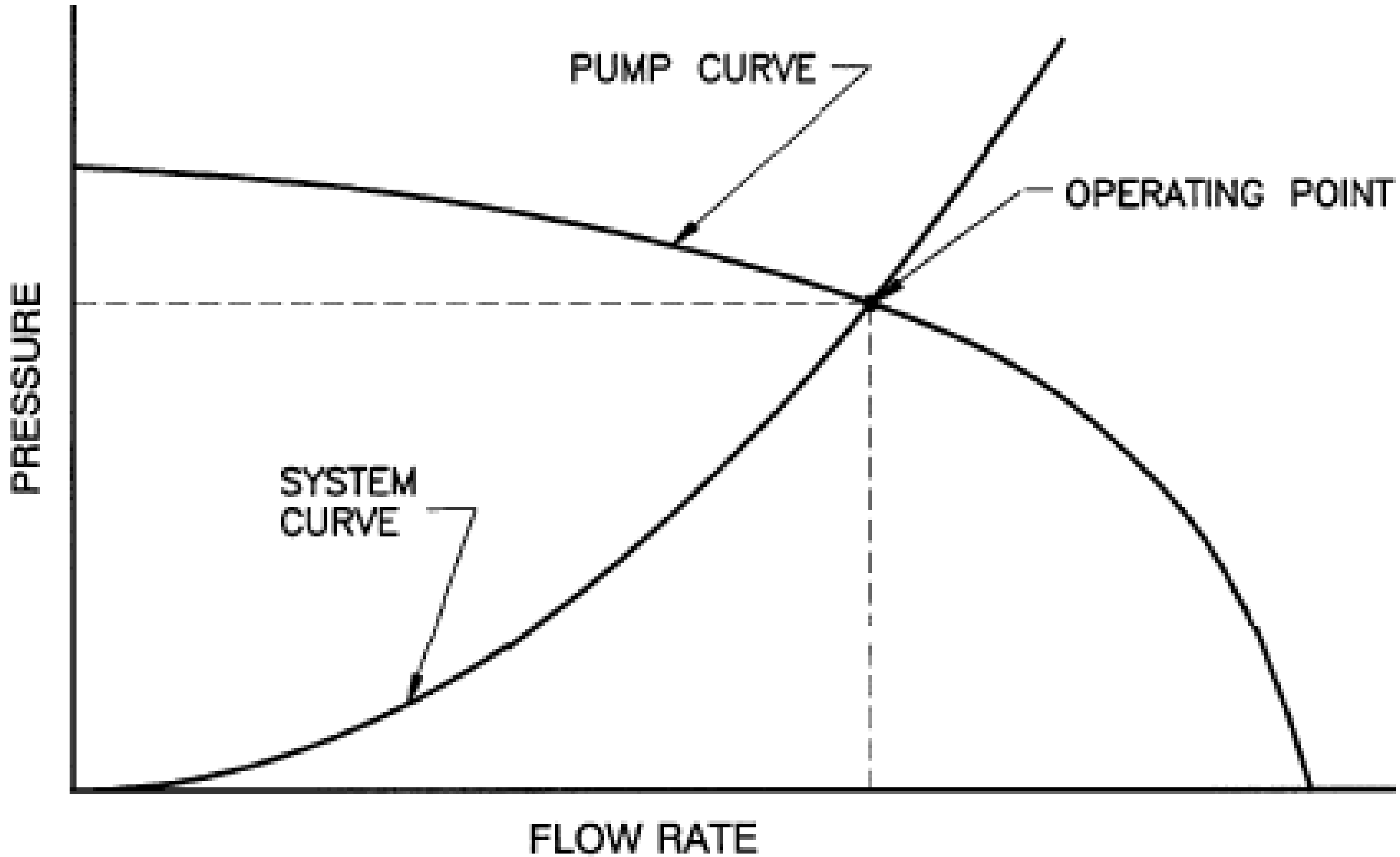


Fig. 5 Pump Curve and System Curve

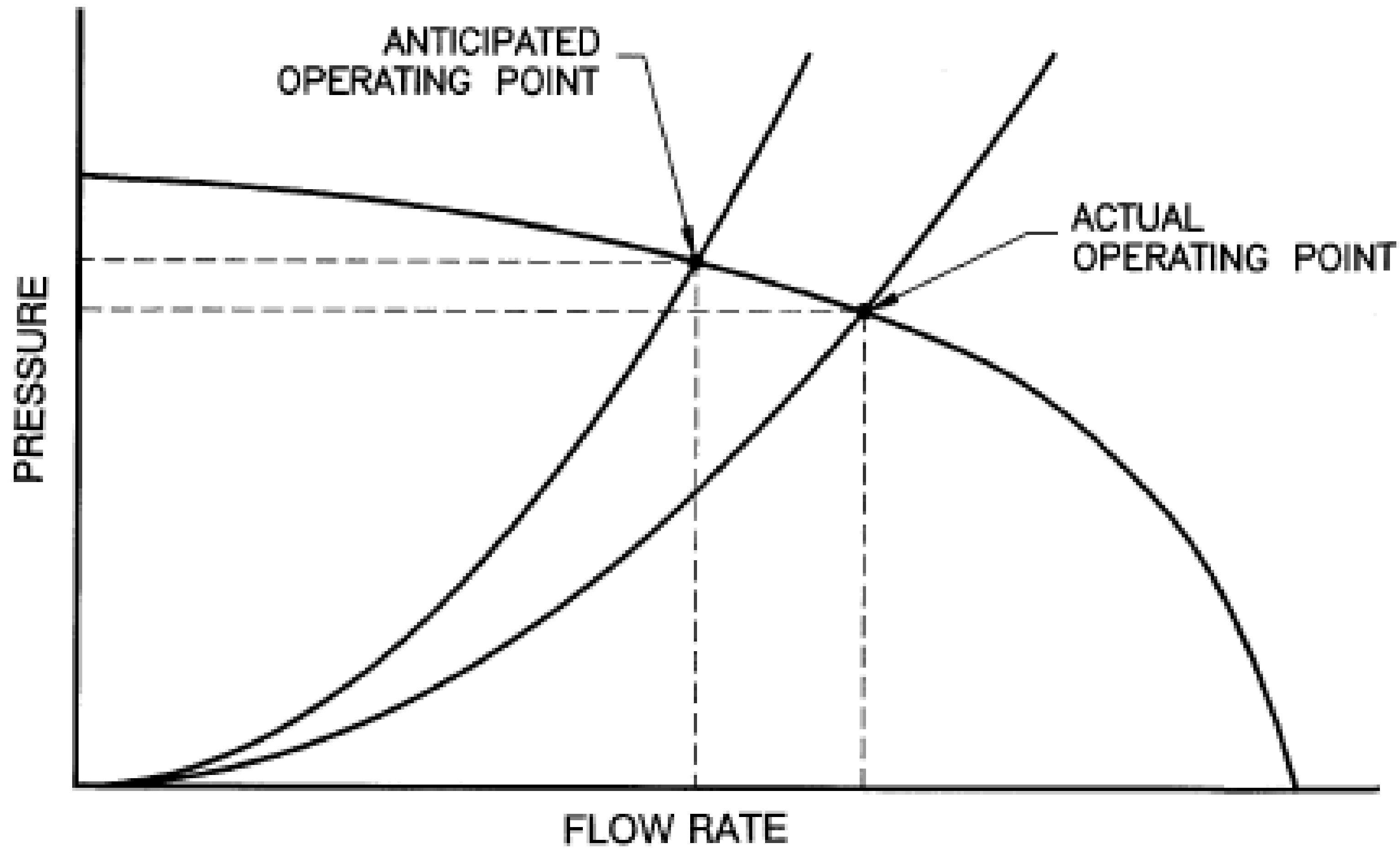
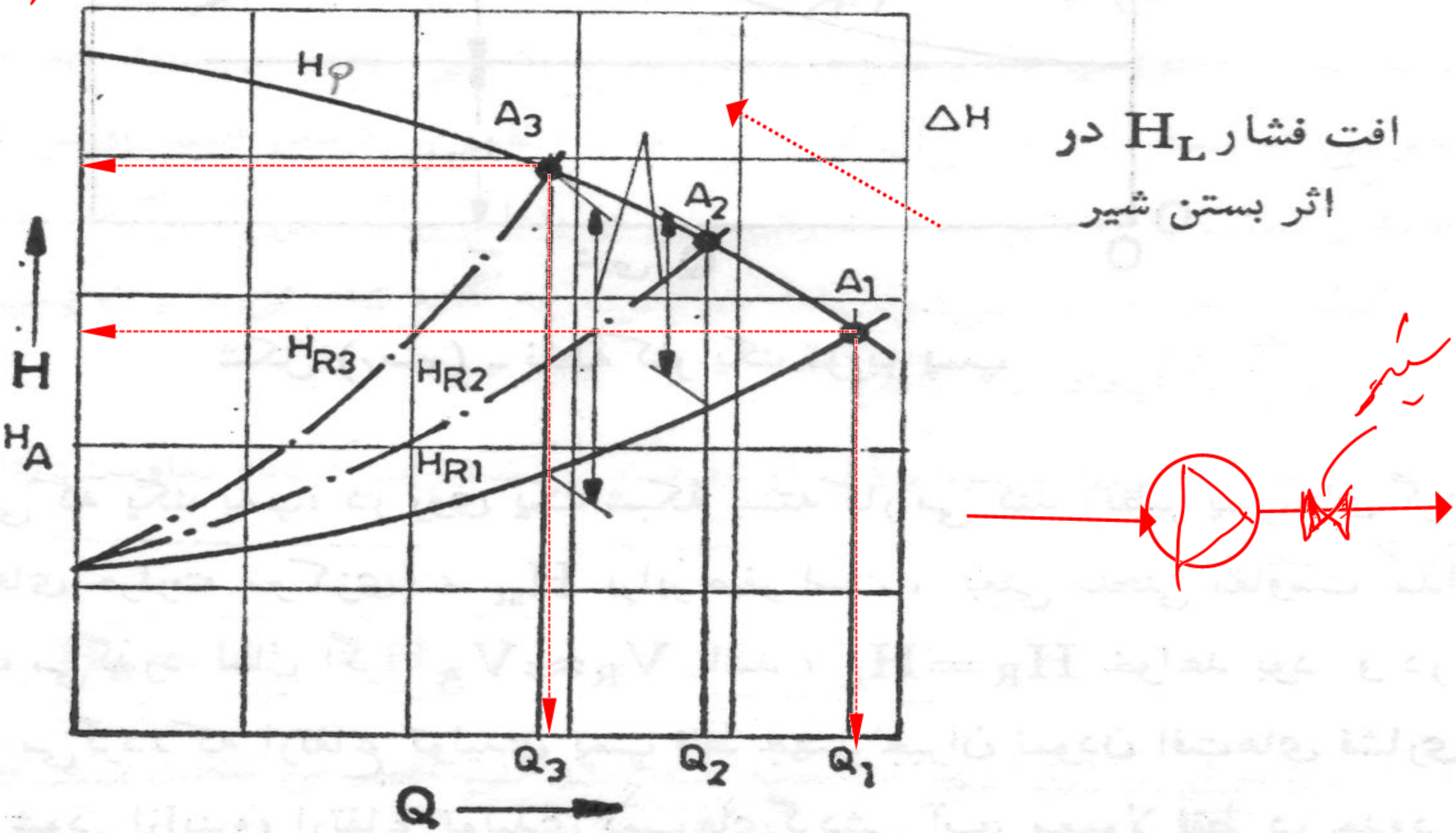


Fig. 6 Shift of System Curve due to Circuit Unbalance

عوامل موثر بر مشخصه مسیر:



شکل (۷-۳) - تأثیر بستن شیر بر منحنی مشخصه مدار

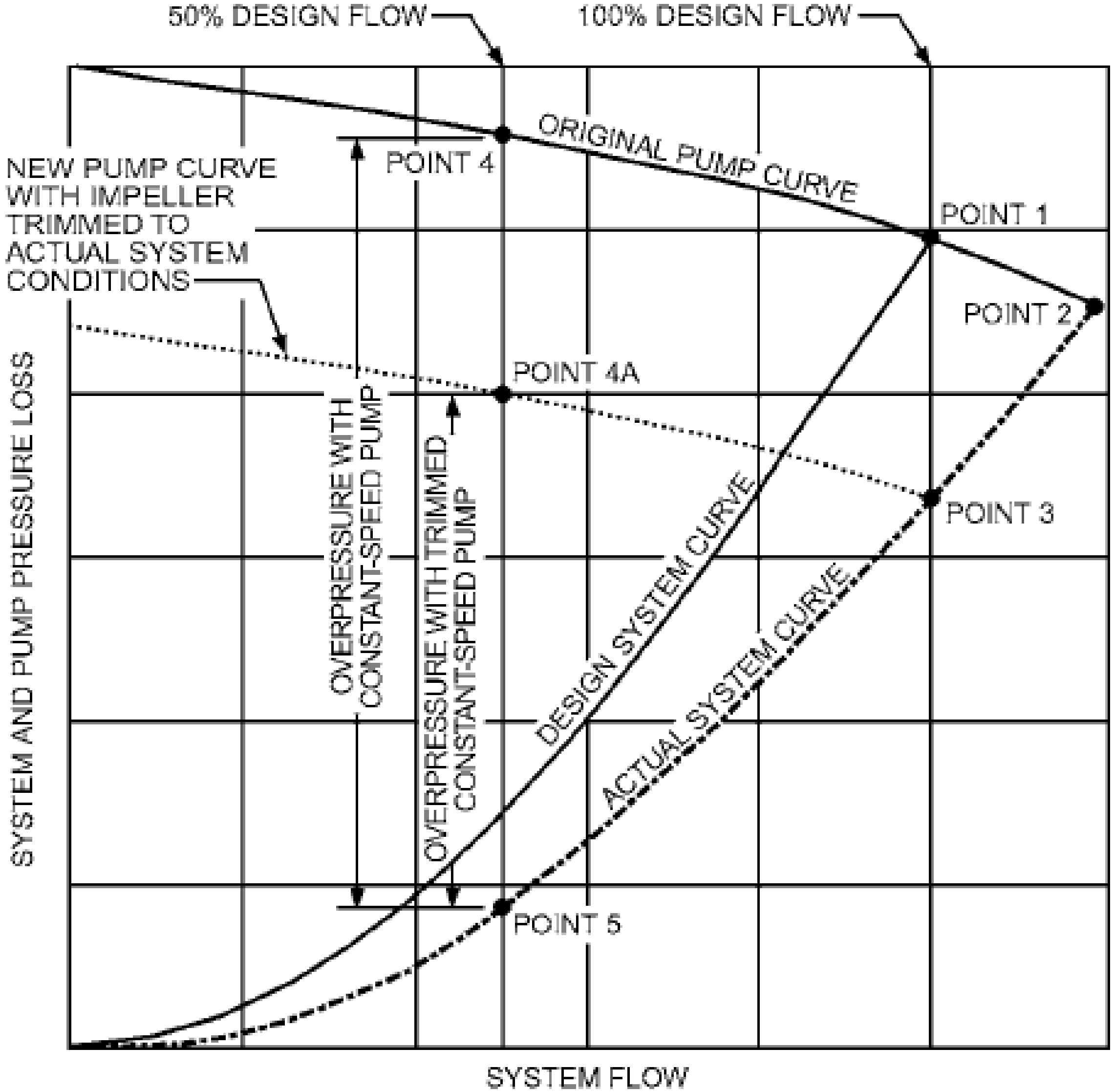


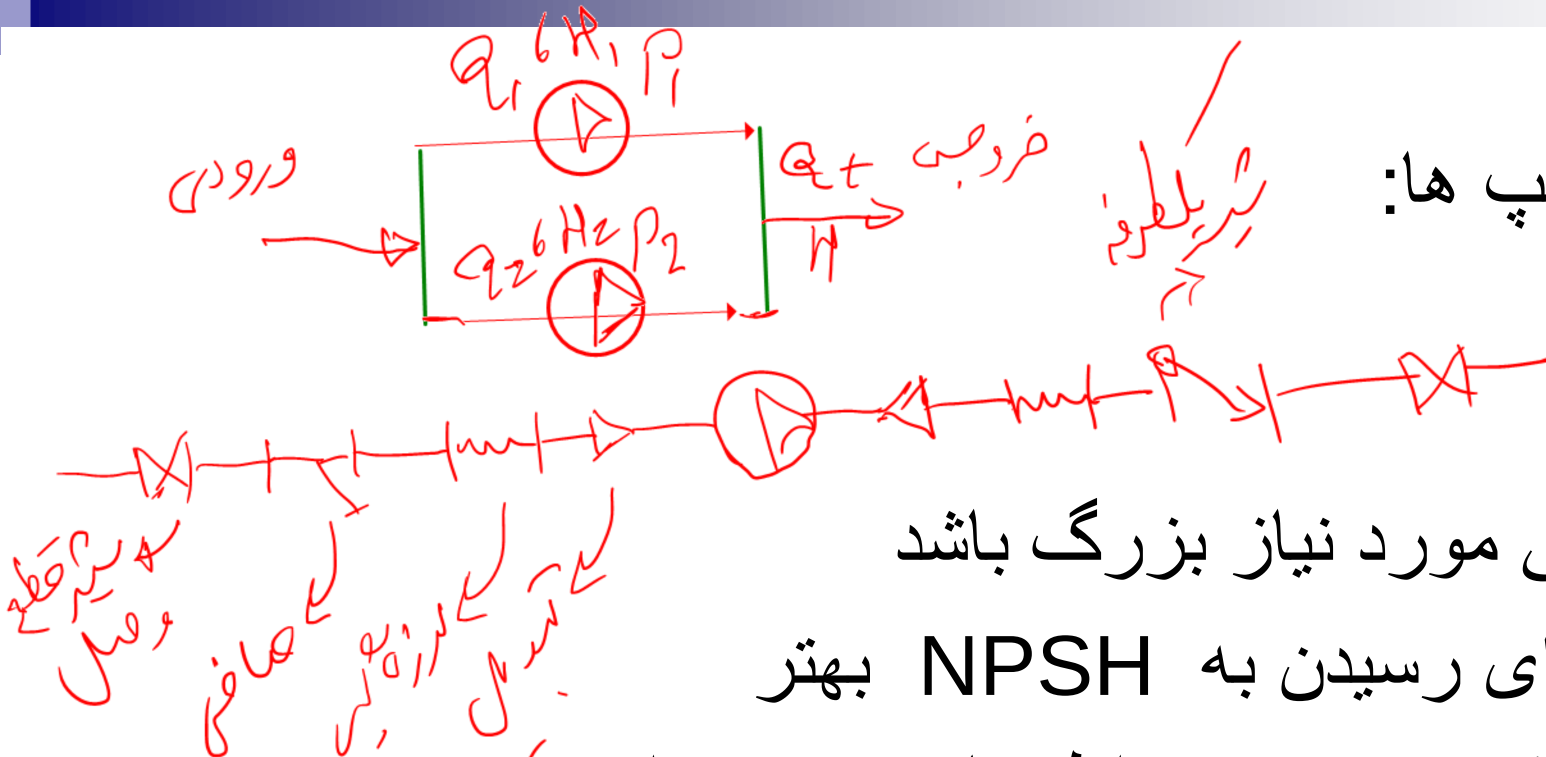
Fig. 19 Pump Operating Points

To reduce the actual flow to the design flow at point 1, a balancing valve downstream from the pump can be adjusted while all the terminal valves are in a wide-open position. This pump discharge balancing valve imposes a pressure drop equal to the pressure difference between point 1 and point 3. The manufacturer's pump curve shows that the capacity may be reduced by substituting a new impeller with a smaller diameter or by trimming the existing pump impeller. After trimming, reopening the balancing valve in the pump discharge then eliminates the artificial drop and the pump operates at point 3. Points 3 and 4A demonstrate the effect a trimmed impeller has on reducing flow.

Figure 20 is an example of a system curve with both fixed pressure loss and variable pressure loss. Such a system might be an open piping circuit between a refrigerating plant condenser and its cooling tower. The elevation difference between the water level in the tower pan and the spray distribution pipe creates the fixed pressure loss. The fixed loss occurs at all flow rates and is, therefore, an independent pressure as shown.

Most variable-flow hydronic systems have individual two-way control valves on each terminal unit to permit full diversity

بهم بستن پمپ ها:



1- موازی

- دبی مورد نیاز بزرگ باشد
- برای رسیدن به NPSH بهتر
- بالا بردن ضریب اطمینان بهره برداری

۱- در این حالت در هدهای ثابت دبی ها با هم جمع می شوند. (برای بدست آوردن منحنی مشخصه مشترک)

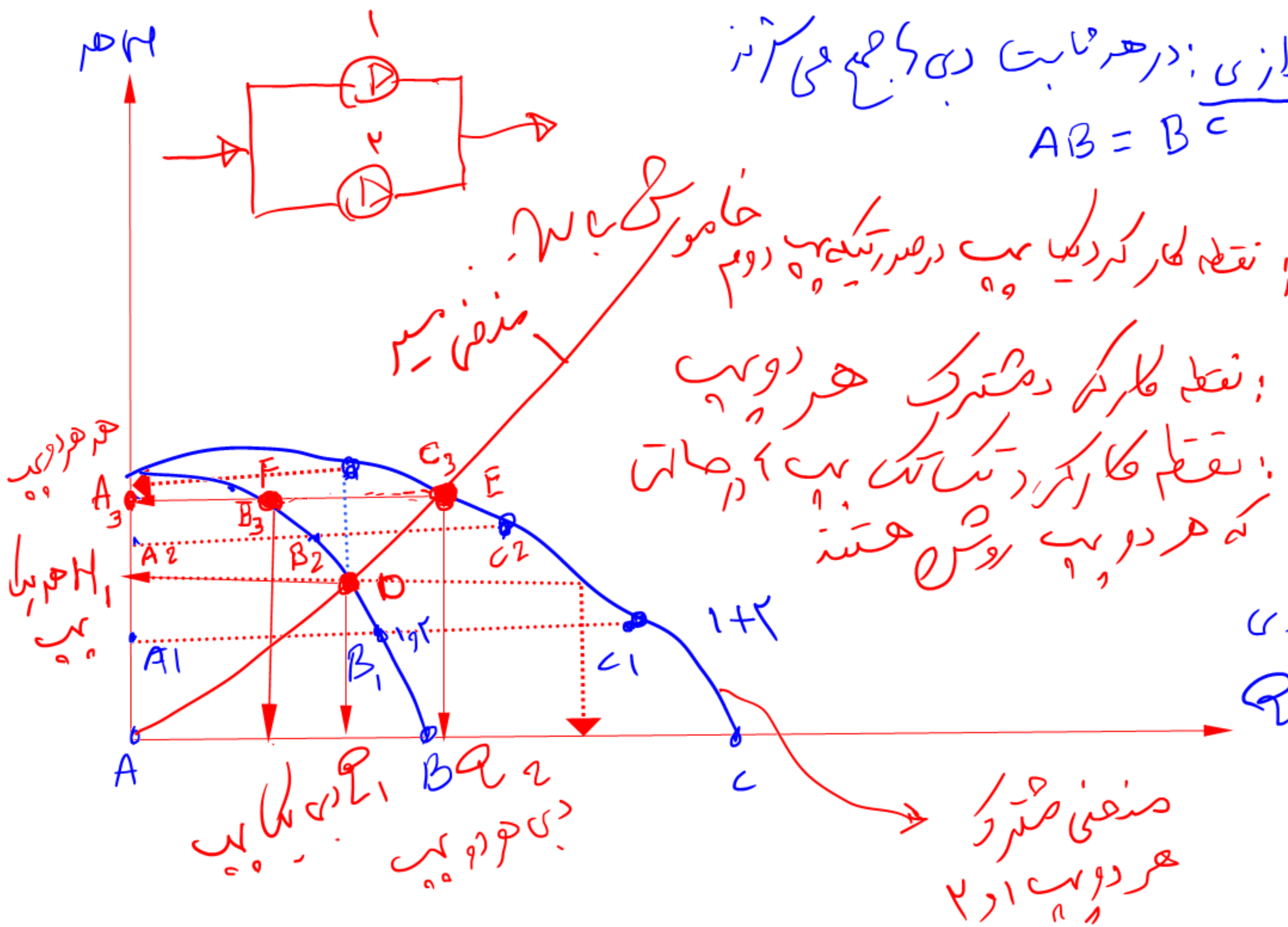
۲- در پمپ های موازی فشار هر دو پمپ با هم برابر است $H_1=H_2$ ولی دبی پمپ ها می توانند برابر نباشد

به عبارتی $H=H_1=H_2$ ، $Q_t=Q_1+Q_2$

نکته: در مدارهای موازی فشار مدارها باهم برابرند ولی دبی می‌تواند متفاوت باشد.

موازی: در هد ثابت دبی‌ها جمع می‌شوند

$AB = BC$



D: نقطه کارکرد یک پمپ در صورتیکه پمپ دوم خاموش باشد

$E = C_3$: نقطه کارکرد مشترک هر دو پمپ

$F = B_3$: نقطه کارکرد تک تک پمپ ۲ در حالتی که هر دو پمپ روشن هستند

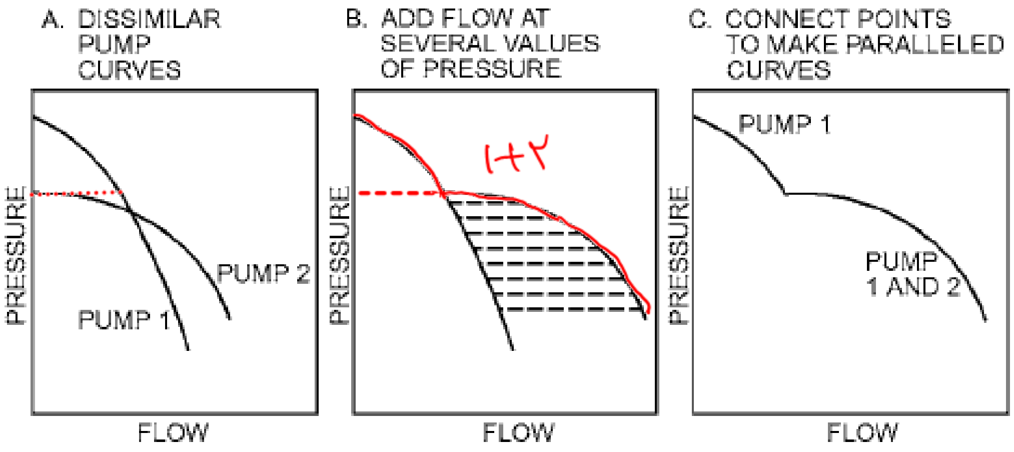


Fig. 36 Construction of Curve for Dissimilar Parallel Pumps

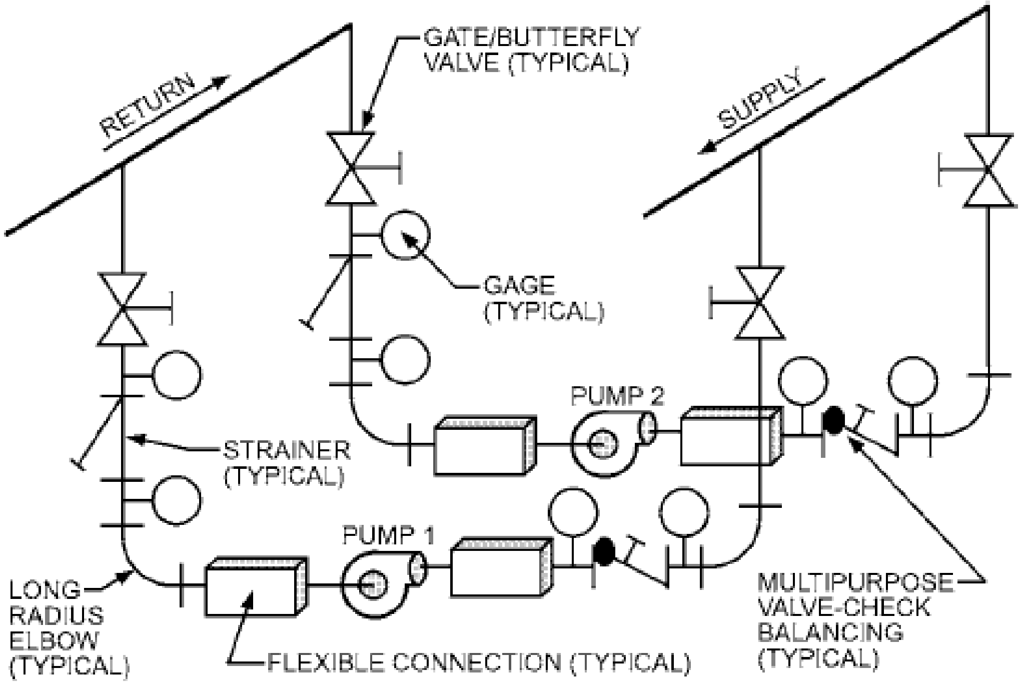


Fig. 37 Typical Piping for Parallel Pumps

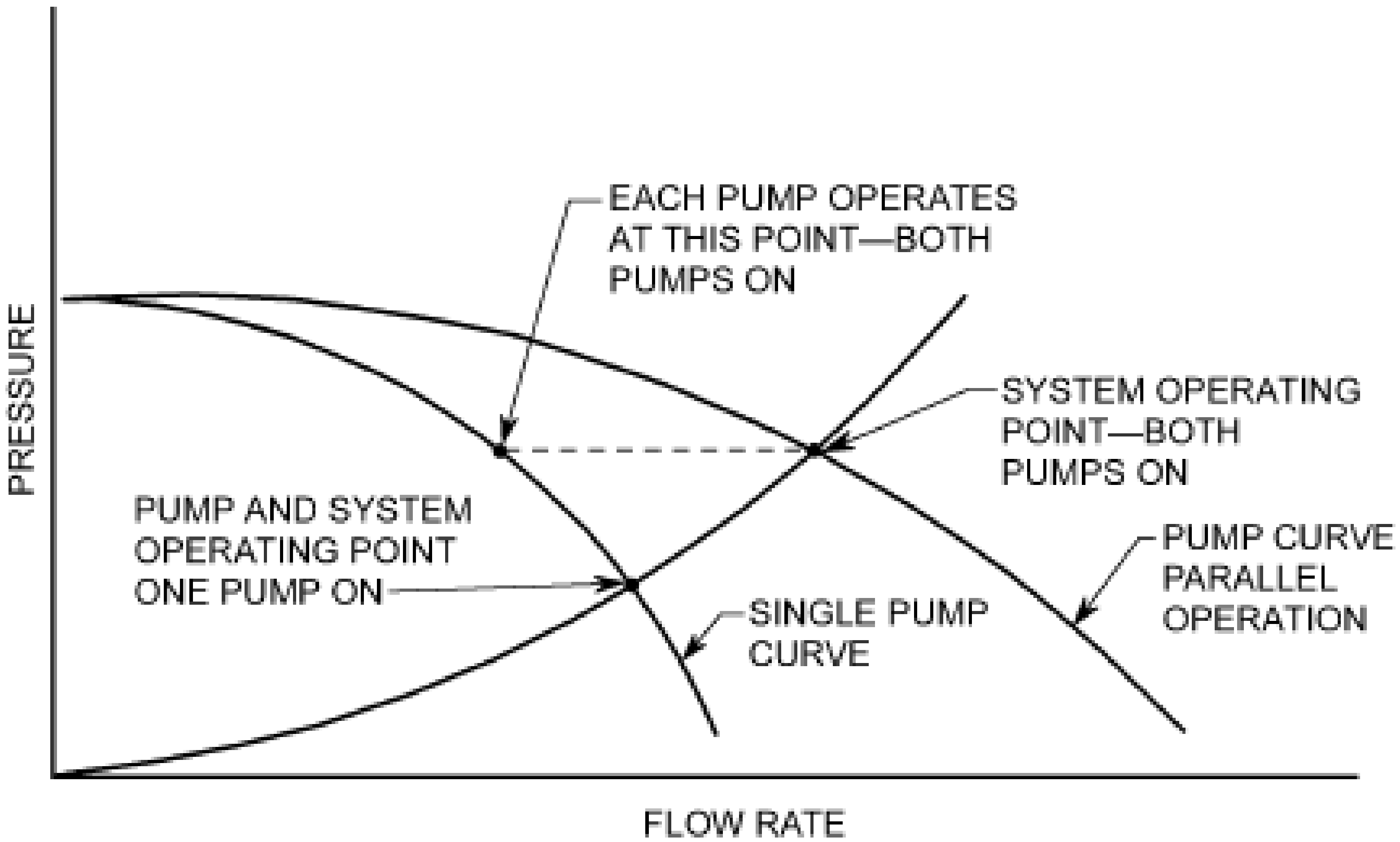
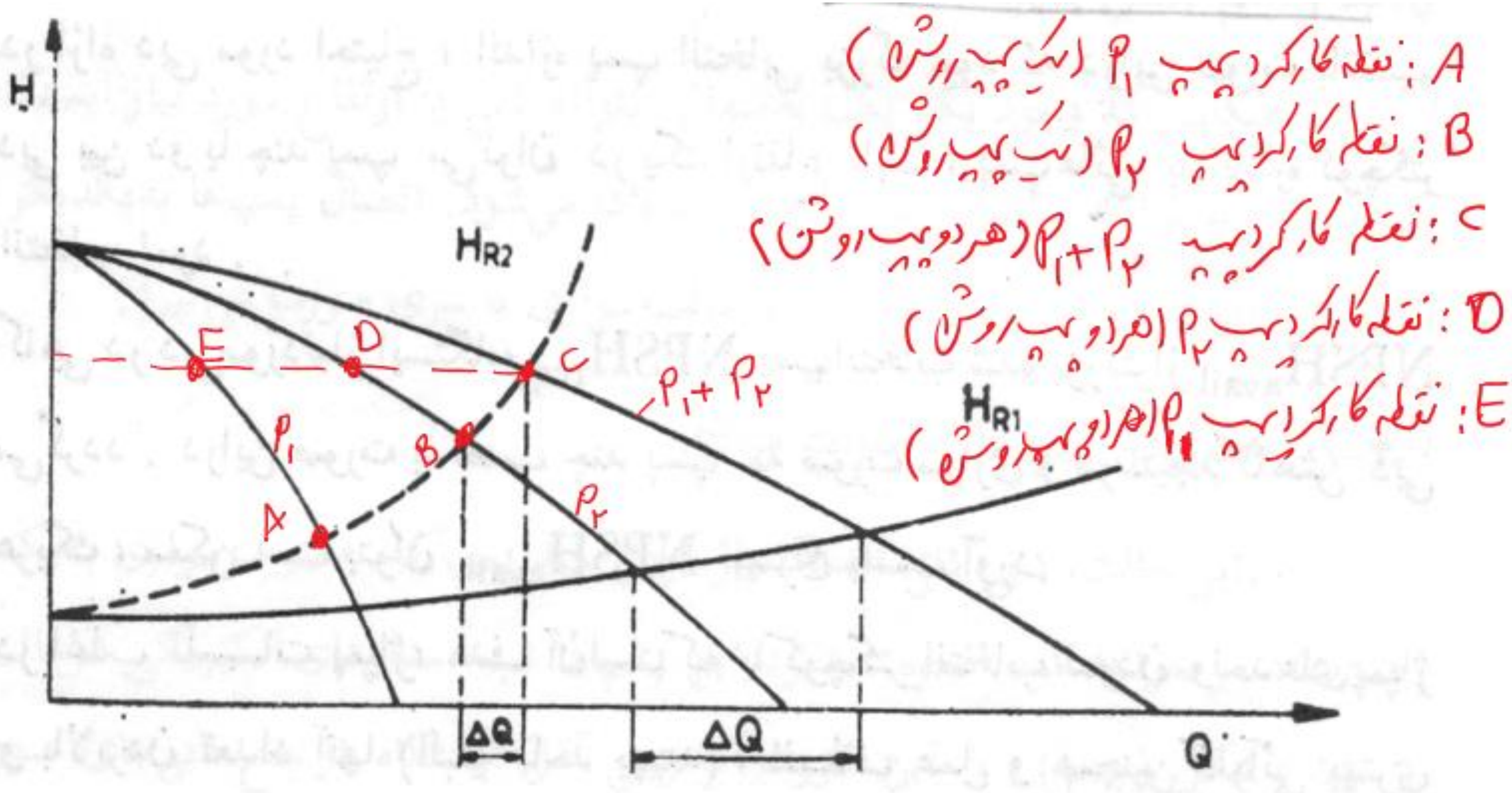


Fig. 7 Operating Conditions for Parallel Pump Installation



شکل (۷-۶) ـ تأثیر افزایش شیب منحنی مشخصه مدار در بستن موازی پمپ ها

ARRANGEMENT OF PUMPS

In a large system, a single pump may not be able to satisfy the full design flow and yet provide both economical operation at partial loads and a system backup. The designer may need to consider the following alternative pumping arrangements and control scenarios:

- Multiple pumps in parallel or series
- Standby pump
- Pumps with two-speed motors
- Primary-secondary pumping
- Variable-speed pumping
- Distributed pumping

Parallel Pumping

When pumps are applied in parallel, each pump operates at the same pressure and provides its share of the system flow at that pressure (Figure 34). Generally, pumps of equal size are recommended, and the parallel pump curve is established by doubling the flow of the single pump curve.

Plotting a system curve across the parallel pump curve shows the operating points for both single and parallel pump operation (Figure 35). Note that single pump operation does not yield 50% flow. The system curve crosses the single pump curve considerably to the right of its operating point when both pumps are running. This leads to two important concerns: (1) the motor must be selected to prevent overloading during operation of a single pump and (2) a single pump can provide standby service for up to 80% of the design flow, the actual amount depending on the specific pump curve and system curve.

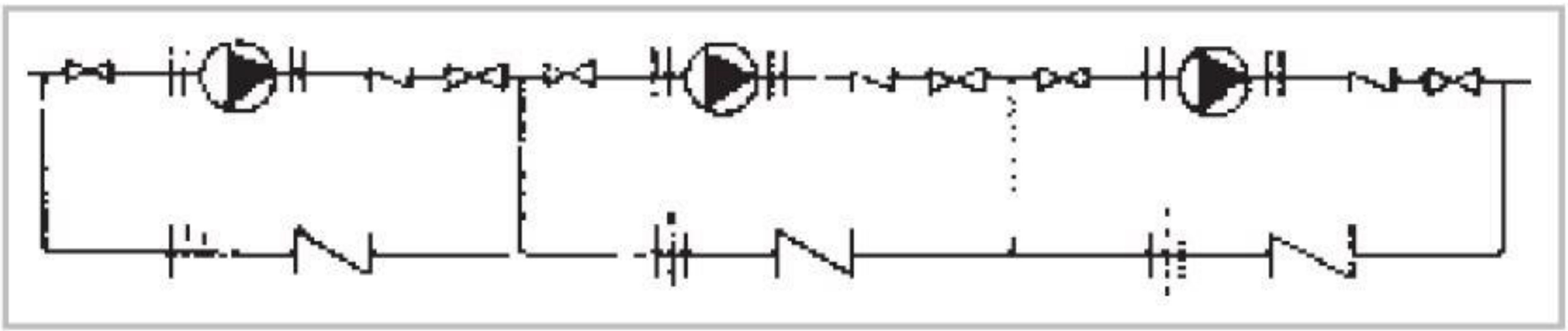
Construction of the composite curve for two dissimilar parallel pumps requires special care; for example, note the shoulder in the composite pump curve in Figure 36.

Operation. The piping of parallel pumps (Figure 37) should permit running either pump. A check valve is required in each pump's discharge to prevent backflow when one pump is shut down. Hand valves and a strainer allow one pump to be serviced while the other is operating. A strainer protects a pump by preventing foreign material from entering the pump. Gages or a common gage with a trumpet valve, which includes several valves as one unit, or pressure taps permits checking pump operation.

Flow can be determined (1) by measuring the pressure increase across the pump and using a factory pump curve to convert the pressure to flow, or (2) by use of a flow-measuring station or multipurpose valve. Parallel pumps are often used for hydronic heating and cooling. In this application, both pumps operate during the cooling season to provide maximum flow and pressure, but only one pump operates during the heating season.

2- سری بستن پمپ

هدف: افزایش فشار پمپ می‌باشد در این حالت در دبی های ثابت هدها با هم جمع می‌شوند

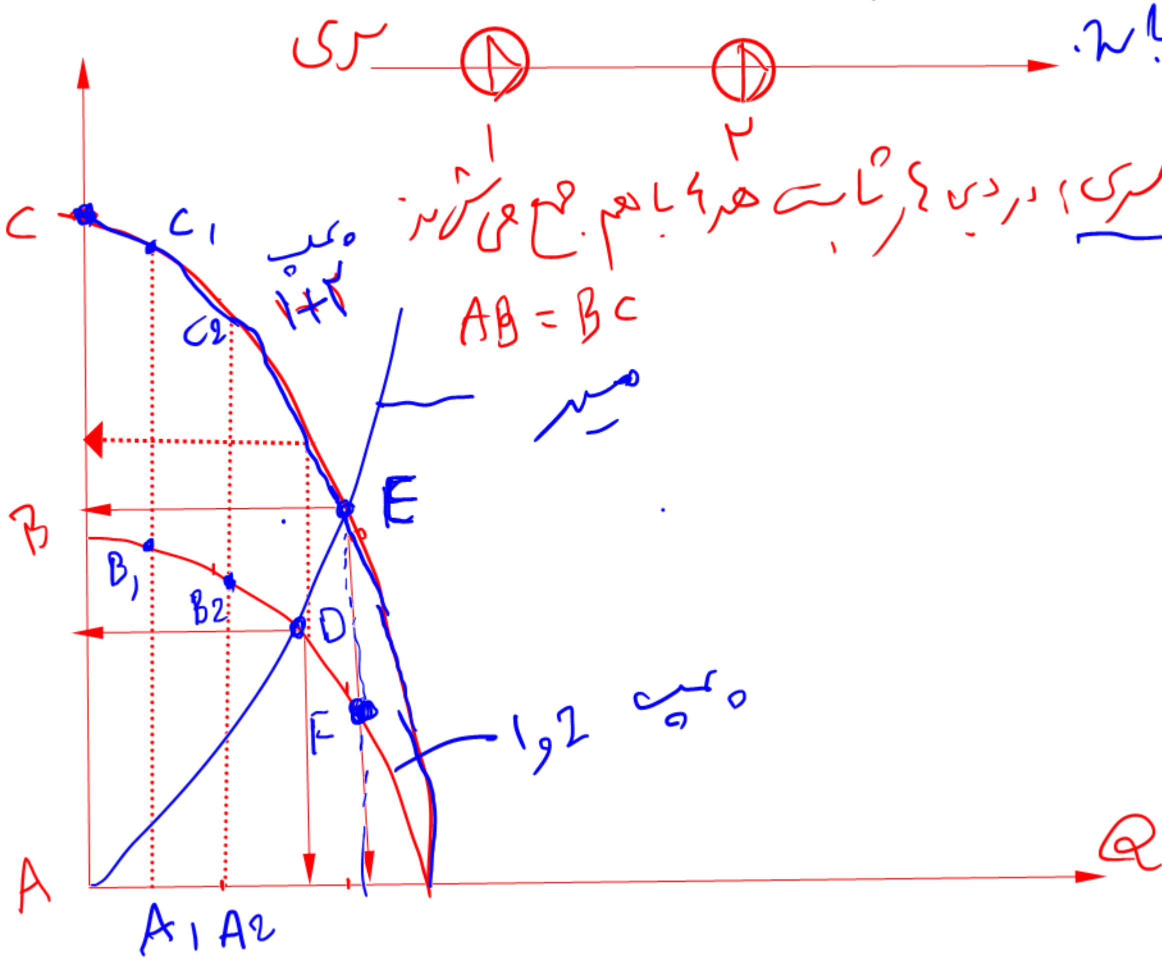


شکل ۹ـ۵ـ نصب سه دستگاه موتور پمپ خطّی به‌طور سری

ـ در حالت سری دبی پمپ ها با هم برابر است $Q_t = Q_2 = Q_1$ ولی فشارها با هم جمع می‌شوند

$H_t = H_1 + H_2$

نکته: در مدارهای سری دبی در مدارها ثابت است ولی هدها می‌توانند متفاوت باشند.



D: //

E: //

F: //

Series Pumping

When pumps are applied in series, each pump operates at the same flow rate and provides its share of the total pressure at that flow (Figure 38). A system curve plot shows the operating points for both single and series pump operation (Figure 39). Note that the single pump can provide up to 80% flow for standby and at a lower power requirement.

As with parallel pumps, piping for series pumps should permit running either pump (Figure 40). A bypass with a hand valve permits servicing one pump while the other is in operation. Operation and flow can be checked the same way as for parallel pumps. A strainer prevents foreign material from entering the pumps.

Note that both parallel and series pump applications require that the pump operating points be used to accurately determine the actual pumping points. The manufacturer's pump test curve should be consulted. Adding too great a safety factor for pressure, using improper pressure drop charts, or incorrectly calculating pressure drops may lead to a poor selection. In designing systems with multiple pumps, operation in either parallel or series must be fully understood and considered by both designer and operator.

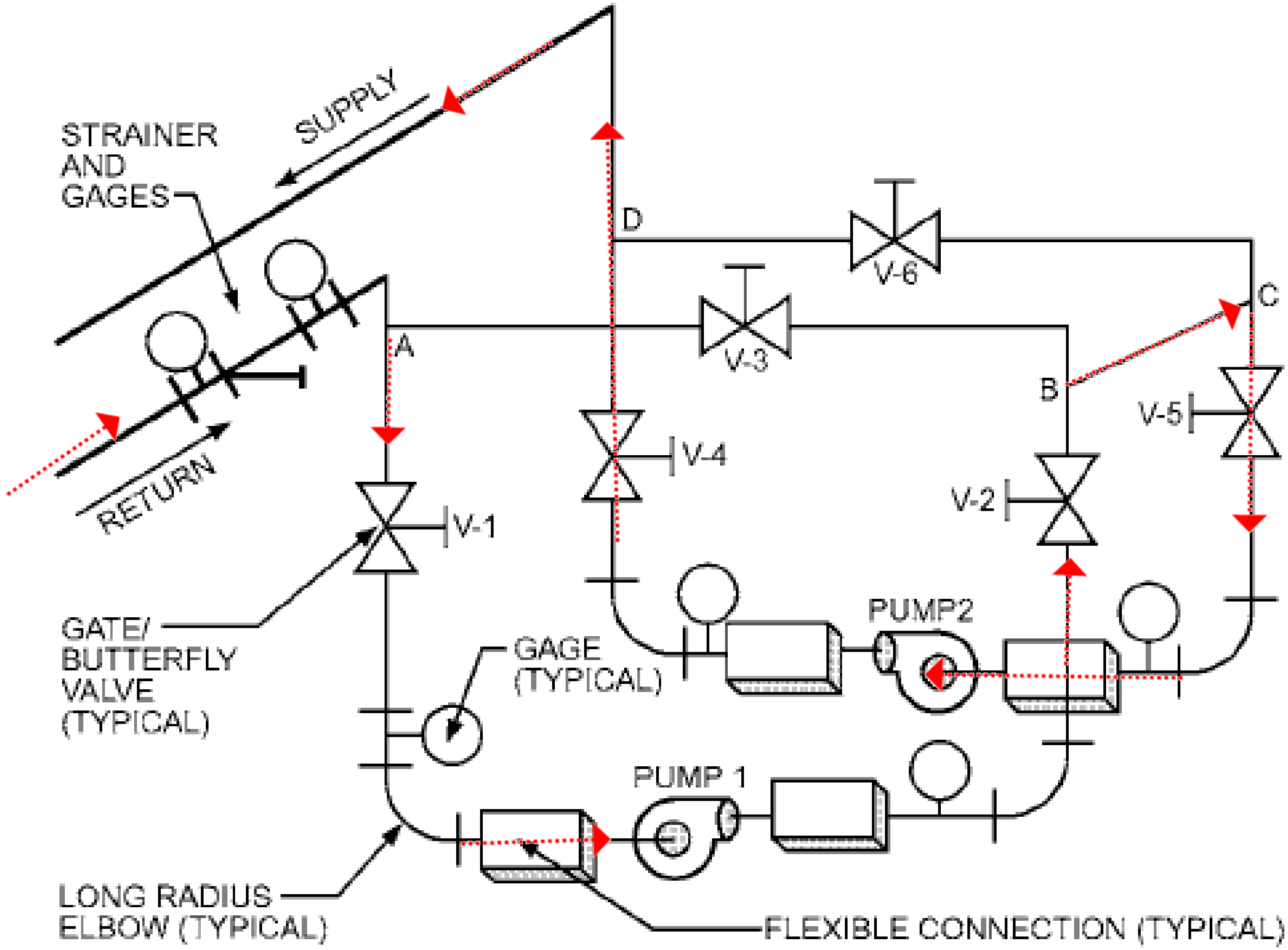


Fig. 40 Typical Piping for Series Pumps

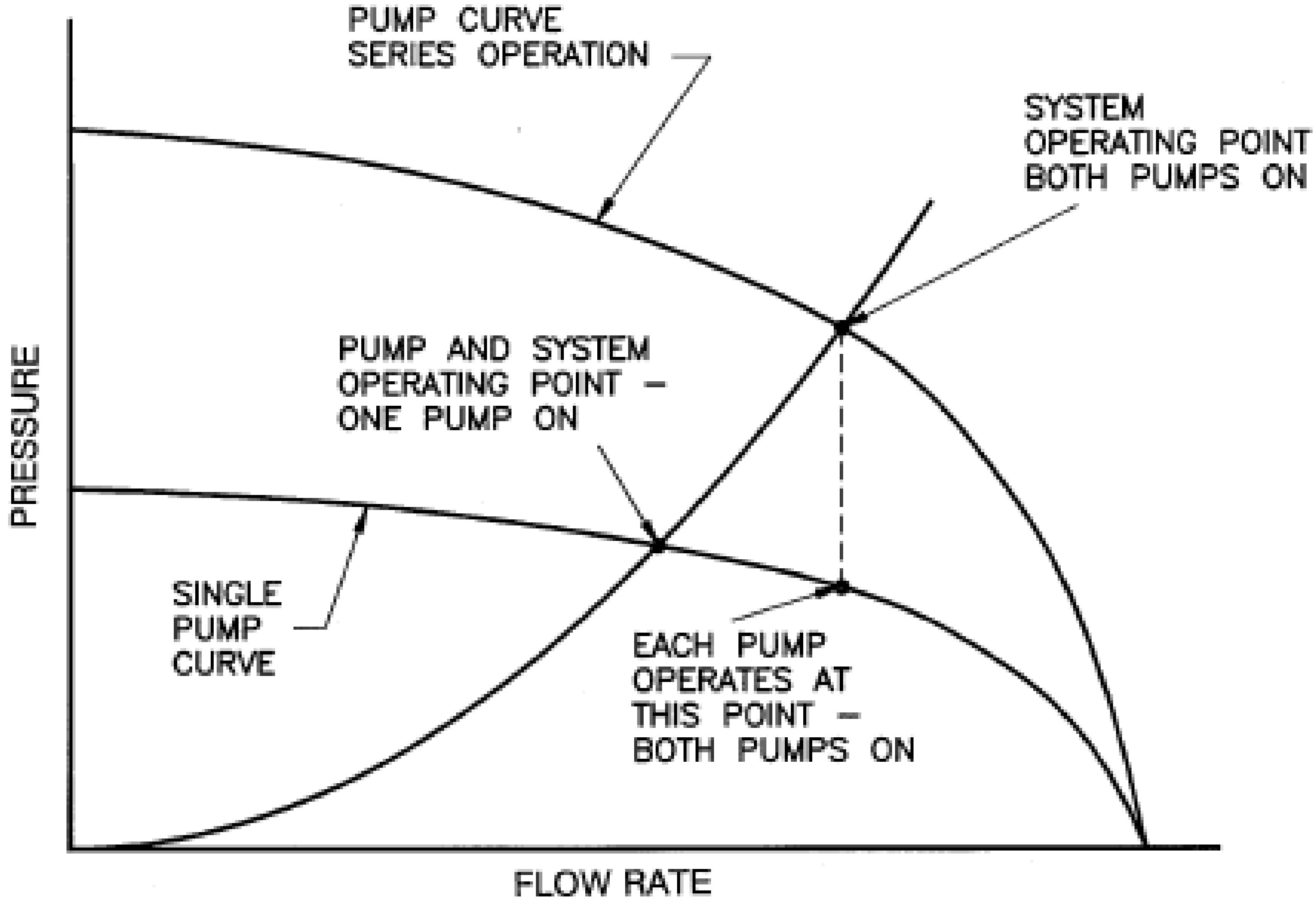
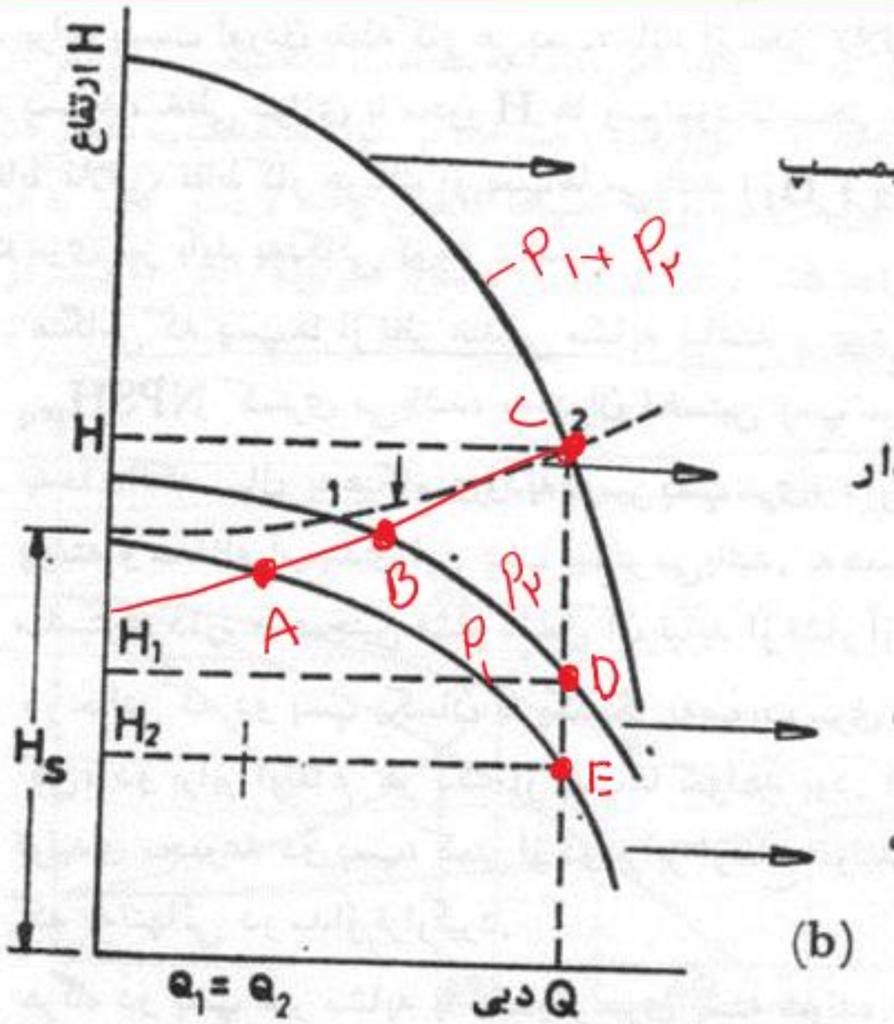


Fig. 8 Operating Conditions for Series Pump Installation



شکل (۷-۷) ـ به هم بستن پمپ‌ها به صورت سری و منحنی مشخصه مجموعه

A: نقطه کارکرد پمپ P_1 (یک پمپ روشن)

B: نقطه کارکرد پمپ P_2 (یک پمپ روشن)

C: نقطه کارکرد پمپ P_1+P_2 (هر دو پمپ روشن)

D: نقطه کارکرد پمپ P_2 (هر دو پمپ روشن)

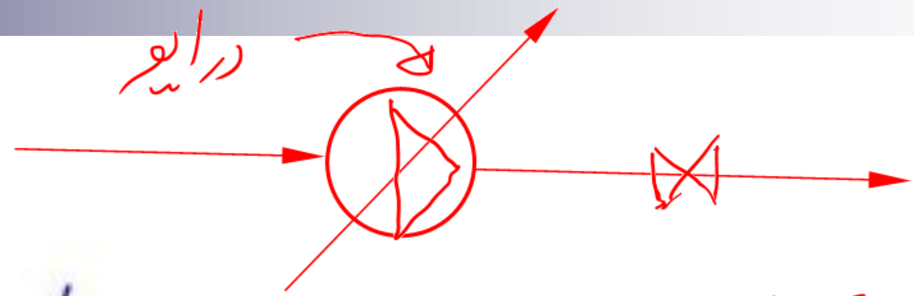
E: نقطه کارکرد پمپ P_1 (هر دو پمپ روشن)

Standby Pump

A backup or standby pump of equal capacity and pressure installed in parallel to the main pump is recommended to operate during an emergency or to ensure continuous operation when a pump is taken out of operation for routine service. A standby pump installed in parallel with the main pump is shown in Figure 37.

Variable-Speed Pumping

In a variable-speed pumping arrangement, constant flow pump(s) recirculate the chiller or boiler source in a primary source loop, and a variable-speed distribution pump located at the source plant draws flow from the source loop and distributes to the load terminals as shown in Figure 43. The speed of the distribution pump is determined by a controller measuring differential pressure across the supply-return mains or across selected critical zones. Two-way control valves are installed in the load terminal return branch to vary the flow required in the load.

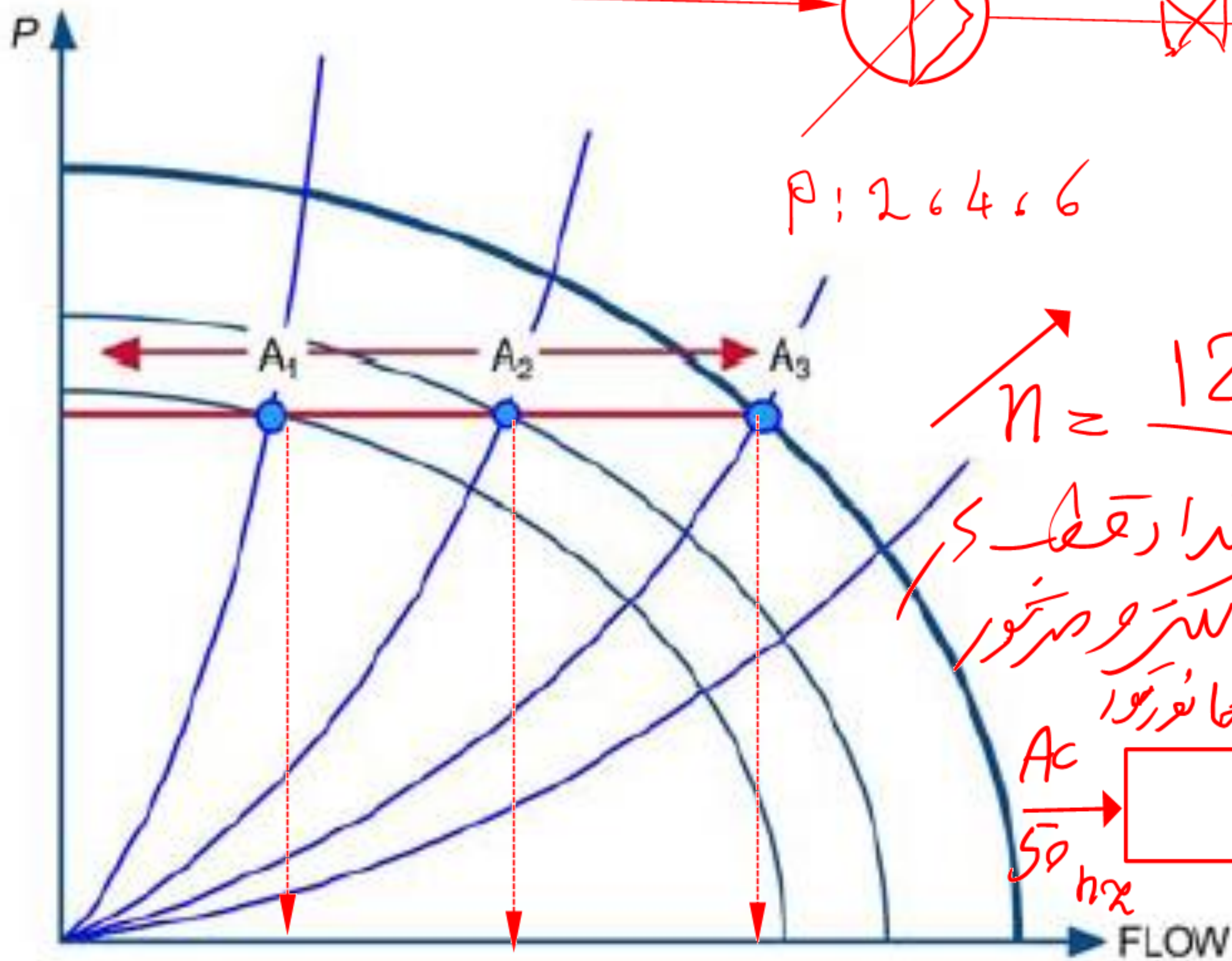


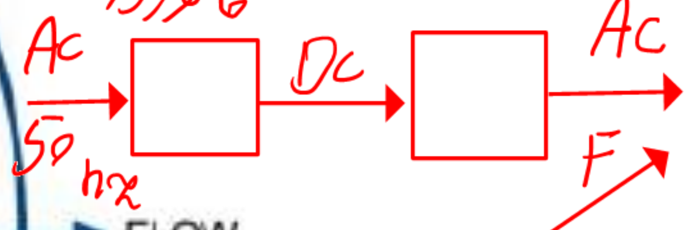
P: 2، 4، 6

پمپ دور متغیر

$$n = \frac{120 \times F(Hz)}{P}$$

P تعداد قطب های الکتروموتور





10Hz, 20Hz,
30H, 100Hz

Fig. 45 Constant-Pressure Control

DESIGNING THE INSTALLATION OF THE END SUCTION PUMP

1. WHEN TO USE – SELECT THE END SUCTION PUMP WHEN THE SYSTEM FLOW IS IN THE RANGE FROM 100 TO 800 GPM.

2. COMPUTE THE FLOW RATE IN GPM – CALCULATE THE FLOW RATE IN GPM BY THE USUAL METHODS AS OUTLINED IN THE ASHRAE GUIDE AND DATA BOOK.

3. COMPUTE THE TOTAL HEAD IN FEET – CALCULATE THE TOTAL HEAD IN FEET AS SHOWN BY THE METHODS ON PAGE 198 FOR CLOSED SYSTEM PIPING OR PAGE 212 FOR CONDENSER WATER PIPING.

4. MOTOR HORSEPOWER – MOTOR SIZES SHOULD BE BASED ON A POSSIBLE 20 PERCENT INCREASE IN CALCULATED SYSTEM FLOW. THIS WILL ASSURE A NON-OVERLOADING SELECTION AND ALLOW FOR SUCH VARIATIONS AS MIGHT OCCUR. MOTOR SIZES MAY BE DETERMINED FROM THE MANUFACTURER'S PERFORMANCE CURVE OR MAY BE COMPUTED BY THE FOLLOWING FORMULA:

$$\text{BRAKE HP REQUIRED} = \frac{(\text{SYSTEM GPM} + 20\%) \times \text{SYSTEM HEAD IN FEET}}{\text{PUMP EFFICIENCY} \times 3960}$$

5. MOTOR CURRENT CHARACTERISTICS – COORDINATE THIS DATA WITH THE ELECTRICAL DESIGN ENGINEER FOR THE PROJECT.

6. MOTOR CONNECTION – THE ELECTRICAL CONNECTION TO THE MOTOR SHOULD BE MADE WITH WATERPROOF FLEXIBLE METALLIC CONDUIT A MINIMUM OF 12-INCHES IN LENGTH.

7. PUMP SELECTION – PUMP EFFICIENCY IN ITSELF IS NOT AN ADEQUATE BASIS FOR THE BEST PUMP SELECTIONS, SINCE THE POINT OF MAXIMUM EFFICIENCY WILL VARY DEPENDING UPON THE PUMP CHARACTERISTICS. AS A RULE, THE BEST SELECTION POINT IS TO THE LEFT OF CENTER OF MAXIMUM EFFICIENCY, THUS PERMITTING THE PUMP TO MOVE OUT ON THE CURVE WITHOUT DANGER OF OVERLOADING. IT IS INTERESTING TO NOTE, THAT WHEN THE PROJECT PIPING IS SIZED IN ACCORDANCE WITH THE TABLE SHOWN ON PAGE 199 OF THIS BOOK, MOST 1750 RPM PUMP SELECTIONS, HAVING A SUCTION OPENING EQUAL TO THE PIPE SIZE TO WHICH THEY ARE CONNECTED, FALL ON THIS POINT OF THE CURVE. THIS RULE GENERALLY VARIES WITH THE PUMP SPEED. AT 3450 RPM, THE PUMP SUCTION IS ONE PIPE SIZE SMALLER, WHILE AT 1150 RPM, IT WILL BE ONE PIPE SIZE LARGER.

8. PUMP BASE – THE PUMP SHOULD BE BOLTED ON A CONCRETE BASE AS SHOWN BY THE DETAIL. CARE SHOULD BE TAKEN IN THE DESIGN TO ALLOW SUFFICIENT SPACE ALL AROUND THE PUMP FOR DISASSEMBLY AND SERVICE.

9. PIPING – THE PIPING SHOULD BE DESIGNED SO THAT NO PIPE WEIGHT RESTS ON THE PUMP CASING. PIPING SHOULD NOT BE SUPPORTED FROM STRUCTURAL STEEL MEMBERS, BECAUSE THESE STEEL MEMBERS WILL PICK UP ANY VIBRATION NOISE AND TRANSMIT THE NOISE TO OTHER PARTS OF THE BUILDING. WHERE IT IS IMPOSSIBLE TO AVOID THE USE OF STRUCTURAL STEEL MEMBERS AS PIPE SUPPORTS, CONSIDERATION SHOULD BE GIVEN TO THE USE OF VIBRATION ELIMINATOR PIPE HANGER SUPPORTS.

10. FLEXIBLE JOINTS – FLEXIBLE SECTIONS OF PIPE AT PUMP SUCTION AND DISCHARGE ARE GENERALLY NOT REQUIRED IN A WELL DESIGNED PUMP INSTALLATION. WHERE EXTREME QUIET IS DESIRED, FLEXIBLE SECTIONS MAY BE USED; HOWEVER, EXTREME CAUTION SHOULD BE TAKEN TO ASSURE THAT THE FLEXIBLE PIPE SECTIONS HAVE ADEQUATE TEMPERATURE AND PRESSURE RATINGS.

11. STRAINERS –

A. STRAINERS ARE NOT GENERALLY REQUIRED ON CLOSED SYSTEM PIPING, BUT IF USED, CARE SHOULD BE TAKEN TO SPECIFY PERFORATIONS IN THE BASKET FOR HOT WATER AND NOT STEAM. IT IS GOOD PRACTICE TO REMOVE THE BASKET AFTER CONSTRUCTION DEBRIS HAS BEEN REMOVED FROM THE SYSTEM AND THE SYSTEM HAS BEEN THOROUGHLY WASHED OUT.

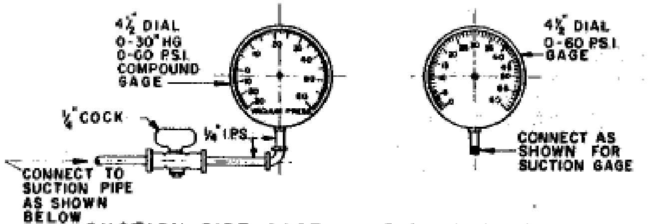
B. CONDENSER WATER PIPING – STRAINERS SHOULD BE PROVIDED FOR THE CONDENSER WATER PUMP, ESPECIALLY WHEN THE PUMP IS CONNECTED TO THE OPEN SUMP OF A COOLING TOWER. SCREEN PERFORATIONS SHOULD BE SIZED FOR CONDENSER WATER.

12. SUCTION PIPING – THE SUCTION PIPE SHOULD BE STRAIGHT FOR FIVE PIPE DIAMETERS AT THE POINT WHERE IT ENTERS THE SUCTION CONNECTION OF THE PUMP; WHERE THIS IS NOT POSSIBLE, USE A SPECIAL STRAIGHTENING ELBOW.

13. CHECK VALVES – A CHECK VALVE OF THE NON-SLAM VERTICAL TYPE SHOULD ALWAYS BE USED FOR CONDENSER WATER PUMPS AND PUMPS OPERATING IN PARALLEL. SINGLE PUMPS ON CLOSED SYSTEM PIPING CIRCUITS DO NOT REQUIRE A CHECK VALVE.

14. GAGES – A COMPOUND GAGE SHOULD BE PROVIDED ON THE SUCTION SIDE OF THE PUMP AND A PRESSURE GAGE SHOULD BE PROVIDED ON THE DISCHARGE SIDE OF THE PUMP TO CHECK THE PRESSURE CHARACTERISTICS OF THE SYSTEM. SHUT-OFF COCKS SHOULD BE PROVIDED TO SHUT THE PRESSURE OFF OF THE GAGES WHEN NOT IN USE.

15. MECHANICAL SEALS – MECHANICAL SEALS SHOULD BE USED ON ALL CLOSED SYSTEM PIPING AND GENERALLY FOR CONDENSER WATER SYSTEM. THE CHEMICALS USED IN A CONDENSER WATER SYSTEM MAY AT TIMES CAUSE CONSIDERATION OF A STUFFING BOX SEAL FOR THE CONDENSER WATER PUMP.



SUCTION SIDE GAGE

DISCHARGE SIDE GAGE

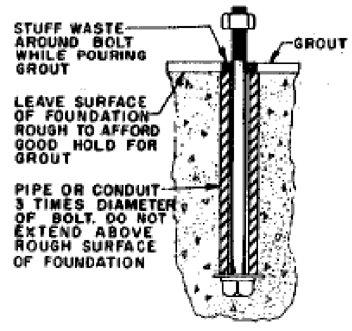


FIG. 1 - ARRANGEMENT OF FOUNDATION BOLT

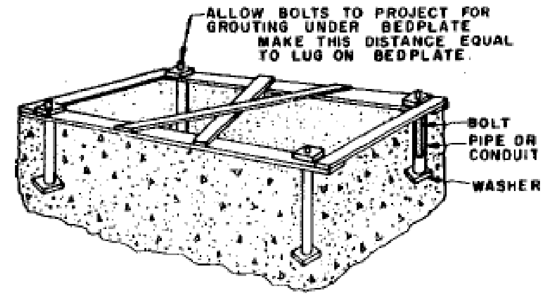
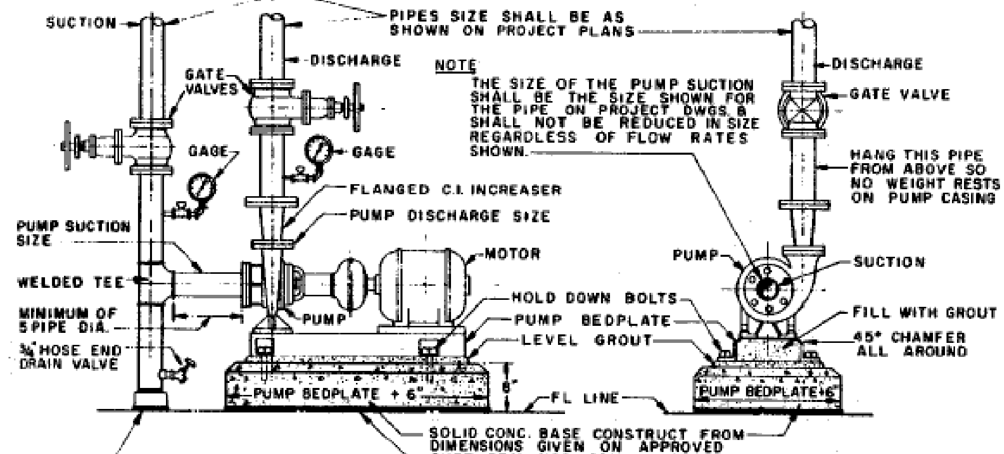


FIG 2 - TEMPLATE FOR HANGING FOUNDATION BOLTS WHILE POURING THE FOUNDATION.



NOTE

THE SIZE OF THE PUMP SUCTION SHALL BE THE SIZE SHOWN FOR THE PIPE ON PROJECT DWGS. & SHALL NOT BE REDUCED IN SIZE REGARDLESS OF FLOW RATES SHOWN.

SIDE ELEVATION

FRONT ELEVATION

VIBRATION ELIMINATOR PAD SHALL BE SCIENTIFICALLY DESIGNED OF RESILIENT MATERIAL, MOLDED OF NEOPRENE, 5/16" THICK, CROSS-RIBBED CONSTRUCTION, INSTALLED UNDER COMPLETE BASE OF PUMP.

PUMP ALIGNMENT

CONTRACTOR SHALL CHECK, TEST, & START EACH BASE MOUNTED PUMP & SHALL HAVE THE PUMP MANUFACTURER ALIGN THE PUMP WITH A DIAL INDICATOR WITHIN .002 AMP. DISCHARGE & SUCTION READINGS SHALL BE RECORDED & FOWARDED FOR RECORD PURPOSES.

BASE MOUNTED PUMP FOUNDATION AND SETTING DETAILS

1.- FOUNDATION

THE FOUNDATION BOLTS (ONE FOR EACH HOLD-DOWN BOLT HOLE IN THE BEDPLATE) SHOULD BE SECURED IN THE FOUNDATION AS SHOWN IN FIG. 1. AT THE LOWER END OF THE BOLT PLACE A LARGE SQUARE WASHER WITH LUGS TO PREVENT THE BOLT FROM TURNING. AROUND EACH FOUNDATION BOLT PLACE A PIPE SLEEVE, THREE TIMES THE DIAMETER OF THE BOLT, BEFORE POURING THE FOUNDATION. DO NOT ALLOW THIS PIPE TO EXTEND ABOVE THE ROUGH SURFACE OF THE FOUNDATION.

IN ORDER TO ALLOW FOR GROUT, MAKE THE TOP SURFACE OF THE FOUNDATION ¾" TO 1½" BELOW THE LEVEL AT WHICH THE BEDPLATE IS TO BE SET. WHEN BUILDING THE FORMS FOR POURING THE FOUNDATION, HANG THE BOLTS IN THEIR CORRECT POSITIONS BY MEANS OF A TEMPLATE AS SHOWN IN FIG. 2. SCREW THE NUT DOWN SO THAT THE BOLT PROJECTS ABOVE THE NUT ¾" MORE THAN THE BEDPLATE THICKNESS ALLOWED FOR GROUT. PLACE THE BOTTOM OF THE TEMPLATE AT THE LEVEL OF THE ROUGH FOUNDATION SURFACE. HANG THE BOLT SO THAT DISTANCE BETWEEN THE BOTTOM OF THE NUT AND BOTTOM OF TEMPLATE IS EQUAL TO THE HEIGHT OF THE LUG ON THE BEDPLATE. WHEN POURING THE FOUNDATION LEAVE THE TOP SURFACE ROUGH TO AFFORD A GOOD HOLD FOR GROUT. DO NOT PUT THE BEDPLATE OR ASSEMBLED UNIT ON THE FOUNDATION UNTIL THE LATTER HAS FIRMILY SET AND HARDENED.

2.-PUTTING UNIT ON FOUNDATION

BEFORE PUTTING THE UNIT OR BEDPLATE ON THE FOUNDATION, CLEAN THE TOP SURFACE OF THE FOUNDATION, BREAKING OFF ANY LOOSE PIECES OF CONCRETE. ROUGHEN THE FOUNDATION TOP WITH A STAR CHISEL, & THOROUGHLY CLEAN IT. THEN THOROUGHLY WET THE TOP SO THAT IT WILL NOT ABSORB MOISTURE FROM THE GROUTING TOO QUICKLY.

STUFF WASTE AROUND THE FOUNDATION BOLT HOLES TO PREVENT GROUT FLOWING INTO THE HOLES. PREPARE ENOUGH IRON WEDGES OR METAL SHIMS TO ALLOW ONE TO BE PLACED ON EACH SIDE OF EACH FOUNDATION BOLT. THESE WEDGES SHOULD BE APPROXIMATELY 4" TO 6" LONG, 2" TO 3" WIDE & THICK ENOUGH TO ALLOW 3/4" TO 1½" OF GROUT BETWEEN THE BOTTOM OF THE BEDPLATE & TOP OF FOUNDATION. ALIGN THE BEDPLATE TO A DEAD LEVEL POSITION WITH THE WEDGES.

CLEAN THE BOTTOM OF THE BEDPLATE & GROUT. AFTER THE GROUT HAS TAKEN ENOUGH SET TO SUPPORT THE UNIT, REMOVE THE WEDGES & FILL THE WEDGE VOIDS WITH GROUT & SMOOTH OFF ALL AROUND.

DETAILS OF THE INSTALLATION OF THE END SUCTION PUMP

NO SCALE

PUMP SCHEDULE

PUMP NO.	SERVICE	G.P.M.	HEAD PRESS.	RPM	HP.	VOLTS	PHASE	CYCLE	REMARKS

LUBRICATION NOTES

1- AFTER COMPLETION OF THE SYSTEM AND BEFORE START-UP OF THE PUMP, THE PUMP SHALL BE LUBRICATED IN STRICT ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS.

2- A METAL INSTRUCTION PLATE SHALL BE ATTACHED TO THE PUMP IN A LOCATION WHERE IT IS CLEARLY VISIBLE. THESE INSTRUCTIONS SHALL INDICATE THE RECOMMENDED LUBRICANT, THE POINTS OF LUBRICATION, AND THE RECOMMENDED FREQUENCY OF LUBRICATION.

DESIGNING THE INSTALLATION OF THE DOUBLE SUCTION HORIZONTALLY SPLIT CASE PUMP

1. WHEN TO USE – SELECT THE DOUBLE SUCTION HORIZONTALLY SPLIT CASE PUMP WHEN THE SYSTEM FLOW IS 800 GPM AND OVER.

2. COMPUTE THE FLOW RATE IN GPM – CALCULATE THE FLOW RATE IN GPM BY THE USUAL METHODS AS OUTLINED IN THE ASHRAE GUIDE AND DATA BOOK.

3. COMPUTE THE TOTAL HEAD IN FEET – CALCULATE THE TOTAL HEAD IN FEET AS SHOWN BY THE METHODS ON PAGE 198 FOR CLOSED SYSTEM PIPING OR PAGE 212 FOR CONDENSER WATER PIPING.

4. MOTOR HORSEPOWER – MOTOR SIZES SHOULD BE BASED ON A POSSIBLE 20 PERCENT INCREASE IN CALCULATED SYSTEM FLOW. THIS WILL ASSURE A NON-OVERLOADING SELECTION AND AL-LOW FOR SUCH VARIATIONS AS MIGHT OCCUR. MOTOR SIZES MAY BE DETERMINED FROM THE MANUFACTURER'S PERFORMANCE CURVE OR MAY BE COMPUTED BY THE FOLLOWING FORMULA:

$$\text{BRAKE HORSEPOWER REQUIRED} = \frac{(\text{SYSTEM GPM} + 20\%) \times \text{SYSTEM HEAD IN FEET}}{\text{PUMP EFFICIENCY} \times 3960}$$

5. MOTOR CURRENT CHARACTERISTICS – COORDINATE THIS DATA WITH THE ELECTRICAL DESIGN ENGINEER FOR THE PROJECT.

6. MOTOR CONNECTION – THE ELECTRICAL CONNECTION TO THE MOTOR SHOULD BE MADE WITH WATERPROOF FLEXIBLE METALLIC CONDUIT A MINIMUM OF 12-INCHES IN LENGTH.

…12 INCHES IN LENGTH.

7. PUMP SELECTION – PUMP EFFICIENCY IN ITSELF IS NOT AN ADEQUATE BASIS FOR THE BEST PUMP SELECTIONS SINCE THE POINT OF MAXIMUM EFFICIENCY WILL VARY DEPENDING UPON THE PUMP CHARACTERISTICS. AS A RULE, THE BEST SELECTION POINT IS TO THE LEFT OF CENTER OF MAXIMUM EFFICIENCY, THUS PERMITTING THE PUMP TO MOVE OUT ON THE CURVE WITHOUT DANGER OF OVERLOADING. IT IS INTERESTING TO NOTE, THAT WHEN THE PROJECT PIPING IS SIZED IN ACCORDANCE WITH THE TABLE SHOWN ON PAGE 199 OF THIS BOOK MOST 1750 RPM PUMP SELECTIONS, HAVING A SUCTION OPENING EQUAL TO THE PIPE SIZE TO WHICH THEY ARE CONNECTED, FALL ON THIS POINT OF THE CURVE. THIS RULE GENERALLY VARIES WITH THE PUMP SPEED. AT 3450 RPM, THE PUMP SUCTION IS ONE PIPE SIZE SMALLER, WHILE AT 1150 RPM, IT WILL BE ONE PIPE SIZE LARGER.

8. PUMP BASE – THE PUMP SHOULD BE BOLTED ON A CONCRETE BASE AS SHOWN BY THE DETAIL. CARE SHOULD BE TAKEN IN THE DESIGN TO ALLOW SUFFICIENT SPACE ALL AROUND THE PUMP FOR DISASSEMBLY AND SERVICE.

9. PIPING – THE PIPING SHOULD BE DESIGNED SO THAT NO PIPE WEIGHT RESTS ON THE PUMP CASING. PIPING SHOULD NOT BE SUPPORTED FROM STRUCTURAL STEEL MEMBERS, BECAUSE

THESE STEEL MEMBERS WILL PICK UP ANY VIBRATION NOISE AND TRANSMIT THE NOISE TO OTHER PARTS OF THE BUILDING. WHERE IT IS IMPOSSIBLE TO AVOID THE USE OF STRUCTURAL STEEL MEMBERS AS PIPE SUPPORTS, CONSIDERATION SHOULD BE GIVEN TO THE USE OF VIBRATION ELIMINATOR PIPE HANGER SUPPORTS.

10. FLEXIBLE JOINTS – FLEXIBLE SECTIONS OF PIPE AT PUMP SUCTION AND DISCHARGE ARE GENERALLY NOT REQUIRED IN A WELL DESIGNED PUMP INSTALLATION. WHERE EXTREME QUIET IS DESIRED, FLEXIBLE SECTIONS MAY BE USED; HOWEVER, EXTREME CAUTION SHOULD BE TAKEN TO ASSURE THAT THE FLEXIBLE PIPE SECTIONS HAVE ADEQUATE TEMPERATURE AND PRESSURE RATINGS FOR THE SERVICE.

11. <u>STRAINERS</u> –

A. STRAINERS ARE NOT GENERALLY REQUIRED ON CLOSED SYSTEM PIPING, BUT IF USED, CARE SHOULD BE TAKEN TO SPECIFY PERFORATIONS IN THE BASKET FOR HOT WATER AND NOT STEAM. IT IS GOOD PRACTICE TO REMOVE THE BASKET AFTER CONSTRUCTION DEBRIS HAS BEEN REMOVED FROM THE SYSTEM AND THE SYSTEM HAS BEEN THOROUGHLY WASHED OUT.

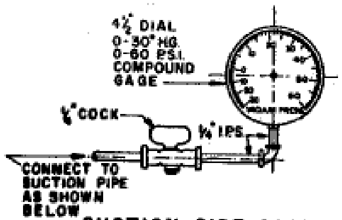
B. CONDENSER WATER PIPING – STRAINERS SHOULD BE PROVIDED FOR THE CONDENSER WATER PUMP, ESPECIALLY WHEN THE PUMP IS CONNECTED TO THE OPEN SUMP OF A COOLING TOWER. SCREEN PERFORATION SHOULD BE SIZED FOR CONDENSER WATER.

12. <u>SUCTION PIPING</u> – THE SUCTION PIPE SHOULD BE STRAIGHT FOR FIVE PIPE DIAMETERS AT THE POINT WHERE IT ENTERS THE SUCTION CONNECTION OF THE PUMP; WHERE THIS IS NOT POSSIBLE, USE A SPECIAL STRAIGHTENING ELBOW.

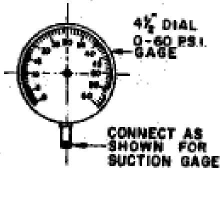
13. <u>CHECK VALVES</u> – A CHECK VALVE OF THE NON-SLAM VERTICAL TYPE SHOULD ALWAYS BE USED FOR CONDENSER WATER PUMPS AND PUMPS OPERATING IN PARALLEL. SINGLE PUMPS ON CLOSED SYSTEM PIPING CIRCUITS DO NOT REQUIRE A CHECK VALVE.

14. <u>GAGES</u> – A COMPOUND GAGE SHOULD BE PROVIDED ON THE SUCTION SIDE OF THE PUMP AND A PRESSURE GAGE SHOULD BE PROVIDED ON THE DISCHARGE SIDE OF THE PUMP TO CHECK THE PRESSURE CHARACTERISTICS OF THE SYSTEM. SHUT OFF COCKS SHOULD BE PROVIDED TO SHUT THE PRESSURE OFF OF THE GAGES WHEN NOT IN USE.

15. <u>MECHANICAL SEALS</u> – MECHANICAL SEALS SHOULD BE USED ON ALL CLOSED SYSTEM PIPING AND GENERALLY FOR CONDENSER WATER SYSTEM. THE CHEMICALS USED IN CONDENSER WATER SYSTEM MAY AT TIMES CAUSE CONSIDERATION OF A STUFFING BOX SEAL FOR THE CONDENSER WATER PUMP.



SUCTION SIDE GAGE



DISCHARGE SIDE GAGE

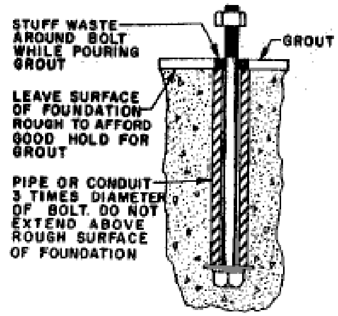


FIG. 1 - ARRANGEMENT OF FOUNDATION BOLT

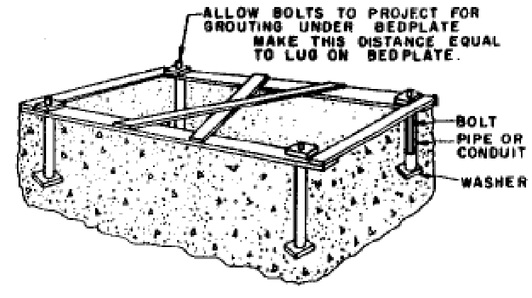
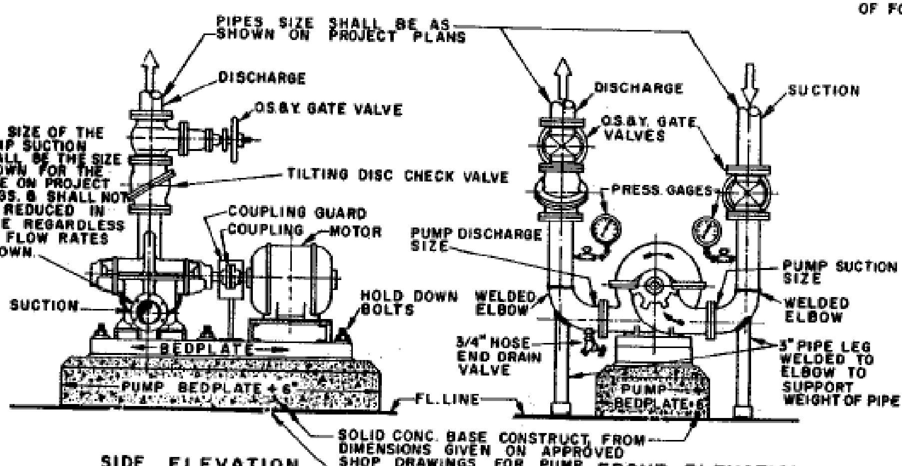


FIG. 2 - TEMPLATE FOR HANGING FOUNDATION BOLTS WHILE POURING THE FOUNDATION.

NOTE:
THE SIZE OF THE PUMP SUCTION SHALL BE THE SIZE SHOWN FOR THE PIPE ON PROJECT DWGS. & SHALL NOT BE REDUCED IN SIZE REGARDLESS OF FLOW RATES SHOWN.



SIDE ELEVATION **FRONT ELEVATION**

VIBRATION ELIMINATOR PAD SHALL BE SCIENTIFICALLY DESIGNED OF RESILIENT MATERIAL, MOLDED OF NEOPRENE, 5/16" THICK, CROSS-RIBBED CONSTRUCTION, INSTALLED UNDER COMPLETE BASE OF PUMP.

PUMP ALIGNMENT

CONTRACTOR SHALL CHECK, TEST, & START EACH BASE MOUNTED PUMP & SHALL HAVE THE PUMP MANUFACTURER ALIGN THE PUMP WITH A DIAL INDICATOR WITHIN .002 AMP. DISCHARGE & SUCTION READINGS SHALL BE RECORDED & FOWARDED FOR RECORD PURPOSES.

BASE MOUNTED PUMP FOUNDATION AND SETTING DETAILS

1.- FOUNDATION

THE FOUNDATION BOLTS (ONE FOR EACH HOLD-DOWN BOLT HOLE IN THE BEDPLATE) SHOULD BE SECURED IN THE FOUNDATION AS SHOWN IN FIG. 1. AT THE LOWER END OF THE BOLT PLACE A LARGE SQUARE WASHER WITH LUGS TO PREVENT THE BOLT FROM TURNING. AROUND EACH FOUNDATION BOLT PLACE A PIPE SLEEVE, THREE TIMES THE DIAMETER OF THE BOLT, BEFORE POURING THE FOUNDATION. DO NOT ALLOW THIS PIPE TO EXTEND ABOVE THE ROUGH SURFACE OF THE FOUNDATION.

IN ORDER TO ALLOW FOR GROUT, MAKE THE TOP SURFACE OF THE FOUNDATION 3/4" TO 1 1/2" BELOW THE LEVEL AT WHICH THE BEDPLATE IS TO BE SET. WHEN BUILDING THE FORMS FOR POURING THE FOUNDATION, HANG THE BOLTS IN THEIR CORRECT POSITIONS BY MEANS OF A TEMPLATE AS SHOWN IN FIG. 2. SCREW THE NUT DOWN SO THAT THE BOLT PROJECTS ABOVE THE NUT 1/4" MORE THAN THE BEDPLATE THICKNESS ALLOWED FOR GROUT. PLACE THE BOTTOM OF THE TEMPLATE AT THE LEVEL OF THE ROUGH FOUNDATION SURFACE. HANG THE BOLT SO THAT DISTANCE BETWEEN THE BOTTOM OF THE NUT AND BOTTOM OF TEMPLATE IS EQUAL TO THE HEIGHT OF THE LUG ON THE BEDPLATE. WHEN POURING THE FOUNDATION LEAVE THE TOP SURFACE ROUGH TO AFFORD A GOOD HOLD FOR GROUT. DO NOT PUT THE BEDPLATE OR ASSEMBLED UNIT ON THE FOUNDATION UNTIL THE LATTER HAS FIRMLY SET AND HARDENED.

2.- PUTTING UNIT ON FOUNDATION

BEFORE PUTTING THE UNIT OR BEDPLATE ON THE FOUNDATION, CLEAN THE TOP SURFACE OF THE FOUNDATION, BREAKING OFF ANY LOOSE PIECES OF CONCRETE. ROUGHEN THE FOUNDATION TOP WITH A STAR CHISEL, & THOROUGHLY CLEAN IT. THEN THOROUGHLY WET THE TOP SO THAT IT WILL NOT ABSORB MOISTURE FROM THE GROUTING TOO QUICKLY.

STUFF WASTE AROUND THE FOUNDATION BOLT HOLES TO PREVENT GROUT FLOWING INTO THE HOLES. PREPARE ENOUGH IRON WEDGES OR METAL SHIMS TO ALLOW ONE TO BE PLACED ON EACH SIDE OF EACH FOUNDATION BOLT. THESE WEDGES SHOULD BE APPROXIMATELY 4" TO 6" LONG, 2" TO 3" WIDE & THICK ENOUGH TO ALLOW 3/4" TO 1 1/2" OF GROUT BETWEEN THE BOTTOM OF THE BEDPLATE & TOP OF FOUNDATION. ALIGN THE BEDPLATE TO A DEAD LEVEL POSITION WITH THE WEDGES.

CLEAN THE BOTTOM OF THE BEDPLATE & GROUT. AFTER THE GROUT HAS TAKEN ENOUGH SET TO SUPPORT THE UNIT, REMOVE THE WEDGES & FILL THE WEDGE VOIDS WITH GROUT & SMOOTH OFF ALL AROUND.

DETAILS OF THE INSTALLATION OF THE DOUBLE SUCTION HORIZONTALLY SPLIT CASE PUMP

NO SCALE

PUMP SCHEDULE

PUMP NO.	SERVICE	G.P.M.	HEAD PRESS.	R.P.M.	H.P.	VOLTS	PHASE	CYCLE	REMARKS

LUBRICATION NOTES

1- AFTER COMPLETION OF THE SYSTEM AND BEFORE START-UP OF THE PUMP, THE PUMP SHALL BE LUBRICATED IN STRICT ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS.

2- A METAL INSTRUCTION PLATE SHALL BE ATTACHED TO THE PUMP IN A LOCATION WHERE IT IS CLEARLY VISIBLE. THESE INSTRUCTIONS SHALL INDICATE THE RECOMMENDED LUBRICANT, THE POINTS OF LUBRICATION, AND THE RECOMMENDED FREQUENCY OF LUBRICATION.

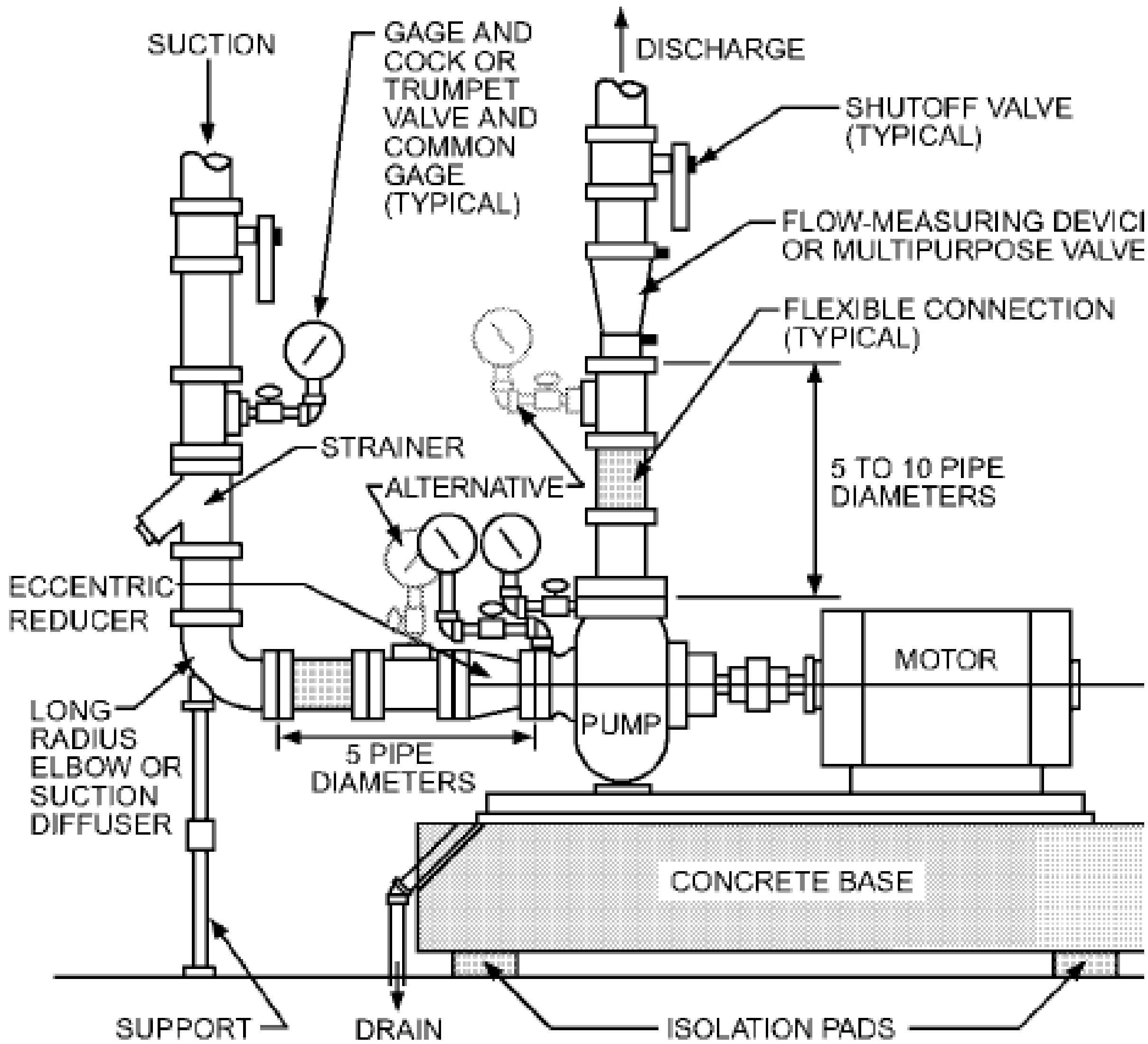


Fig. 49 Base-Plate-Mounted Centrifugal Pump Installation

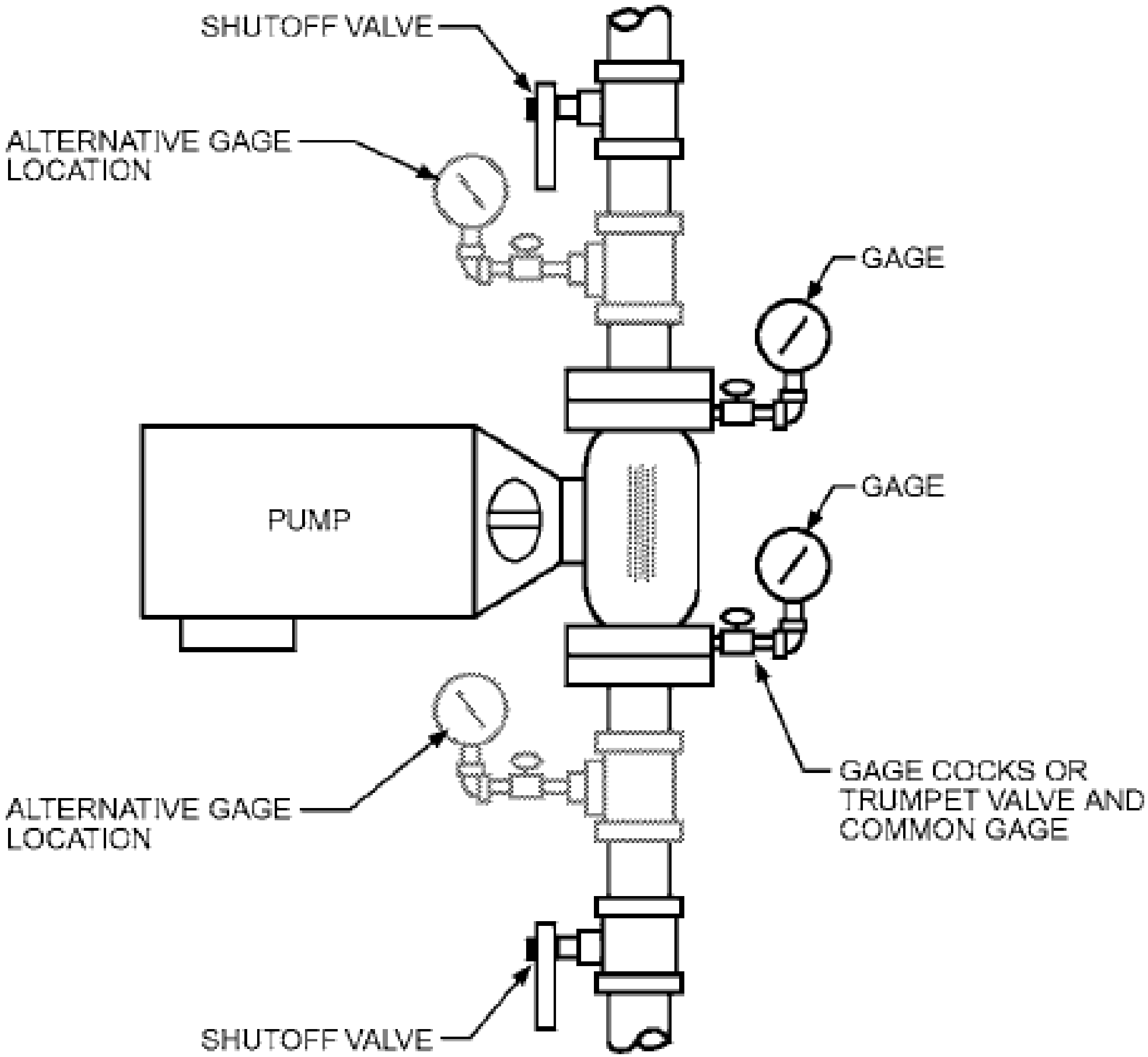
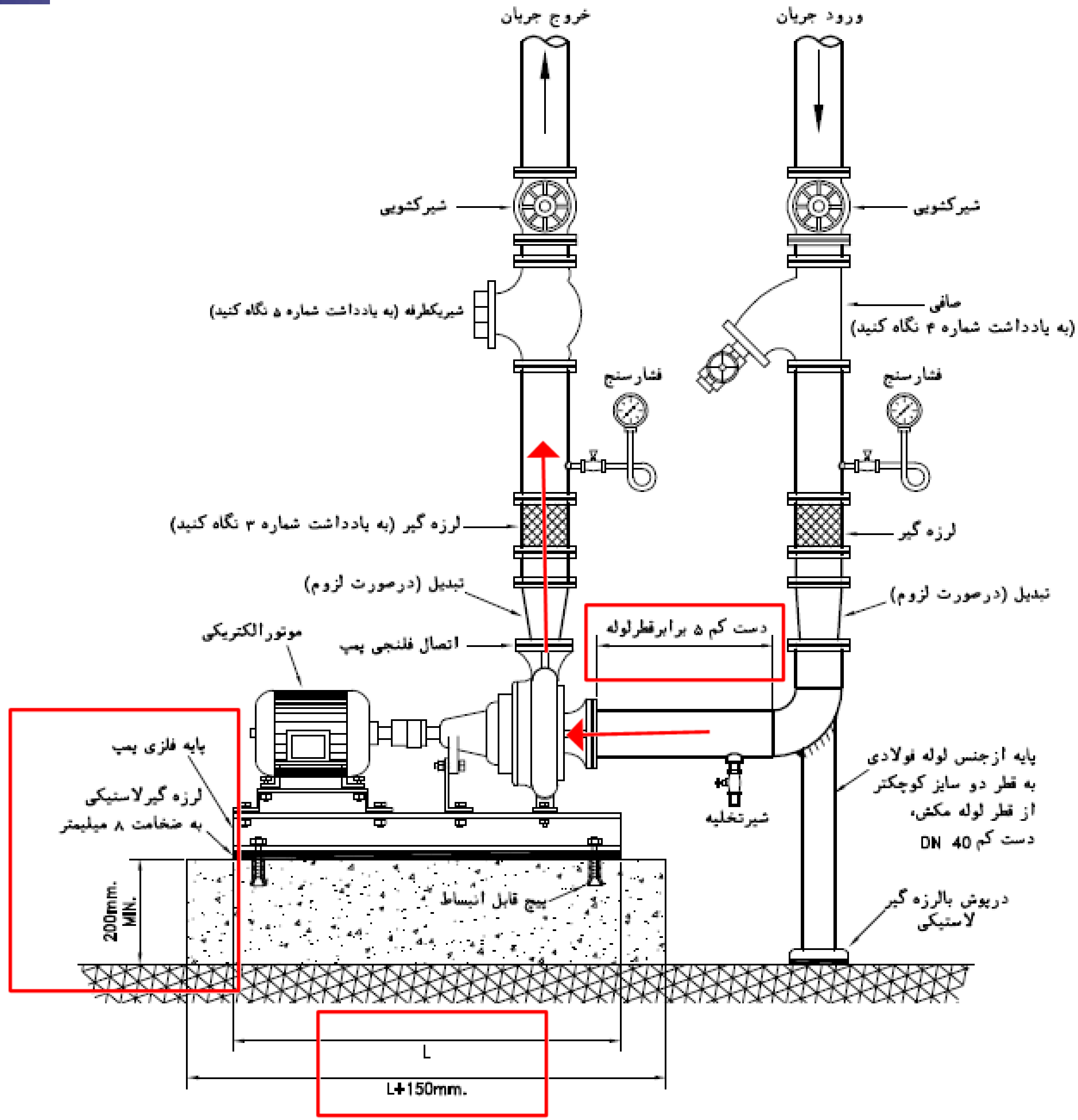


Fig. 50 In-Line Pump Installation



خروج جریان
ورود جریان
شیرکشویی
شیرکشویی
شیریکطرفه (به یادداشت شماره ۵ نگاه کنید)
صافی
(به یادداشت شماره ۴ نگاه کنید)
فشارسنج
فشارسنج
لرزه گیر (به یادداشت شماره ۳ نگاه کنید)
لرزه گیر
تبدیل (درصورت لزوم)
تبدیل (درصورت لزوم)
موتورالکتریکی
اتصال فلنجی پمپ
دست کم ۵ برابرقطرلوله
پایه فلزی پمپ
لرزه گیرلاستیکی
به ضخامت ۸ میلیمتر
شیرتخلیه
پایه ازجنس لوله فولادی
به قطر دو سایز کوچکتر
از قطر لوله مکش،
دست کم DN 40
پیچ قابل انبساط
درپوش بالرزه گیر
لاستیکی
200mm. MIN.
L
L+150mm.

۱-این نقشه، نصب پمپ ازنوع زمینی سانتریفوژ (END SUCTION) ، مخصوص نصب روی فونداسیون، در سیستم گردش آب گرم کننده یا سردکننده، را نشان می‌دهد.

۲-اطراف پمپ باید فضای کافی برای دسترسی و تعمیر و تنظیم باشد. کمترین فاصله تا دیوار یا تجهیزات دیگر، ۵۰۰ میلیمتر توصیه می‌شود.

۳-در شرایط عادی لازم نیست لرزه‌گیر روی لوله‌های ورود و خروج پمپ نصب شود. مگرآنکه در طرح مشخص شده باشد و یا شرایط محل نصب لزوم حذف هرگونه ارتعاش را ایجاب کند.

۴-نصب صافی(STRAINER)روی لوله‌ی ورودی ضروری نیست. مگرآنکه برای‌جداکردن‌ذرات‌اضافی ازجریان سیال، که ممکن است‌در زمان‌لوله‌کشی یا تعمیرات وارد لوله ها شده باشد، لازم تشخیص داده شود. دراین صورت پس‌از راه اندازی وآزمایش اولیه پمپ، بهتر است صافی برداشته شود.

۵-درصورت نصب پمپ برای گردش آب برج خنک کننده و یا نصب دو (یا چند) پمپ موازی در یک سیستم، نصب شیریکطرفه در خروج‌جریان از هرپمپ ضروری است.

٦-لوله های ورود وخروج سیال، با استفاده ازآویز وتکیه گاه مناسب بایدطوری مهارشوند که وزن لوله و اتصالات به پمپ منتقل نشود.

ENERGY CONSERVATION IN PUMPING

Pumps for heating and air conditioning consume appreciable amounts of energy. Economical use of energy depends on the efficiency of pumping equipment and drivers, as well as the use of the pumping energy required. Equipment efficiency (sometimes called the wire to water efficiency) shows how much energy applied to the pumping system results in useful energy distributing the water. For an electric-driven, constant speed pump, the equipment efficiency is

$$\eta_e = \eta_p \eta_m \tag{7}$$

where

η_e = equipment efficiency, 0 to 1
η_p = pump efficiency, 0 to 1
η_m = motor efficiency, 0 to 1

For a variable-speed pump, the variable-speed drive efficiency η_v (0 to 1) must be included in the equipment efficiency equation:

$$\eta_e = \eta_p \eta_m \eta_v \tag{4}$$

SELECTION OF PUMPS

A substantial amount of data is required to ensure that an adequate, efficient, and reliable pump is selected for a particular system. The designer should review the following criteria:

Centrifugal Pumps

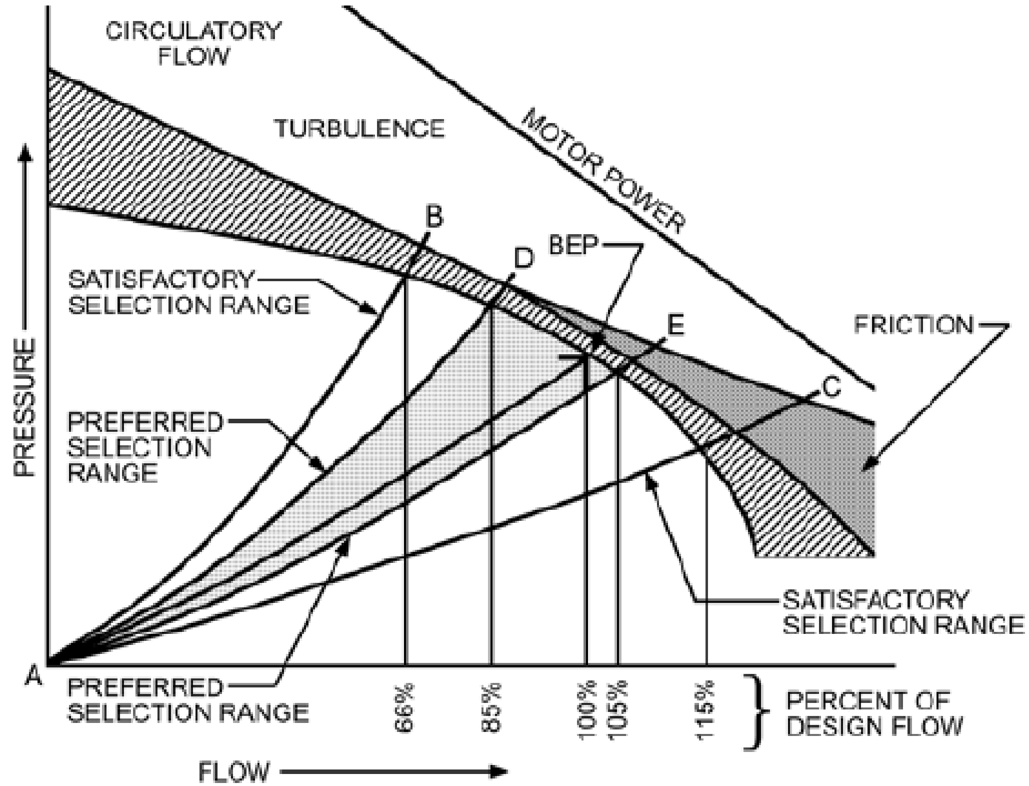


Fig. 33 Pump Selection Regions

- Design flow
- Pressure drop required for the most resistant loop
- Minimum system flow
- System pressure at maximum and minimum flows
- Type of control valve: two-way or three-way
- Continuous or variable flow
- Pump environment
- Number of pumps and standby
- Electric voltage and current
- Electric service and starting limitations
- Motor quality versus service life
- Water treatment, water conditions, and material selection

When a centrifugal pump is applied to a piping system, the operating point satisfies both the pump and system curves (Figure 17). As the load changes, control valves change the system curve and the operating point moves to a new point on the pump curve. Figure 33 shows the optimum regions to use when selecting a centrifugal pump. The areas bounded by lines AB and AC represent operating points that lie in the preferred pump selection range. But, because pumps are only manufactured in certain sizes, selection limits of 66% to 115% of flow at the BEP are suggested. The satisfactory range is that portion of a pump's performance curve where the combined effect of circulatory flow, turbulence, and friction losses are minimized. Where possible, pumps should be chosen to operate to the left of the BEP because the pressure in the actual system may be less than design due to overstated data for pipe friction and for other equipment. Otherwise, the pump operates at a higher flow and possibly in the turbulent region (Stethem 1988).

قوانین پمپ ها

$$\frac{m'2}{m'1} = \left(\frac{\rho 2}{\rho 1}\right) \times \left(\frac{N2}{N1}\right) \times \left(\frac{D2}{D1}\right)$$

$$\frac{Q2}{Q1} = \left(\frac{N2}{N1}\right) \times \left(\frac{D2}{D1}\right)$$

$$\frac{P2}{P1} = \left(\frac{\rho 2}{\rho 1}\right) \times \left(\frac{N2}{N1}\right)^2 \times \left(\frac{D2}{D1}\right)^2$$

$$\frac{HP2}{HP1} = \left(\frac{\rho 2}{\rho 1}\right) \times \left(\frac{N2}{N1}\right)^3 \times \left(\frac{D2}{D1}\right)^3$$

Table 1 Pump Affinity Laws

Function	Speed Change	Impeller Diameter Change
Flow	$Q_2 - Q_1\left(\frac{N_2}{N_1}\right)$	$Q_2 - Q_1\left(\frac{D_2}{D_1}\right)$
Pressure	$p_2 - p_1\left(\frac{N_2}{N_1}\right)^2$	$p_2 - p_1\left(\frac{D_2}{D_1}\right)^2$
Power	$p_2 - p_1\left(\frac{N_2}{N_1}\right)^3$	$p_2 - p_1\left(\frac{D_2}{D_1}\right)^3$

مثال : دور پمپ $n_1=1450\ rpm$ ، $P_1=20\ m$ ، $Q_1=10\ lit/s$ ، $P_0=5\ KW$

مطلوبست P_2 ، Q_2 ، P_{02} در صورتیکه دور پمپ دو برابر شود؟

$n_2=2900\ rpm=2N_1$

$D_1=D_2$

حل :

$$\frac{Q_2}{Q_1}=\left(\frac{2N_1}{N_1}\right)\left(\frac{D_2}{D_1}\right) \Rightarrow Q_2=2Q_1$$

$$Q_2=2\times 10=20\ lit/s$$

$$\frac{P_2}{P_1}=\left(\frac{\rho_2}{\rho_1}\right)\left(\frac{2N_1}{N_1}\right)^2\left(\frac{D_2}{D_1}\right)^2 \Rightarrow P_2=4P_1$$

$$P_2=4\times 20=80\ m$$

$$\frac{P_{02}}{P_{01}}=\left(\frac{\rho_2}{\rho_1}\right)\left(\frac{2N_1}{N_1}\right)^3\left(\frac{D_2}{D_1}\right) \Rightarrow P_{02}=8P_{01}$$

$$P_{02}=8\times 5=40\ KW$$

INSTALLATION, OPERATION, AND COMMISSIONING

1. Pumps may be base-plate-mounted (Figure 49), either singly or in packaged sets, or installed in-line directly in the piping system (Figure 50). Packaged sets include multiple pumps, accessories, and electrical controls shipped to the job site on one frame. Packaged pump sets may reduce the requirements for multiple piping and field electrical connections and can be factory tested to ensure specified performance.
2. A concrete pad provides a secure mounting surface for anchoring the pump base plate and raises the pump off the floor to permit housekeeping. The minimum mass of concrete that should be used is 2.5 times the mass of the pump assembly. The pad should be at least 100 mm thick and 150 mm wider than the pump base plate on each side.
3. In applications where the pump bolts rigidly to the pad base, level the pad base, anchor it, and fill the space between pump base and the concrete with a non-shrink grout. Grout prevents the base from shifting and fills in irregularities. Pumps mounted on vibration isolation bases require special installation (see the section on Vibration Isolation and Control in Chapter 48 of the 2011 *ASHRAE Handbook—HVAC Applications*).

4. Support in-line pumps independently from the piping so that pump flanges are not overstressed.
5. Once the pump has been mounted to the base, check the alignment of the motor to the pump. Align the pump shaft couplings properly and shim the motor base as required. Incorrect alignment may cause rapid coupling and bearing failure.
6. Pump suction piping should be direct and as smooth as possible. Install a strainer (coarse mesh) in the suction to remove foreign particles that can damage the pump. Use a straight section of piping at least 5 to 10 diameters long at the pump inlet and long radius elbows to ensure uniform flow distribution. Suction diffusers may be installed in lieu of the straight pipe requirement where spacing is a constraint. Eccentric reducers at the pump flange reduce the potential of air pockets forming in the suction line.
7. If a flow-measuring station (venturi, orifice plate, or balancing valve) is located in the pump discharge, allow 10 diameters of straight pipe between the pump discharge and the flow station for measurement accuracy.
8. Pipe flanges should match the size of pump flanges. Mate flat-face pump flanges with flat-face piping flanges and full-face gaskets. Install tapered reducers and increasers on suction and discharge lines to match the pipe size and pump flanges.

9. If fine mesh screen is used in the strainer at initial start-up to remove residual debris, replace it with normal-sized screen after commissioning to protect the pump and minimize the suction pressure drop.
10. Install shutoff valves in the suction and discharge piping near the pump to permit removing and servicing the pump and strainer without draining the system. Install a check valve in the pump discharge to prevent reverse flow in a nonrunning pump when multiple pumps are installed.
11. Install vibration isolators in the pump suction and discharge lines to reduce the transmission of vibration noise to building spaces (Figure 49). Properly located pipe hangers and supports can reduce the transmission of piping strains to the pump.
12. Various accessories need to be studied as alternates to conventional fittings. A suction diffuser in the pump inlet is an alternate to an eccentric reducer and it contains a strainer. Separate strainers can be specified with screen size. A multipurpose valve in the pump discharge is an alternate way to combine the functions of shutoff, check, and balancing valves.

الکتروموتورهای سه فاز با ولتاژ ۳۸۰ ولت
با فریمهای چدنی سایز ۲۵۰-۱۸۰

اندازه بدنه نوع	تعداد قطب	سرعت در بار نامی دور در دقیقه	قدرت خروجی	
			اسب بخار	کیلووات
180 L4A	4	1457	25	18.5
180 L2	2	2923	30	22
180 L4B	4	1457		
200 L6B	6	969		
200 L2A	2	2943	40	30
200 L4	4	1465		
225 M6	6	975		
200 L2B	2	2954	50	37
225 M4A	4	1461		
250 M6	6	980		
225 M2	2	2985	60	45
225 M4B	4	1464		
250 M2	2	2971	75	55
250 M4	4	1473		

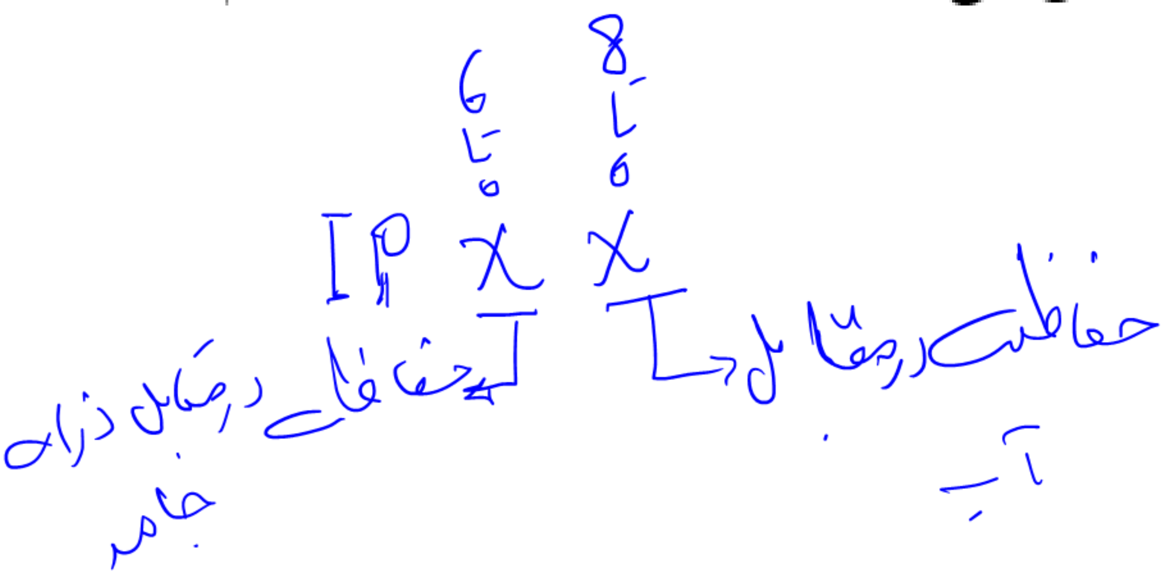
درجه حفاظت IP۵۵

کلاس حرارتی F

درجه حفاظت

درجه حفاظت یا **کد آی‌پی** (به انگلیسی: IP code) اصطلاحی در استاندارد آی‌ئی‌سی ۶۰۵۲۹ است که بر اساس آن محفظه‌های تجهیزات الکتریکی با کدهای استانداردی با دو حرف IP در کنار دو رقم، از نظر نفوذ در برابر عوامل خارجی تقسیم‌بندی می‌شوند. رقم اول که بین ۰ تا ۶ است سطح حفاظت در برابر جسم سخت خارجی و نیز حفاظت افراد را مشخص می‌کند. رقم دوم بین ۰ تا ۸ است و میزان حفاظت را در برابر نفوذ آب (و نه هیچ مایع دیگر) مشخص می‌کند. هر چه این رقم‌ها بیشتر باشند میزان حفاظت بیشتر است.[۱]

- IEC standard 60529



Solid particle protection

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

Level	Object size protected against	Effective against
0	—	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, screws, etc.
5	Dust protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact (dust proof)
6	Dust tight	No ingress of dust; complete protection against contact (dust tight)

توضیح رقم نخست کد آی‌پی مطابق آی‌ئی‌سی[۲] ۶۰۵۲۹

رقم اول کد آی‌پی	حفاظت تعریف شده برای افراد	حفاظت در برابر جسم خارجی	نیروی اعمال‌شده بر جسم خارجی
۰	نیاز به آزمایش نیست	نیاز به آزمایش نیست	نیاز به آزمایش نیست
۱	پشت دست	اجسام جامد خارجی با قطر ۵۰ میلی‌متر یا بیشتر	۵۰ نیوتون
۲	یک انگشت	اجسام جامد خارجی با قطر ۱۲٫۵ میلی‌متر یا بیشتر	۱۰ نیوتون
۳	یک ابزار	اجسام جامد خارجی با قطر ۲٫۵ میلی‌متر یا بیشتر	۳ نیوتون
۴	یک سیم	اجسام جامد خارجی با قطر ۱٫۰ میلی‌متر یا بیشتر	۱ نیوتون
۵	یک سیم	حفاضت شده در برابر نفوذ گرد و غبار	۱ نیوتون
۶	یک سیم	ضد گرد و غبار	۱نیوتون

توضیح رقم دوم در کد آی‌پی[۳]

رقم دوم	حفاظت‌شده در برابر	آزمایش‌شده با	جزئیات
۰	محافظت نشده	—	—
۱	چکیدن آب	چکیدن آب (ریزش عمودی قطرات آب) اثر مضری نخواهند گذاشت.	مدت‌زمان: ۱۰ دقیقه آبی معادل ریزش ۱ میلی‌متر باران در درقیقه
۲	چکیدن آب هنگام کج‌شدگی تا ۱۵°	اگر محفظه تا ۱۵° نسبت به حالت عادی کج شود چکیدن عمودی آب اثر زیان‌باری نمی‌گذارد.	مدت آزمایش: ۱۰ دقیقه آبی معادل ریزش ۳ میلی‌متر باران در درقیقه
۳	آب افشانده‌شده	ریزش آب به صورت افشانه تا زاویهٔ ۶۰° از حالت عمودی اثر زیان‌باری ندارد.	مدت آزمایش: ۵ دقیقه حجم آب: 0.7 لیتر بر دقیقه Pressure: 80–100 kPa
۴	پاشیدن آب	پاشش آب روی محفظه از هر جهتی روی آن اثر زیان‌بار نمی‌گذارد.	مدت‌زمان: 5 دقیقه حجم آب: 10 لیتر بر دقیقه فشار: 80–100 کیلوپاسکال
۵	جت‌های آب	آب افشانده‌شده با یک افشانک (6.3 میلی‌متر) بر روی محفظه از هر جهتی اثر زیان‌بار نخواهد داشت.	مدت آزمایش: دست کم 15 دقیقه حجم آب: 12.5 لیتر بر دقیقه Pressure: 30 kPa at distance of 3 m
۶	جت‌های قوی آب	آب افشانده‌شده با جت‌های قوی (افشانهٔ 12.5 mm) بر روی محفظه از هر جهتی اثر زیان‌بار خواهد داشت.	مدت آزمایش: دست کم ۳ دقیقه حجم آب: 100 لیتر بر دقیقه فشار آب: 100 کیلو پاسکال از فاصلهٔ 3 متر
۷	غوطه‌وری تا 1 متر	در شرایط تعیین‌شده برای غوطه‌وری از نظر زمان و فشار، نفوذ آب به میزان زیان‌بار به درون محفظه ناممکن خواهد بود (تا 1 متر غوطه‌وری).	زمان آزمایش: 30 دقیقه غوطه‌وری در ژرفای کمینهٔ 1 متر اندازه‌گیری‌شده از پایین وسیله، و دست کم 15 سانتی‌متر اندازه‌گیری‌شده از بالای وسیله
۸	غوطه‌وری ورای 1 متر	تجهیز برای غوطه‌وری دائم در آب در شرایط یادشده توسط سازنده مناسب است. معمولاً این به معنای آن است که وسیله آب‌بندی شده است. با این وجود، در برخی تجهیزات، به معنای آن است که آب می‌تواند نفوذ کند اما اثر زیان‌باری ندارد.	مدت آزمایش: غوطه‌وری مداوم در آب ژرفای تعیین‌شده توسط سازنده

Liquid ingress protection

The second digit indicates the level of protection that the enclosure provides against harmful ingress of water.[6]

Level	Protected against	Testing for	Details
0	Not protected	—	—
1	Dripping water	Dripping water (vertically falling drops) shall have no harmful effect.	Test duration: 10 minutes Water equivalent to 1 mm rainfall per minute
2	Dripping water when tilted up to 15°	Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.	Test duration: 10 minutes Water equivalent to 3 mm rainfall per minute
3	Spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.	Test duration: 5 minutes Water volume: 0.7 litres per minute Pressure: 80–100 kPa
4	Splashing of water	Water splashing against the enclosure from any direction shall have no harmful effect.	Test duration: 5 minutes Water volume: 10 litres per minute Pressure: 80–100 kPa

5	Water jets	Water projected by a nozzle (6.3 mm) against enclosure from any direction shall have no harmful effects.	Test duration: at least 3 minutes Water volume: 12.5 litres per minute Pressure: 30 kPa at distance of 3 m
6	Powerful water jets	Water projected in powerful jets (12.5 mm nozzle) against the enclosure from any direction shall have no harmful effects.	Test duration: at least 3 minutes Water volume: 100 litres per minute Pressure: 100 kPa at distance of 3 m
6K	Powerful water jets with increased pressure	Water projected in powerful jets (6.3 mm nozzle) against the enclosure from any direction, under elevated pressure, shall have no harmful effects.	Test duration: at least 3 minutes Water volume: 75 litres per minute Pressure: 1000 kPa at distance of 3 m
7	Immersion up to 1 m	Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).	Test duration: 30 minutes The lowest point of enclosures with a height less than 850 mm is located 1000 mm below the surface of the water, the highest point of enclosures with a height equal to or greater than 850 mm is located 150 mm below the surface of the water

8	Immersion beyond 1 m	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects.	Test duration: continuous immersion in water Depth specified by manufacturer, generally up to 3 m
9k	Powerful high temperature water jets	Protected against close-range high pressure, high temperature spray downs.	—

Additional letters

The standard defines additional letters that can be appended to classify only the level of protection against access to hazardous parts by persons:

Level	Protected against access to hazardous parts with
A	Back of hand
B	Finger
C	Tool
D	Wire

Further letters can be appended to provide additional information related to the protection of the device:

Letter	Meaning
f	Oil resistant
H	High voltage device
M	Device moving during water test
S	Device standing still during water test
W	Weather conditions

Mechanical impact resistance

An additional number has sometimes been used to specify the resistance of equipment to mechanical impact. This mechanical impact is identified by the energy needed to qualify a specified resistance level, which is measured in joules (J). This has now been superseded by the separate 'IK code' specified in EN 62262.

Although dropped from the 3rd edition of IEC 60529 onwards, and not present in the EN version, older enclosure specifications will sometimes be seen with an optional third IP digit denoting impact resistance. Newer products are likely to be given an IK rating instead. However there is not an exact correspondence of values between the old and new standards.

Dropped IP level	Impact energy	Equivalent drop mass and height
0	—	—
1	0.225 J	150 g dropped from 15 cm
2	0.375 J	250 g dropped from 15 cm
3	0.5 J	250 g dropped from 20 cm
5	2 J	500 g dropped from 40 cm
7	6 J	1.5 kg dropped from 40 cm
9	20 J	5.0 kg dropped from 40 cm

IK number	Impact energy (joules)	Equivalent impact
00	Unprotected	No test
01	0.15	Drop of 200 g object from 7.5 cm height
02	0.2	Drop of 200 g object from 10 cm height
03	0.35	Drop of 200 g object from 17.5 cm height
04	0.5	Drop of 200 g object from 25 cm height
05	0.7	Drop of 200 g object from 35 cm height
06	1	Drop of 500 g object from 20 cm height
07	2	Drop of 500 g object from 40 cm height
08	5	Drop of 1.7 kg object from 29.5 cm height
09	10	Drop of 5 kg object from 20 cm height
10	20	Drop of 5 kg object from 40 cm height

IPXX Codings

The letter X is used in any place in the code where specifying a digit is meant to be avoided (or indicates irrelevance based on the common application). Among other common IP ratings using the letter X are IPX4. IP2X is frequently used on electrical items to specify that the item must prevent finger access to live terminals, for example, in electrical sockets.

IP Code	Meaning & Test Standard
IPX0	No special protection
IPX1	Protected against falling water Equivalent to 3-5mm rainfall per minute for a duration of 10 minutes. Unit is placed in its normal operating position.
IPX2	Protected against falling water when tilted up to 15 degrees - Same as IPX1 but unit is tested in 4 fixed positions - tilted 15 degrees in each direction from normal operating position.
IPX3	Protected against spraying water - Water spraying up to 60 degrees from vertical at 10 liters/min at a pressure of 80–100 kN/m2 for 5 min.
IPX4	Protected against splashing water - Same as IPX3 but water is sprayed at all angles.
IPX5	Protected against water jets - Water projected at all angles through a 6.3 mm nozzle at a flow rate of 12.5 liters/min at a pressure of 30 kN/m2 for 3 minutes from a distance of 3 meters.
IPX6	Protected against heavy seas - Water projected at all angles through a 12.5 mm nozzle at a flow rate of 100 liters/min at a pressure of 100 kN/m2 for 3 minutes from a distance of 3 meters.
IPX7	Protected against water immersion - Immersion for 30 minutes at a depth of 1 meter.
IPX8	Protected against water submersion - The equipment is suitable for continual submersion in water under conditions which are identified by the manufacturer.

IP69K

German standard DIN 40050-9 extends the IEC 60529 rating system described above with an **IP69K** rating for high-pressure, high-temperature wash-down applications.[7] Such enclosures must not only be dust-tight (IP6X), but it must also be able to withstand high-pressure and steam cleaning.

The test specifies a spray nozzle that is fed with 80 °C water at 8–10 MPa (80–100 bar) and a flow rate of 14–16 L/min. The nozzle is held 10–15 cm from the tested device at angles of 0°, 30°, 60° and 90° for 30 seconds each. The test device sits on a turntable that rotates once every 12 seconds (5 rpm).

The IP69K test specification was initially developed for road vehicles, especially those that need regular intensive cleaning (dump trucks, cement mixers, etc.), but it also finds use in other areas (for example, the food industry and car wash centers).

NEMA rating

The National Electrical Manufacturers Association defines enclosure types in NEMA standard number 250. Ratings are not directly equivalent between the two standards, but the following table outlines the NEMA ratings that would correspond to the performance required by an IP code. NEMA ratings also require additional product features and tests (such as functionality under icing conditions, enclosures for hazardous areas, knock-outs for cable connections and others) not addressed by IP ratings.

IP Code	Min. NEMA Enclosure rating to satisfy IP Code
IP20	1
IP54	3
IP55	12
IP65	4
IP66	4X
IP67	6
IP69	6P

NOTES ON COMPLETING THE MOTOR AND MOTOR STARTER SCHEDULE

1.	CONDENSER WATER PUMP:	CONDENSER WATER PUMP SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH AND RED RUNNING LIGHT. AT 208 OR 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. CHILLER SHOULD BE INTERLOCKED WITH THIS PUMP. USUALLY WIRE AUTOMATIC POSITION IN H-O-A TO AUXILIARY CONTACT IN CHILLED WATER PUMP STARTER.
2.	CHILLED WATER PUMP:	CHILLED WATER PUMP SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH START-STOP PUSHBUTTON AND RED RUNNING LIGHT. AT 208 OR 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. CHILLER SHOULD BE INTERLOCKED WITH THIS PUMP SO THAT CHILLER CANNOT RUN UNLESS THIS PUMP IS RUNNING. ALSO INTERLOCK CONDENSER WATER PUMP WITH THIS PUMP.
3.	HOT WATER PUMP:	HOT WATER PUMP SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH AND RED RUNNING LIGHT. UP TO 208 OR 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. ALWAYS PROVIDE MAINTAINED CONTACT ON HEATING PUMPS.
4.	IN-LINE PUMP, SINGLE PHASE:	IN-LINE PUMPS OF FRACTIONAL HP AND SINGLE PHASE SHALL HAVE MANUAL STARTERS WITH RED RUNNING LIGHT. THIS DOES NOT APPLY TO PUMPS THAT REQUIRE AUTOMATIC CONTROL, WHICH WILL REQUIRE MAGNETIC ACROSS-THE-LINE STARTERS WITH HOA SWITCH AND RED RUNNING LIGHT.
5.	IN-LINE PUMP, THREE PHASE:	SHALL HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH AND RED RUNNING LIGHT.
6.	RECIPROCATING REFRIGERATION COMPRESSOR:	UP TO 25 HP, USE MAGNETIC ACROSS-THE-LINE STARTER WITH START-STOP PUSHBUTTON AND RED RUNNING LIGHT. FROM 30 HP THRU 100 HP, WHERE THE VOLTAGE IS 240 OR LESS, USE INCREMENT TYPE STARTER. BE SURE AND SPECIFY PART WINDING TYPE MOTOR FOR COMPRESSOR, FROM 30 HP THRU 100 HP, WHERE THE VOLTAGE IS 400 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER.
7.	CENTRIFUGAL REFRIGERATION COMPRESSOR:	USE REDUCED VOLTAGE STARTER NORMALLY OF THE STAR DELTA CLOSED TRANSITION TYPE. THE MANUFACTURER OF THIS EQUIPMENT SHOULD ALWAYS BE CONTACTED. CONTROL CIRCUIT SHOULD BE WIRED THRU AUXILIARY CONTACTS IN CHILLED WATER AND CONDENSER WATER PUMP STARTERS.
8.	COOLING TOWER FANS:	COOLING TOWER FANS SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH AND RED RUNNING LIGHT, AT 208 OR 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. WIRE AUTOMATIC POSITION ON HOA SWITCH TO THERMOSTAT IN CONDENSER WATER LINE.
9.	EXHAUST FANS, SINGLE PHASE:	EXHAUST FANS OF FRACTIONAL HP AND SINGLE PHASE SHALL HAVE MANUAL STARTERS WITH RED RUNNING LIGHT. THIS DOES NOT APPLY TO FANS THAT REQUIRE AUTOMATIC CONTROL, WHICH WILL REQUIRE MAGNETIC ACROSS-THE-LINE STARTERS WITH HOA SWITCH AND RED RUNNING LIGHT.
10.	EXHAUST FANS, THREE PHASE:	SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH OR STOP-START PUSHBUTTON AND RED RUNNING LIGHT. UP TO 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. CONTACT CAN BE MOMENTARY UNLESS IT IS IMPORTANT THAT THIS FAN STARTS AGAIN AFTER POWER FAILURE.

10. EXHAUST FANS, THREE PHASE: SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH OR STOP-START PUSHBUTTON AND RED RUNNING LIGHT. UP TO 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. CONTACT CAN BE MOMENTARY UNLESS IT IS IMPORTANT THAT THIS FAN STARTS AGAIN AFTER POWER FAILURE.

11. AIR HANDLING UNITS: AIR HANDLING UNITS SHOULD NORMALLY HAVE MAGNETIC ACROSS-THE-LINE STARTER WITH HOA SWITCH AND RED RUNNING LIGHT. UP TO 240 VOLTS, IF HP EXCEEDS 25 HP, USE INCREMENT STARTER AND PART WINDING MOTOR. WHERE VOLTAGE IS 440 OR GREATER, USE MAGNETIC ACROSS-THE-LINE STARTER UP TO 100 HP. IF AIR HANDLING UNIT HAS HEATING COIL, PROVIDE MAINTAINED CONTACT.

12. OIL BURNER MOTORS: OIL BURNER MOTORS SHALL HAVE MAGNETIC ACROSS-THE-LINE STARTERS WITH RED RUNNING LIGHT. CONTROL CIRCUIT SHOULD BE PROPERLY WIRED THRU ALL SAFETY DEVICES PROVIDED BY OIL BURNER AND BOILER MANUFACTURER.

13. MAINTAINED CONTACT SHOULD BE USED ON ALL MOTORS WHICH SHOULD COME BACK ON AUTOMATICALLY AFTER A POWER FAILURE. MAINTAINED CONTACT DEVICES ARE ON-OFF OR H-O-A AND SHOULD BE USED ON ALL MOTORS THAT SUPPLY HEAT TO THE BUILDING.

14. CHECK WITH ELECTRICAL DESIGNER TO SEE IF STARTER SHOULD BE FLUSH MOUNTED OR SURFACE MOUNTED.

GENERAL

1. ON CONTROL DEVICES MOMENTARY CONTACTS WILL CAUSE MOTOR TO DROP OUT ON POWER FAILURE AND WILL REMAIN OFF UNTIL RESTARTED MANUALLY. MAINTAINED CONTACTS WILL CYCLE MOTOR AND WILL RESTART MOTOR UPON FAILURE OF POWER AND RESTORED POWER.
2. ON TWO-SPEED MOTORS, DUAL WOUND MOTORS WILL PROVIDE FOR 1200 RPM AND 1800 RPM ONLY. IF 900 RPM AND 1800 RPM ARE REQUIRED, USE SINGLE WINDING TYPE MOTOR AND STARTER.
3. NEMA TYPE I STARTERS ARE GENERALLY USED FOR ALL INTERIOR LOCATIONS. REFER TO NEMA CLASSFICATIONS FOR OTHER LOCATIONS.

SCHEDULE

MOTOR	LOCATION	HP	VOLTS	PHASE	AMPS		STARTER				IND. LTS.	CONTROL VOLTAGE	MANUAL CONTROL		AUTOMATIC CONTROL		INTERLOCKING				REMARKS
					FL.	LR.	TYPE	NEMA SIZE	CIR. BKR.	MTG.			DEVICE	LOCATION	DEVICE	LOCATION	SAFETY DEVICE	NO. CONTACTS		ITEM	
																		N.O.	N.C.		

ABBREVIATIONS

GENERAL:

N.O. - NORMALLY OPEN
N.C. - NORMALLY CLOSED
F.L. - FULL LOAD RUNNING CURRENT
L.R. - LOCKED ROTOR CURRENT
MTG. - TYPE MOUNTING
S - SURFACE
F - FLUSH
FS - FLOOR MOUNTING
MCC - MOUNTED IN MOTOR CONTROL CENTER

TYPE:

MAN. - MANUAL
M-A-L - MAGNETIC FULL VOLTAGE ACROSS-THE-LINE
S-D - STAR DELTA - REDUCED VOLTAGE
A-T - AUTO TRANSFORMER-REDUCED VOLTAGE
2-S - TWO SPEED - MAGNETIC

IND. LTS INDICATOR RUNNING LIGHTS

R - RED
A - AMBER
G - GREEN
B - BLUE

MANUAL CONTROL DEVICES:

H.O.A. — 3-POSITION SELECTOR SWITCH (HAND-OFF- AUTOMATIC)
O. — ON-OFF 2-POSITION SELECTOR SWITCH
S-S — START-STOP PUSHBUTTONS (MOMENTARY CONTACTS)
START — START PUSHBUTTON (N.O. CONTACTS)
STOP — STOP PUSHBUTTON (N.C. CONTACTS)

SAFETY DEVICES:

F — FIRESTAT
Z — FREEZESTAT
A — ALARM DEVICE
M — SAFETY CONTROLS BY EQUIPMENT MFR.

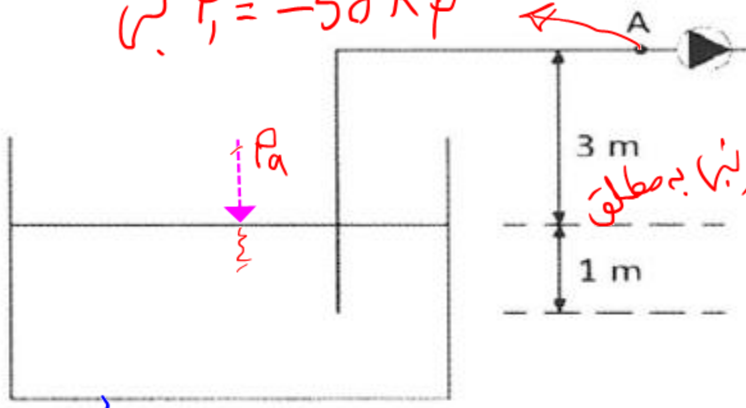
AUTOMATIC CONTROL DEVICES:

P.E. — PNEUMATIC ELECTRIC SWITCH
E.P. — ELECTRIC PNEUMATIC SWITCH
T. — THERMOSTAT
AQ. — AQUASTAT
P.S. — PRESSURE SWITCH
FL.S. — FLOAT SWITCH
C. — CONTACTS ON ANOTHER STARTER (INTERLOCK)

NOTES

1. ALL STARTERS SHALL BE FURNISHED TO THE ELECTRICAL CONTRACTOR BY THE MECHANICAL CONTRACTOR UNLESS OTHERWISE NOTED, & WHEN IN A MOTOR CONTROL CENTER.
2. ALL REDUCED VOLTAGE STARTERS SHALL BE CLOSED TRANSITION TYPE.
3. ALL STARTER ENCLOSURES SHALL BE NEMA I UNLESS OTHERWISE SHOWN.
4. ALL THREE PHASE STARTERS SHALL INCLUDE A THREE COIL THERMAL OVERLOAD RELAY MOUNTED IN THE STARTER ENCLOSURE. ALL SINGLE PHASE STARTERS SHALL INCLUDE A SINGLE COIL THERMAL OVERLOAD RELAY.
5. ALL FEATURES SHALL BE BUILT INTO ENCLOSURE UNLESS OTHERWISE SHOWN UNDER REMARKS
6. ALL STARTERS SHALL HAVE A LAMACOID ENGRAVED NAMEPLATE NAMING THE MOTOR IT CONTROLS.
7. WHERE MOTORS ARE SHOWN TWO SPEED, THE MOTORS SHALL BE TWO WINDING TYPE MOTORS & THE STARTERS SHALL BE TWO WINDING, UNLESS OTHERWISE INDICATED.
8. SUPPLY NECESSARY CONTROL TRANSFORMERS FOR INTERLOCKING STARTERS OF DIFFERENT VOLTAGE, & FOR 120 V CONTROL CIRCUITS.
9. ALL CONTROL CIRCUITS 120 V. & ABOVE SHOULD BE FUSED. PROVIDE DUAL FUSING ON PRIMARY OF CONTROL TRANSFORMER & SINGLE FUSING ON SECONDARY SIDE.
10. MOTOR OVERLOAD RELAY COILS (HEATERS) SHALL BE INSTALLED IN EACH MOTOR STARTER & SHALL BE PROPERLY SIZED IN ACCORDANCE WITH N.E.C. AFTER EXACT MOTOR FULL LOAD RUNNING CURRENT IS KNOWN FROM APPROVED SHOP DRAWINGS.

۵۳- در ورودی یک پمپ آب‌دهی (نقطه A) مطابق شکل داده‌های زیر اندازه‌گیری شده است:



فشار استاتیکی -50 kPa

دمای آب 22 درجه سلسیوس

سرعت آب 2 m/s

NPSHA سیستم چند متر ستون آب است؟

(فشار اتمسفر را 100 کیلوپاسکال، فشار اشباع بخار آب در دمای 22 درجه سلسیوس را 2 کیلوپاسکال، چگالی آب را $1000\ kg/m^3$ و $g=10\ m/s^2$ درنظر بگیرید.)

۱) 5 ✓ ۲) 4 ۳) 4.8 ۴) 3.8

نسبی $P_1 = -50\ Kp$

مطلق $P_1 = 10 - 5 = 5\ m$ مطلق

تبدیل فشار نسبی به مطلق $P_1 = P_a + P_A$

هد ارتفاع

فشار هیدرواستاتیک $\leftarrow P = \rho . g . h$

$$NPSHA = \frac{P_1}{\rho . g} + \frac{V_1^2}{2g} - \frac{P_v}{\rho . g}$$

$100\ kPa = 100{,}000\ Pa$ ، $50\ Kp = 50{,}000$

$2\ KPa = 2000\ Pa$

مطلق

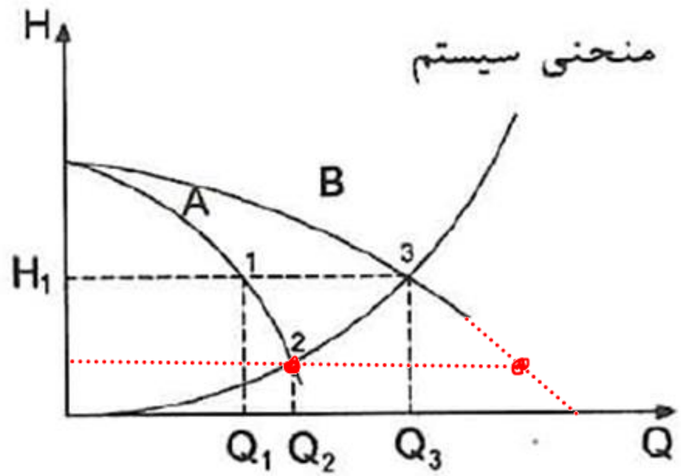
$$NPSHA = \frac{(10-5)\rho . g}{\rho . g} + \frac{2^2}{2 \times 10} - \frac{2000\ Pa}{1000 \times 10} = 5\ m$$

یا

$$NPSHA = \frac{100{,}000 - 50{,}000}{1000 \times 10} + \frac{2^2}{2 \times 10} - \frac{2000}{1000 \times 10} = 5\ m$$

$$NPSHA = H_{st} + \frac{v^2}{2g} - H_v = (-5 + 10) + \frac{2^2}{2 \times 10} - 2 = 5\ m$$

۵۸- شکل مقابل منحنی عملکرد پمپ‌های یک سیستم آبرسانی با دو پمپ مشابه است. کدامیک از عبارات زیر در مورد این منحنی‌ها درست است؟



۱) منحنی A مربوط به عملکرد یک پمپ به تنهایی و منحنی B مربوط به عملکرد دو پمپ به صورت سری است و $Q_3<2Q_2$

۲) منحنی A مربوط به عملکرد یک پمپ به تنهایی و منحنی B مربوط به عملکرد دو پمپ به صورت موازی است و $Q_3=2Q_1$

۳) منحنی A مربوط به عملکرد یک پمپ به تنهایی و منحنی B مربوط به عملکرد دو پمپ به صورت سری است و $Q_3<2Q_1$

۴) منحنی A مربوط به عملکرد یک پمپ به تنهایی و منحنی B مربوط به عملکرد دو پمپ به صورت موازی است و $Q_3>2Q_2$

۹- یک پمپ سانتریفیوژ دور متغیر مفروض است. در صورت کاهش دور آن به نصف، میزان کاهش انرژی مصرفی پمپ در این حالت نسبت به حالت تمام دور چقدر است؟

۱) 75%
۲) 25%
۳) 50%
۴) 87.5% ✓

$n_2 = 0.5 n_1$

$\frac{hp_2}{hp_1} = \left(\frac{n_2}{n_1}\right)^3 = \left(\frac{0.5 n_1}{n_1}\right)^3 = 0.125$

$\Rightarrow hp_2 = 0.125\, hp_1 \Rightarrow$ صرفه‌جویی $= 1 - 0.125 = 0.875$

$= 87.5\%$

شرط عدم کاویتاسیون پمپ $NPSHA > NPSHR$

۴۲- در یک سیستم پمپاژ چگالیدۀ بخار، با افزایش دمای سیال مقدار NPSH موجود: (NPSHA)

۱) در دمای کمتر از دمای اشباع تغییر نمی‌کند. ۲) افزایش می‌یابد.

۳)تغییر نمی‌کند. ۴) کاهش می‌یابد. ✓

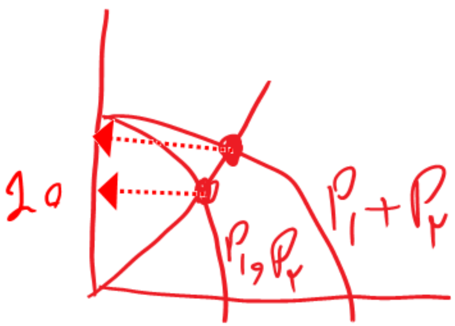
$$NPSHA = \frac{P_1}{\rho g} + \frac{V_1^2}{2g} - \frac{P_v}{\rho g}$$

$$\text{if } T \uparrow \rightarrow P_v \uparrow \Rightarrow NPSHA \downarrow$$

۴۳- در یک مدار گردش آب سردکننده و گرم‌کنندۀ فن‌کویل در موتورخانه که شامل ۲ پمپ مشابه است که بصورت موازی نصب شده‌اند، زمانی که تنها یک پمپ روشن است، فشارسنج‌های نصب شده روی کلکتورهای مکش و دهش، اختلاف فشاری برابر ۲۰ PSI را نشان می‌دهد. اگر پمپ دوم هم روشن شود، کدام یک از روابط زیر در مورد اختلاف فشار کلکتورهای مکش و دهش صادق است؟

۱) $20^{PSI} < \Delta p < 40^{PSI}$ ✓ ۲) $\Delta p = 40^{PSI}$

۳) $40^{PSI} < \Delta p < 80^{PSI}$ ۴) $\Delta p = 20^{PSI}$



۱۹– در پمپ تغذیه دیگ بخار، با افزایش فشار مکش مثبت مورد نیاز پمپ انتخابی باید :

۱) به دمای کندانسیت و فشار کار دیگ بستگی دارد.

۲) ارتفاع استاتیک روی مکش افزایش یابد.

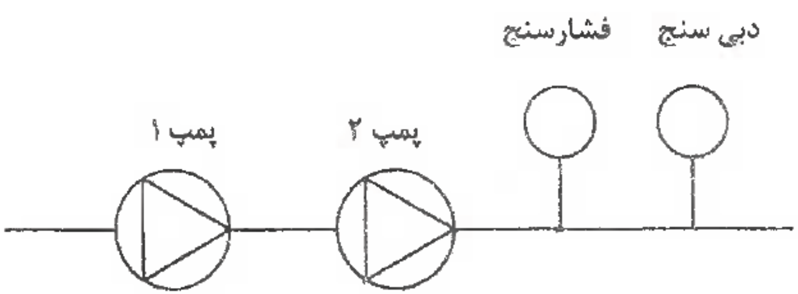
۳) فشار کلی پمپ افزایش یابد.

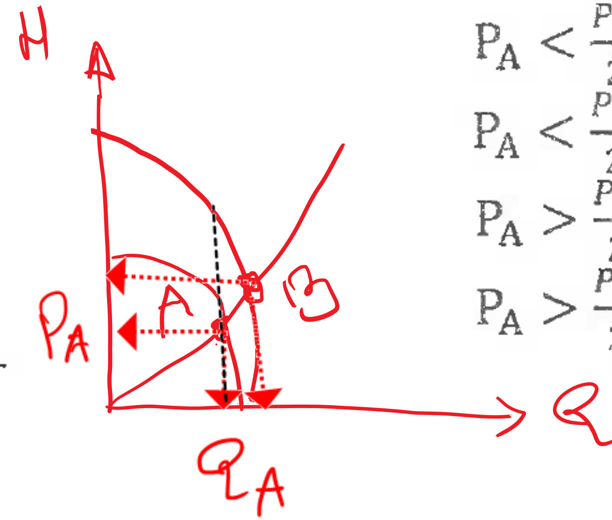
۴) ارتفاع استاتیک روی مکش کاهش یابد.

$$NPSHa > NPSHR$$

$$NPSHa = \frac{P_1}{\rho g} + \frac{V_0^2}{2g} - \frac{P_v}{\rho g}$$

۱- مطابق شکل دو پمپ همسان (۱) و (۲) در یک مسیر لوله‌کشی به صورت سری نصب شده‌اند. در حالت (A)، پمپ (۱) روشن و پمپ (۲) خاموش است. در این حالت فشارسنج P_A و دبی‌سنج Q_A را نشان می‌دهد. در حالت (B) پمپ (۱) و (۲) هر دو روشن می‌باشند. در این حالت فشارسنج P_B و دبی‌سنج Q_B را نشان می‌دهد. کدام گزینه صحیح است؟





۱) $Q_A > Q_B$ و $P_A < \frac{P_B}{2}$

۲) $Q_A < Q_B$ و $P_A < \frac{P_B}{2}$

۳) $Q_A > Q_B$ و $P_A > \frac{P_B}{2}$

۴) $Q_A < Q_B$ و $P_A > \frac{P_B}{2}$ ✓

۱۵- مقرر است یک پمپ با دبی 15 gpm آب را از چاهي به عمق 200 فوت به سطح زمین پمپ نماید. راندمان پمپ 65 درصد است. افت فشار مسیر لوله‌کشي 30 فوت در نظر گرفته می‌شود. توان ترمزی پمپ چقدر است؟

۱) 650 وات
۲) 567 وات
۳) 872 وات
۴) 1000 وات ✓

۱۵	۴

$1\,Kw = 1.341\,hp = 1000\,W$

$1\,hp = 0.746\,Kw$

$H = h + h_L = 200 + 30 = 230\,ft$

$\dot{v} = 15\,gpm$

$h = 200\,ft$

$\eta = 65\%$

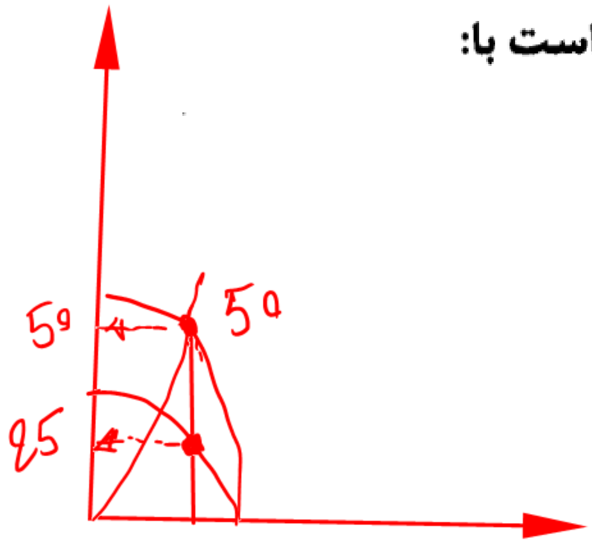
$h_L = 30\,ft$

$P_0 = ?\,w$

$$P_0(hp) = \frac{\dot{v}(gpm) \times H(ft)}{3960 \times \eta} = \frac{15 \times 230}{3960 \times 0.65}$$

$= 1.34\,hp = 1\,Kw$

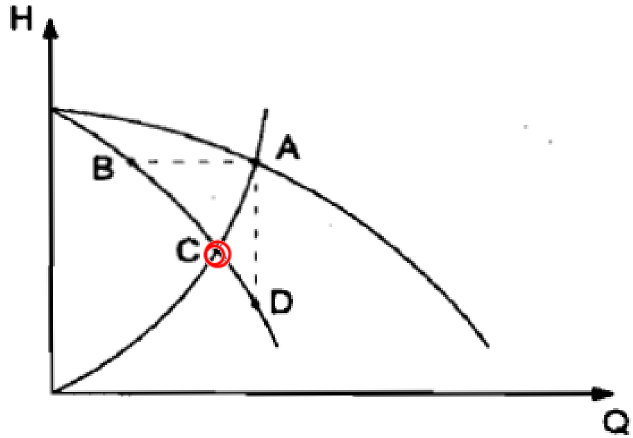
۱۷- اگر مقدار گذر جریان از یک مجموعه شامل دو پمپ مشابه و سری، 200 گالن در دقیقه و فشار کل تولیدی این مجموعه 50 فوت ستون آب باشد، در هنگام روشن بودن و کار همزمان هر دو پمپ، مقدار گذر جریان و فشار تولیدی هر پمپ برابر است با:



۱) 200 گالن در دقیقه و 25 فوت
۲) 200 گالن در دقیقه و 50 فوت
۳) 100 گالن در دقیقه و 50 فوت
۴) 100 گالن در دقیقه و 25 فوت

۱۷	۱

۱۹- شکل زیر نمودار هد - دبی یک سیستم لوله‌کشي و کارکرد دو پمپ یکسان که به صورت موازی در این سیستم در حال کارکردن می‌باشند را نشان می‌دهد. در صورتی‌که تنها یکی از دو پمپ روشن باشد، نقطه کارکرد آن کدام نقطه می‌باشد؟



۱) A

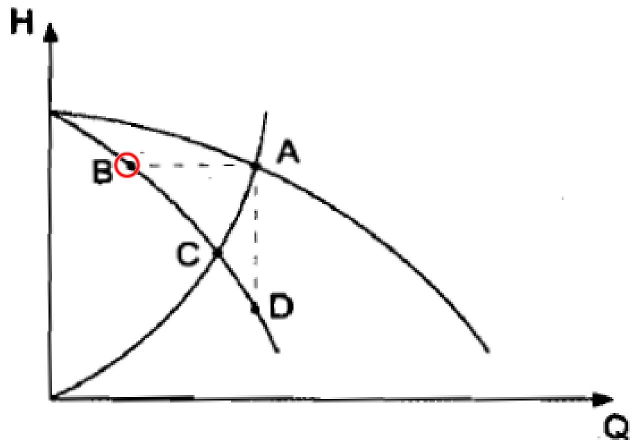
۲) C

۳) B

۴) D

۱۹	۲

۵۲- شکل مقابل نمودار هد – دبی یک سیستم لوله‌کشی بسته و کارکرد دو پمپ یکسان که به صورت موازی در این سیستم در حال کارکردن می‌باشند را نشان می‌دهد. در صورتی‌که هر دو پمپ روشن باشند، نقطه کارکرد هر کدام از پمپ‌ها کدام نقطه می‌باشد؟



۱) A

۲) B

۳) C

۴) D

۵۲	۲

$$\text{توان } \frac{P_{o2}}{P_{o1}} = \left(\frac{\rho_2}{\rho_1}\right) \times \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{D_2}{D_1}\right)^3 \quad \text{و} \quad \frac{\dot{V}_2}{\dot{V}_1} = \left(\frac{n_2}{n_1}\right)$$

۵۸– یک پمپ گریز از مرکز با دور متغیر در یک مدار بسته سیستم گرمایی با هد و دبی به ترتیب 43 ft و 130 gpm در حال کار است و توان مصرفی شافت آن 2.1 hp می‌باشد. اگر با تغییر دور، گذر عبوری را به 100 gpm تغییر دهیم، توان مصرفی شافت در حالت جدید چه مقدار می‌باشد؟

۱) 2.73 hp

۲) 0.96 hp

۳) 1.61 hp

۴) 1.24 hp

۵۸	۲

$hp_1 = 43\ ft$

$\dot{V}_1 = 130\ gpm$

$P_{o1} = 2.1\ hp$

$\dot{V}_2 = 100\ gpm$

$P_{o2} = ?$

$$\frac{P_{o2}}{P_{o1}} = \left(\frac{Q_2}{Q_1}\right)^3$$

$$\frac{P_{o2}}{P_{o1}} = \left(\frac{100}{130}\right)^3$$

$$\frac{P_{o2}}{P_{o1}} = 0.455$$

$$\Rightarrow P_{o2} = 0.455 \times 2.1 = 0.955 \simeq 0.96$$

۶۰- در لوله رانش پمپ و پس از دهانه خروجی آن، محل نصب شیر کشویی، شیر یک‌طرفه و تبدیل افزایش قطر به ترتیب عبارت است از:

۱) شیر یک‌طرفه – شیر کشویی - تبدیل

۲) شیر کشویی- شیر یک‌طرفه - تبدیل

۳) تبدیل – شیر یک‌طرفه – شیر کشویی

۴) تبدیل – شیر کشویی – شیر یک‌طرفه

۶۰	۳

باتشکراز توجه شما

مهندس رحمت اله یوسفی