SECTION 9.4
FIRE PUMPS

MARIO DI MASI
RUDOLPH KAWOHL

Compelling reasons dictate the installation of fire protection systems driven by stationary fire pumps. Foremost among these reasons is protection—protection of lives, of equipment, possessions, and inventories, and of major assets, such as hospitals, hotels, office and residential buildings, and warehouses. There are two additional, less obvious but equally compelling, reasons: the reduction of costs and the protection of income-generating operations.

Costs are reduced in a simple manner. Over the projected life of a facility, the total of construction costs plus fire protection equipment costs plus fire insurance costs is lower than the total of construction costs plus fire insurance costs without fire protection equipment.

FIRE PROTECTION SYSTEMS

Protection may be provided by a combination of several complementary means, acting at various levels:

- First by a simple fire detection system activating an alarm
- On the second level, the detection and warning system is combined with a first degree of fire fighting; for example, with a *sprinkler installation*, the role of which is to extinguish the fire at the beginning or, at least to limit its extension so as to permit intervention with additional equipment
- The third level is a combination of detection, warning, sprinkler and extinguishing systems (water, inert gases, foam)

The degree of protection is obviously a function of risk. Whereas a fire in a single-family-dwelling may be warned by phone and then efficiently contained by means of fire hydrants or fire fighting trucks, the risk of fire in a chemical plant requires a completely different approach. The rules for adequate protection vary from one country to another. There are, for instance, well known pamphlets published by the U.S. National Fire Protection Association (NFPA). In Europe, various national rules exist, based on the recommendations of the European Committee of Insurances, such as those of APSAD in France (Assemblée Plénière des Sociétés d'Assurances Dommages), V d S in Germany (Verband der Sachversicherer e;v), and LPC in the United Kingdom (Loss Prevention Council).

FIRE PUMP CRITERIA

The most common liquid available for fire protection and fire fighting continues to be water. The efficiency of a fire fighting installation depends to a great extent on a dependable water supply, which will supply the required flow at the required pressure and be continuously available during the time necessary to extinguish the particular type of fire in question.

The needs for fire fighting liquid vary considerably with the degree of danger involved. When these needs cannot be satisfied from local water sources, such as public water networks, high level reservoirs, or pressurized water tanks, pumping stations need to be designed and situated (located) to address the types of fire possible and the national codes and standards that exist in a particular country or geographical area.

A typical fire fighting station may be composed of the following:

- A jockey pump (Figure 1) that maintains the desired system pressure within the fire fighting system. Typical performance for a jockey pump is 10 gpm (38 l/min) at heads up to 300 ft (92 m).
- A first intervention fire fighting pump (Figure 2) capable of feeding a limited number (up to 5) of sprinklers. This pump is typically driven by an electrical motor and is fed from a reservoir capable of supplying at least one hour of liquid flow without interruption at required flow and pressure. Records indicate that as many as 95% of all fires are extinguished by this first intervention pump. Typical performance for a first intervention pump is 250 gpm (950 l/min) at a head of 200 ft (60 m).
- An emergency fire fighting pump, capable of feeding all available sprinklers, and other supplementary fire fighting equipment, such as deluge installations and fire-hose nozzles. This pump is typically driven by a diesel engine and supplied with fire fighting water from a (practically) inexhaustible source. The emergency fire fighting pump standard in North America is a split case pump (Figure 3), whereas the European standard is an end suction pump (Figure 4). In each case, typical pump performance is from 500 to 5000 gpm (100 to 1200 m^3/h) at a head of 260 ft (80 m).
- High-rise buildings, protected by sprinklers or standpipes and hose systems, require an overpressure pump. This pump is generally a close coupled end suction pump (Figure

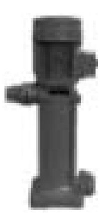

FIGURE 1 Jockey pump (Flowserve Corporation)

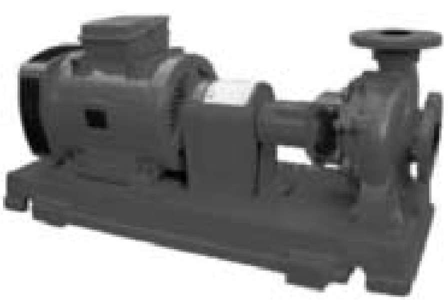

FIGURE 2 First intervention fire pump (Flowserve Corporation)

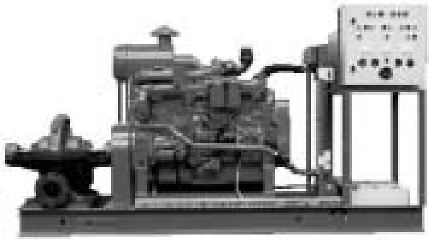

FIGURE 3 Split case fire pump (Flowserve Corporation)

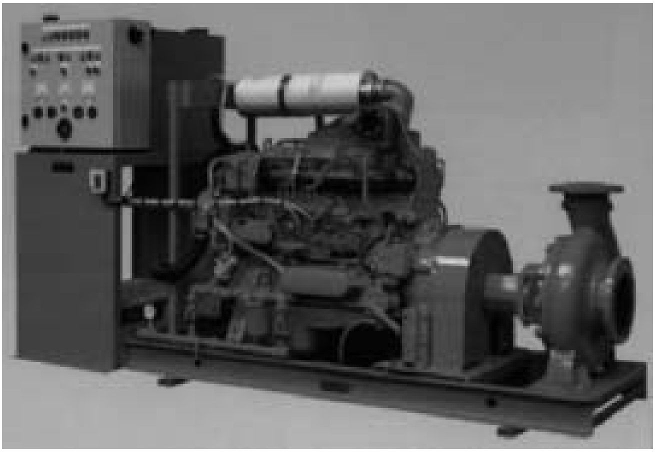

FIGURE 4 End suction fire pump (Flowserve Corporation)

FIGURE 5 Close-coupled end suction fire pump (Flowserve Corporation)

5) driven by an electrical motor, with typical performance of 150 gpm (34 m^3/h) and a head (according to the building height) of at least 200 ft (60 m), sourced from a public water network.

Although the various national authorities have different approaches to the details of fire fighting equipment and arrangement, they nevertheless have a similar basic philosophy. The pumps utilized in fire protection systems are usually classical designs. Specifications require skillful packaging of the complete fire protection system, including the pump(s), driver(s), starting and control devices and other accessories.

Most European codes give considerable freedom of choice relative to pump type and design, whereas NFPA 20 (United States) is more restrictive. According to NFPA, the pumps must be of horizontal end-suction or horizontal split-case design. Single stage close coupled vertical in-line pumps may be used for limited capacities, but these pump types may not be used where a static suction lift is required. If the pump must lift water from a well, panel, river, and so on, NFPA 20 requires the use of vertical pumps installed so the static water level is never below the bottom impeller.

Very high importance is given in all regulations to permanent availability of fire fighting water. Pumps must always be filled with water and must be ready for starting at any moment. This requirement is obviously satisfied when NFPA 20 compliance is mandatory. Although the same approach is preferred in Europe, some European codes nevertheless allow the use of horizontal pumps with a static suction lift. In such cases, the suction pipe must be fitted with a foot valve, and the pump set must be equipped with a controlled filling device.

Some rules common to both North America and Europe are

- The shape of the pump performance curves must conform to precise specifications.
- The design pressure of the pump casings is regulated.
- Hydrostatic tests are required.
- Certified performance test curves are required for most fire pumps.
- Fire fighting pumps must be approved, "de jure" (according to written law or regulations) in North America and in most European countries; "de facto" (according to well-established practices) in the others.

Stationary fire pumps can be purchased as packaged systems, which saves installation time and money. Single or multiple units of horizontal or vertical pumps can be packaged, and each packaged unit generally includes the pump(s), driver(s), controller(s), headers, accessories, and piping mounted on a common base. To the extent possible, all wiring and piping connections are made and the unit is factory-tested. Installation consists simply of positioning and leveling the package and making external piping and electrical connections.

FIRE PUMP DRIVERS

The principal objective of a fire pump driver is to provide the pump with motive power under any circumstances. Usual drivers are electric motors, diesel engines or, to a lesser extent, steam turbines. Although the reliability of the drivers themselves does not really pose problems, careful consideration must be given to the dependability of the power supply for electric motors and turbines, and to the fuel supply for diesel engines. Very complete regulations exist in every country which must be considered.

Electric motors are the most economical driver type when a reliable power source is available. If this is not the case, power must be supplied by two or more independent sources, one of which may be an emergency generator set. Another choice might be to use one motor-driven pump and one diesel engine-driven pump. General guidelines for electric drives are

- Motor power and speed must be selected in accordance with the pump characteristics.
- Depending upon codes and available current, wound rotor, star delta, wye delta primary resistance, or part-winding start motors may be used.

Diesel engines are frequently used to drive stationary fire pumps. Equipped with battery packs and automatic controls, they rival electric motors for reliability and eliminate concern over the dependability of the source of electric power. In order to guarantee the fuel supply, the tank must be located above ground at an appropriate height. The prevailing philosophy of a diesel engine driven pump is that "the pump must run" in actual fire conditions. All engine failures (oil pressure, cooling water temperature, speed) should be indicated only, and should not stop the engine. The only exception to this is the NFPA 20 requirement that a shut-down occur at an over speed of 120%.

Here are some general guidelines for diesel engines:

- Engine power and speed must be selected in accordance with the pump characteristics (diesel engines are very sensitive to altitude and ambient temperature).
- All energy sources for engine starting must be doubled: two batteries, or two air containers, or electrical and manual recharge of the hydraulic starting system, and so on.
- An instrument panel secured to the engine at an appropriate place must include a tachometer, an hour meter, an oil pressure gage, and a water temperature gage.

Occasionally, a fire pump is driven by a steam turbine. When it is desirable to use steam as the power source, details of the steam supply and exhaust need to be carefully planned to ensure that the required level of reliability exists.

FIRE PUMP CONTROLLERS

Regardless of the type of driver, most fire pumps are started automatically by a pressure signal from the pump discharge line. Each fire pump must have its own controller, including the jockey pump.

Depending upon application requirements, fire pump electric motor controllers must conform to the appropriate national regulations. Each controller must be arranged to match the starting characteristics of its motor and must include

- Manual disconnect switch
- Circuit breaker
- Starter without heaters or contactors
- Pressure switch (when NFPA is mandatory)
- Minimum-run timer to prevent motor cycling

The diesel engine controller is arranged to permit either automatic or manual start. The manual start is required to permit periodic run tests. The power source for the controller and for starting is a dual set of batteries or air containers. The controller is arranged to show the following engine conditions:

- Low lubrication oil pressure
- High water jacket temperature
- Failure to start automatically
- Shut-down due to overspeed (when NFPA 20 is mandatory)
- Battery and battery charger failure or, when equipped with one, an air system failure

The engine controller must also provide a means of relaying the following information to remote indicators:

- Engine running
- Engine switch off or manual position
- Trouble signal (activated by one or any combination of the engine or controller signals described above)

Approval of the control system for all pumps, except the jockey pump, is required in nearly all national codes.

GENERAL ENGINEERING PROCEDURE FOR FIRE PROTECTION SYSTEMS

As described earlier, fire protection systems can vary greatly depending on the type and significance of the fire risk, the site conditions and, finally, the various national regulations in force in the given country. Outlined below are engineering guidelines for stationary installations using water as protection agent. Figures 6 and 7 show typical installations for horizontal and vertical fire pumps.

Here are some project basics to keep in mind:

1. Refer to an insurance expert, or to a specialist of a certification board, to confirm that water may be used for the risks of concerned and to determine which kind of spray system is recommended: sprinklers, water jets, deluge installations, and so on.

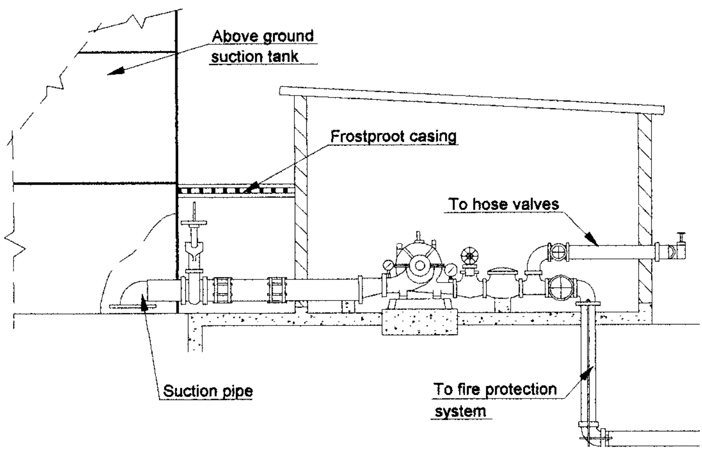

FIGURE 6 Typical installation for horizontal fire pumps

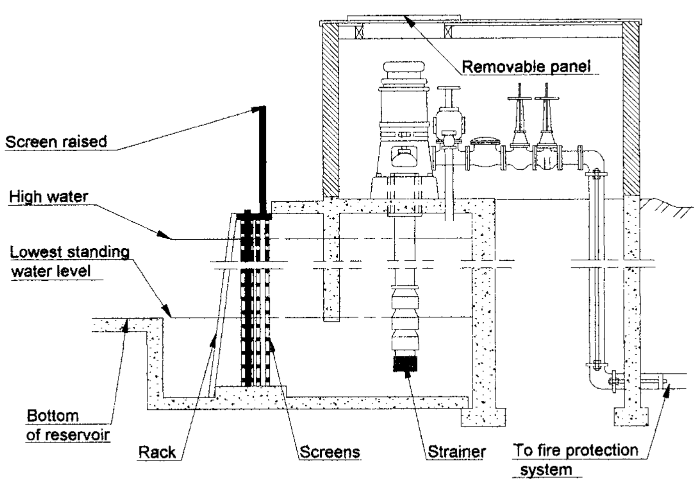

FIGURE 7 Typical installation for vertical fire pumps

2. Determine the appropriate governing regulations: NFPA (North America), APSAD (France), VDS (Germany), and so on.
3. Ensure the availability of sufficient water capacity, according to the type of risk. Preference should be given to a water supply above ground, which is generally more reliable and less expensive than a below-ground supply.
4. Distinguish all the critical areas and functions to be protected on the site.
5. Determine the motive power of the pump drivers. The objective is to be independent from the site of risk. Diesel engine-driven installations many times provide a convenient, independent power source that addresses this concern. The costs associated with a diesel engine power source is usually equivalent to those of electrical installations; in some cases, they are even lower.
6. Provide a pump house, or a pump room, so the pump, driver and controller may be protected against possible damage or injury. In addition to the normal precautions and concerns of a pump installation, also consider the following factors:
   - Easy access for installation and maintenance
   - Sufficient ventilation for motors and engines
   - Risk of earthquakes
   - Risk of freezing
   - Noise protection, where required
7. Determine the pipe network and all required fittings and accessories in order to obtain the lowest project costs.
8. Smaller pipe sizes (less expensive) increase friction losses and may require more powerful (more expensive) pump sets.
9. Larger pipe sizes (more expensive) decrease friction losses and may allow the use of less powerful (less expensive) pump sets.

Keep in mind the following factors when selecting a pump:

1. Compute the total capacity and pressure required to feed the protection system.
2. Determine the *NPSH* available at the pump suction nozzle. This is an important selection criterion for establishing the speed and design of the pump. Reminder: U.S regulations forbid static suction lifts for fire pumps, whereas most European regulations will allow limited suction lifts.
3. Select the highest possible pump speed based on the required capacity and the available *NPSH*. The higher the allowable pump speed, the lower the cost of the pump set. Figures 8 and 9 give recommended operating speeds for single suction and double suction pumps.
4. Select pump size and design according to the governing (applicable) regulations.

Drivers and Controllers As outlined earlier under "Fire Pump Criteria," it is recommended that a completely packaged fire pump set, including the pump(s), driver(s), controller(s), headers, accessories and piping, mounted on a common base, be furnished.

PUMP DESIGN AND MATERIALS

Constant operational readiness and a high degree of operational reliability are the most important aspects of fire pump designs. Although not mandatory, the features listed and described next are recommended for fire pumps.

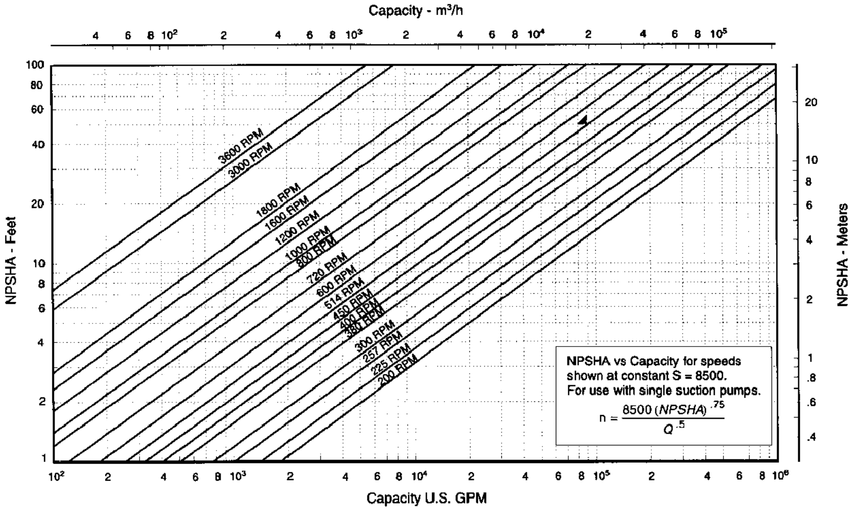

FIGURE 8 Recommended operating speeds for single suction fire pumps (Hydraulic Institute ANSI/HI 2000 Edition Pump Standards, Refernce 1)

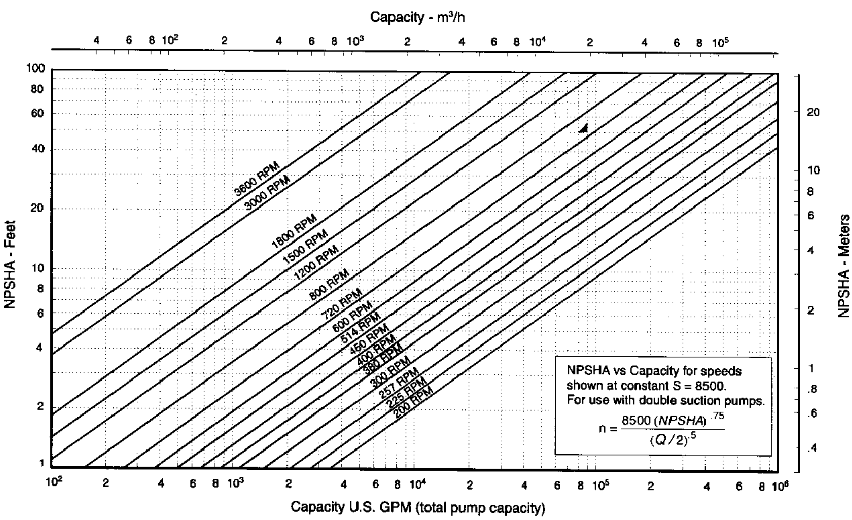

FIGURE 9 Recommended operating speeds for double suction fire pumps (Hydraulic Institute ANSI/HI 2000 Edition Pump Standards, Refernce 1)

- Shaft sealing should be by means of stuffing boxes (packing).
- Grease-lubricated rolling element bearings should be used on horizontal pumps. Water-lubricated (rubber) sleeve bearings (open line shaft) or oil-lubricated bronze sleeve bearings (enclosed line shaft) and, if so equipped, a grease-lubricated thrust bearing should be used on vertical pumps.
- Combinations of materials, running clearances, and rotor end plays should permit trouble-free operation, even if the pump has been idle (not run) for extended periods of time.

- Repairs should be achievable by means of standard tools.
- Corrosion-resistant materials must be utilized if the fire-fighting water is corrosive, such as brackish or salt water.
- Additional features or specific materials, as may be mandated by specific national standards and codes.

Because most fire pumps handle clear water, and because wear (from severe usage) is not usually a problem, fire fighting pumps should be of the simplest design possible and should be made of commonly used industrial materials. The most economical fire pump is either a single-stage, end suction, or vertical in-line pump. This class of pump is readily available to heads of approximately 260 ft (80 m). Unfortunately, capacities have been limited in the United States (by NFPA 20) to 750 gpm (200 m^3/h) for horizontal end suction pumps and to 500 gpm (115 m^3/h) for vertical in-line pumps. The 1996 edition of NFPA 20 eliminated these historical limitations. In Europe, however, end suction volute pumps are commonly employed up to 4000 gpm (900 m^3/h).

The jockey pump (Figure 10), used to maintain the pressure within the system, is generally a small, vertical multistage pump, utilizing an extended motor shaft (no shaft coupling). Recommended materials for jockey pumps are

Casings:	Cast iron
Impellers:	Bronze or thermoplastic resin
Diffusers:	Cast iron
Shaft:	Chromium steel
Bearings:	Grease lubricated rolling element bearings, with an additional product lubricated bronze line bearing in close coupled designs

A large end suction fire fighting pump, as shown in Figure 11, is typical of units used in Europe and allowed to be operated over the entire pump capacity range, from shut-off to the highest capacities. The pump exhibits the following features:

- Back pull out construction for ease of maintenance without disturbing the driver
- The absence of shaft sleeves, giving highest possible shaft stiffness

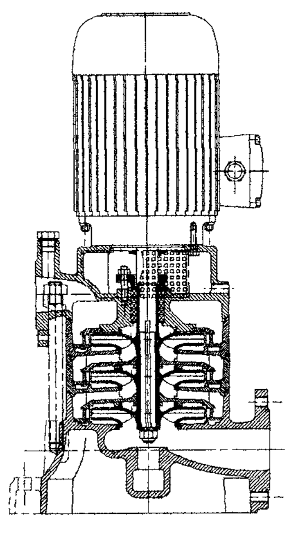

FIGURE 10 Small, vertical multistage jockey pump using an extended motor shaft (Flowserve Corporation)

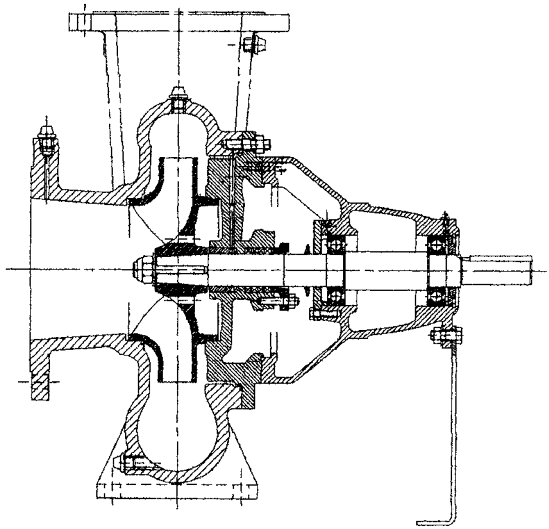

FIGURE 11 Large end suction fire pump, typical of units used in Europe (Flowserve Corporation)

- A bronze bearing bushing located behind the impeller that acts as a product lubricated auxiliary line bearing
- A conical (tapered shaft) impeller fit to ensure no looseness between the mounted impeller and the shaft (critical when pumps are driven by a diesel engine)

Recommended materials for end suction fire fighting pumps are

Casing:	Cast iron or ductile iron
Impeller:	Bronze
Shaft:	13% chromium steel
Bearings:	Grease-lubricated rolling element bearings

For larger capacities, in excess of 500—750 gpm (115–200 m^3/h) in the United States and above approximately 4000 gpm (900 m^3/h) in Europe, single stage double suction axially split case pumps (Figure 12) are required. These larger units are more costly than the simple single stage overhung designs, but they do offer some advantages that could make them desirable even at lower flow rates, such as

- The required *NPSH* is lower (double suction impeller), thus allowing higher operating speeds.
- The axially split case design provides easy access to the pump interior (neither the pump nor the driver need to be disconnected) for inspection and rotor removal.
- Axially balanced hydraulic axial forces, and bearings on each end of the rotor supports unbalanced radial loads.

Recommended materials for single stage double suction axially split case for fighting pumps are

Casing:	Cast Iron
Impeller:	Bronze
Shaft:	Carbon steel

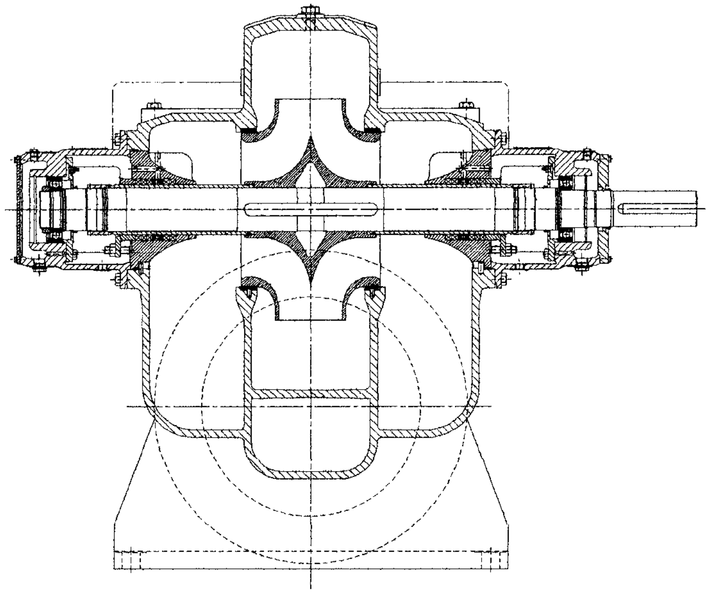

FIGURE 12 Single stage double suction axially split case pump used for larger capacities (Flowserve Corporation)

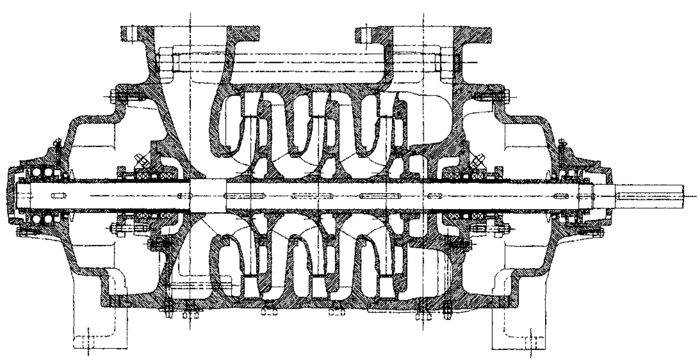

FIGURE 13 Multistage ring-section fire pump (Flowserve Corporation)

Sleeves:	Bronze
Casing Rings:	Bronze
Bearings:	Grease-lubricated rolling element bearings

Normally, head requirements for fire pumps do not exceed 260 ft (80 m). For those systems that do require more head, end-suction and axially split case pumps may be available up to 450 ft (140 m). Beyond this head range, multistage pumps are typically employed. Multistage pumps for fire services in Europe are usually of the ring-section design (Figure 13), whereas the axially split case design (Figure 14 shows a typical two-stage pump; Figure 15 shows a typical multistage pump) tends to be more popular in North America.

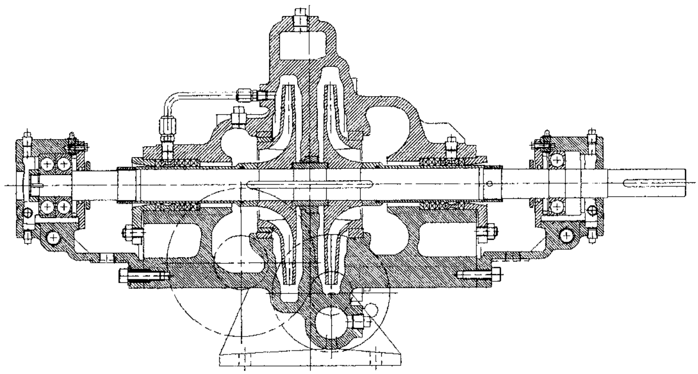

FIGURE 14 Two-stage axially split fire pump (Flowserve Corporation)

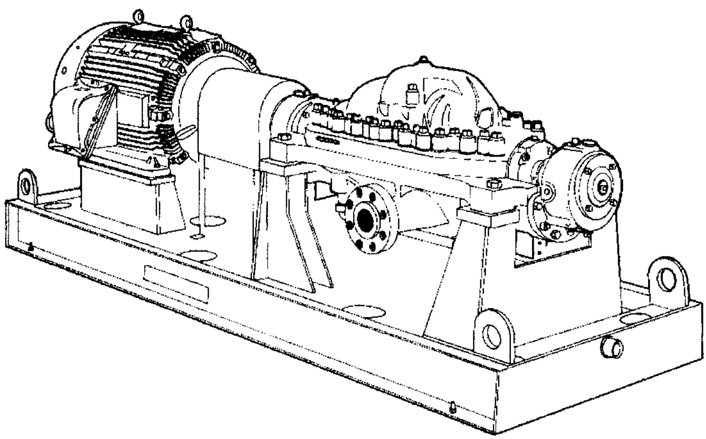

FIGURE 15 Typically axially split multistage pump used for fire fighting (Flowserve Corporation)

In North America, vertical pumps must be used when the water source is located below ground. In Europe, where the use of a limited static suction lift is generally permitted, such vertical pumps are required only when the *NPSH* available at the suction nozzle of a horizontal pump would exceed a certain limit, as may be established by national regulations in each country—for instance 16.4 ft (5 m) in France.

The submergence of vertical pumps require a particular care. As a minimum, the second stage (second impeller up from the bottom end of the pump) should always be submerged below the minimum water level.

The inner column (drive shafting) for vertical pumps is available in either of two configurations:

- Open line shaft (OLS) construction (Figure 16), within which a steel shafting rotates in water-lubricated rubber bearings, centered and stabilized by rigid bearing retainers, is used for static water levels 50 ft (15 m) or less below the pump discharge flange.

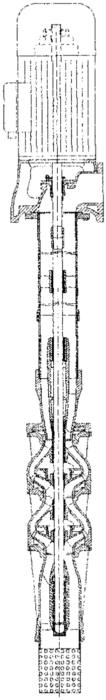

FIGURE 16 Vertical pump with open line shaft construction (Flowserve Corporation)

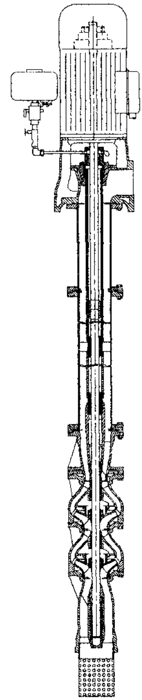

FIGURE 17 Vertical pump with enclosed line shaft construction (Flowserve Corporation)

- Enclosed line shaft (ELS) construction (Figure 17), in which steel shafts rotate in oil-lubricated bronze sleeve bearings, is used for static water levels of more than 50 ft (15 m). In ELS construction, the outside of the sleeve bearings are threaded and tubes enclosing and supporting the bearings and shafts isolate the shafting from the water being pumped.

If an oil-lubricated line shaft design is utilized, the appropriate environmental protection or health department should be consulted with regard to special requirements for installation and protection.

Recommended materials for vertical pumps are

Discharge head and columns:	Cast iron or welded steel
Water-lubricated line shaft:	Carbon steel protected by non-rusting shaft sleeves through packing and water-lubricated bearings (Note: chromium steel shafts typically do not require shaft sleeve protection.)
Oil-lubricated line shaft:	Carbon steel possible, but chromium steel is preferred
Pump shaft:	Chromium steel
Bowls:	Cast iron
Impellers:	Bronze

OVERVIEW OF COMMONLY USED ACCESSORIES

See Figures 18 and 19 for typical fire pump systems.

1. Common to horizontal and vertical pumps:
   - a. **Casing relief valve** To prevent a no-flow condition when system is running at shutoff

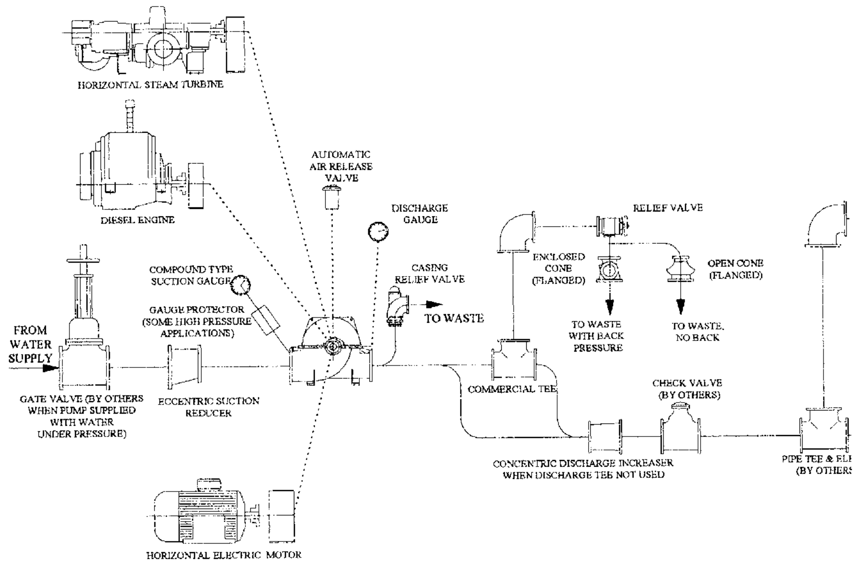

FIGURE 18 Typical horizontal fire pump system

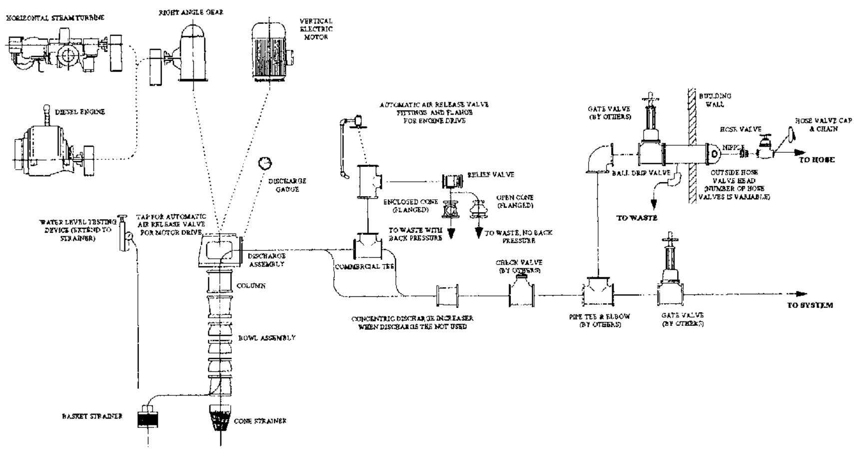

FIGURE 19 Typical vertical fire pump system

- **b. Automatic air release valve** To vent entrapped air in automatic systems
- **c. Umbrella cock** To vent air in manually operated systems
- **d. Hose valve head with hose valves, caps, and chains** To permit pump flow (capacity) tests (most modern systems use flowmeters in lieu of hose valve heads)
- **e. Ball drip valve** Installed upstream to prevent freeze damage to hose valve head installed outside
- **f. Overflow cone** To show whether the relief valve is open
- **g. Commercial discharge tee with (if required) 90° elbow** Used when main relief valve is required

2. Horizontal pumps only

- **a. Eccentric suction reducer** Required when the size of the suction pipe does not match the size of the pump suction connection
- **b. Concentric discharge increaser** Required when the size of the discharge pipe does not match the size of the pump discharge connection
- **c. Main relief valve** Required when pump shutoff pressure plus suction pressure exceeds system design pressure and when engine or other variable-speed driver is used
- **d. Splash partition** Used for motor-driven units where hose head are mounted indoors near pump

3. Vertical pumps only

- **a. Main relief valve** Required when engine or other variable-speed driver is used
- **b. Water level testing device** To determine distance to surface of water; required for well pump installations

REFERENCES AND FURTHER READING

United States

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France

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