Fire Pump Systems-Design and Specification

Think your fire pumps are just like the rest of your fluid-movers? Think again. Rigorous standards and certifications make sure these life-savers are up to snuff.

by George Lingenfelder and Paul Shank, Precision Powered Products

Point of view is everything when discussing fire pump systems. For the engineering-contractor, they are relatively uncommon systems referencing specifications unheard of in conventional process units. To the purchaser, they are mandated systems that take time, space and capital away from money-making units. For users, fire pump systems are (or should be) a once a week test requirement.

But in spite of the time, space and money constraints, fire pump systems must work as required. Period. Hundreds of lives and millions of dollars in hardware and production costs rely on the performance of these systems. Fortunately, they almost always work.

Because of the critical nature of this service, one might think that industry standards could simply be invoked to insure reliable design and specification. Of course they can. They just never are. At least not without the addition of supplemental proprietary specifications that can conflict with industry standards, government regulations and sometimes with the basic system design. Seemingly minor requirements can result in the loss of a listing agency label and render a perfectly functional system unacceptable to insurers or governmental agencies.

Pumps

The basic fire pump system includes a UL (Underwriters Laboratory) or FM (Factory Mutual) listed pump, driver and controller. Pumps are rated in discrete increments starting at 25 gpm and extending through 5000 gpm. Each capacity designation is tested for compliance with NFPA 20 (National Fire Protection Association) requirements for performance and by independent testing institutions such as UL or FM for design, reliability and safety. A single pump can be certified for more than one operating point, but it must meet all performance and design criteria at both points.

In the area of basic hydraulic performance, a pump must deliver at least 65% of rated discharge pressure at 150% of rated flow to achieve NFPA 20 acceptance. So a 1500 gpm pump rated at 150 psig must deliver 2250 gpm at a discharge pressure of not less than 97.5 psig. This operating range then establishes the design parameters for the piping system and fire fighting equipment. Another requirement establishes that the maximum shut-off head must not exceed 140% of design head.

Both horizontal and vertical centrifugal pumps are available as listed pumps. (For brevity, we will use the term "listed" to refer to any equipment certified by UL, FM, the Canadian Standards Association (CSA) or other agency as suitable for fire pump system application.) While there are some obvious design differences between the requirements for these two styles, the performance prerequisites remain un-changed. It is important to note that listed pumps are not designed or manufactured to API 610 standards.

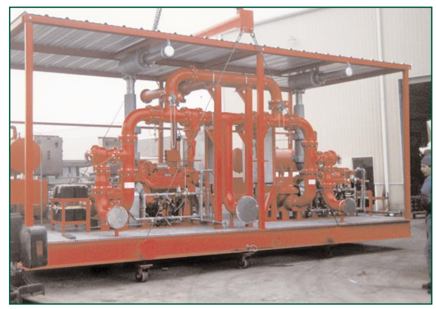

Photo 1. Fire water pump with diesel engine and air start with a nitrogen back-up system

Materials of construction vary with the type of system and the fire fighting fluid. The standard cast iron case with bronze impellers and wear surfaces is the most common in land-based applications. This material is generally suitable for fresh water and sometimes brackish or even salt water services, depending on the length of service and anticipated life of the unit. Even in fresh water services, it is critical to consider casing corrosion rates when choosing materials. For more aggressive fluids, many manufacturers offer various grades of bronze, including zinc-free and nickel-aluminum bronze. Higher alloys of 300 series stainless steel and Alloy 20 may also be available for very corrosive services or situations in which the expected project life is extremely long.

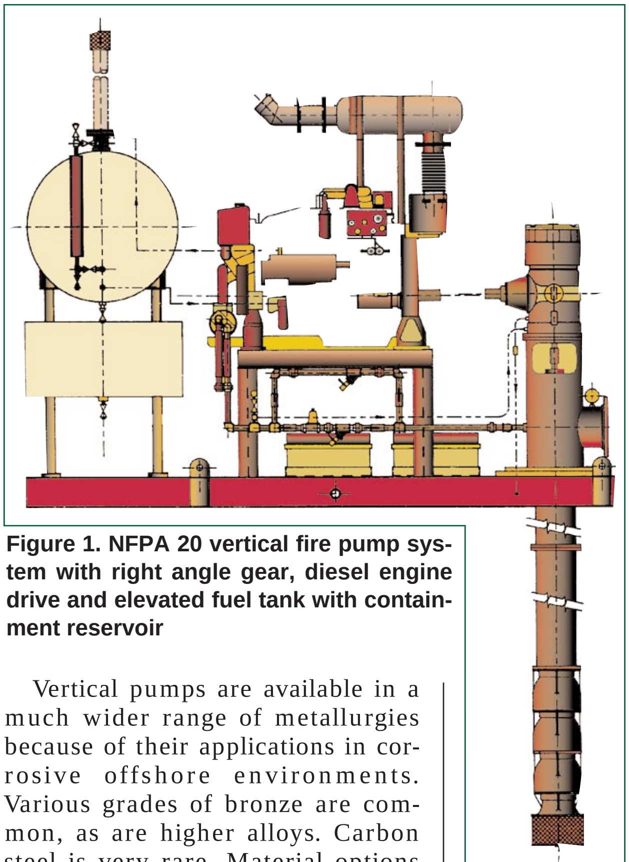

Figure 1. NFPA 20 vertical fire pump system with right angle gear, diesel engine drive and elevated fuel tank with containment reservoir

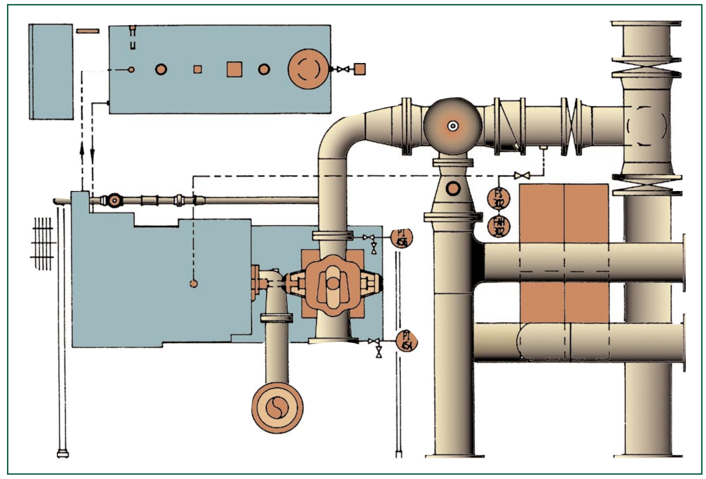

Figure 2. Plan view of horizontal fire water pump system with diesel engine drive, discharge piping main relief valve and discharge cone

Vertical pumps are available in a much wider range of metallurgies because of their applications in corrosive offshore environments. Various grades of bronze are common, as are higher alloys. Carbon steel is very rare. Material options for horizontal units include bronze casing materials, moving up to carbon steel and then austenitic steels for both case and internals. As with vertical pumps, higher alloys are also available for special situations.

From a commercial standpoint, cast iron-bronze fitted (CIBF) pumps are the basic choice. Standard aluminum bronze materials such as ASTM B148 Alloy 952 (for vertical units) generally command price premiums in the 4.5-5 multiplier range. Nickel-aluminum bronze (B148 Alloy 955) will increase this pricing by an additional 10-15%. Carbon steel (for horizontal units) will raise standard CIBF costs by 3-4 times. Stainless steel, typically 316SS, increases base costs by a factor of 5-8 depending on size. Higher alloys can increase CIBF costs by up to 8 times.

Auxiliary equipment and accessories offer many possible options for the pump. While these will be discussed in greater detail later, it is important to note that most fire water pump manufacturers only offer a limited number of materials and options for listed pumps. Pumps (like drivers and other equipment) can be listed for fire pump service only when they are manufactured in the same materials and configuration as the design tested by the certifying agency. Changes in casing materials, even when poured by the same foundry using the same patterns, can prevent a manufacturer from labeling the pump. Likewise, changing accessories, especially on engines, can result in the loss of the label.

In practice, this is usually a semantic issue and rarely becomes a significant problem, provided that the original design or unit was labeled and that the changes are clearly upgrades in materials, control and/or reliability. The importance of labeling also varies with the location and type of fire pump service, as well as responsible government agencies and insurance carriers. Most manufacturers offer labeled equipment in the most elemental fashion for application in the widest range of markets. This makes it possible for the specifying engineer and user to work together with the supplier to develop the best system for their application. Even though the end user might customize the system and add accessories that void the label, the original equipment was labeled, and this shows the intent of the user to install labeled equipment.

Drivers

While the pump is the mechanical heart of a fire water system, the driver is a critical component, frequently requiring more attention in specification and design. Diesel engines power the vast majority of fire water pumps, creating another difficulty for the specifying engineer. Most of us have limited experience with this category of equipment. They are rare in general plant design and frequently used only because the power required exceeds the available UPS (Uninterruptible Power Source). Unlike the situation with motors, the specification and selection of diesel engines cannot be foisted off on another discipline.

The basic, listed fire pump engine, offered by many manufacturers, is more than adequate in terms of reliability and service life. After all, this system will only operate once a week for thirty minutes until it is called on to run in a real emergency. Then it will operate for eight hours (the standard fuel tank sizing) or until it is destroyed in the conflagration.

A great deal of time and energy is expended on the starting system,

Photo 2. Custom fire water pump system designed for Class 1, Groups C & D and Division II. The controller features all NEMA 7 switches mounted in a stainless steel cabinet. The battery charger and battery case are purged and constructed of 316SS. The system has a primary electric start with a back-up hydraulic system.

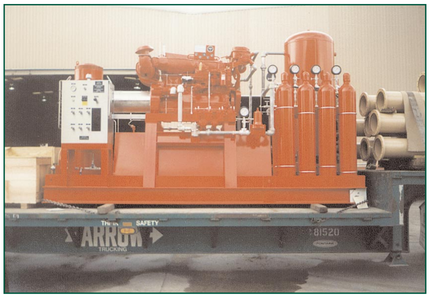

Photo 3. Vertical fire water pump for offshore installation. Compressed air start with back-up nitrogen system and expansion receiver

which often includes back-up start systems and sometimes even multiple starting systems. Basic systems include dual sets of batteries. Also commonly available are pneumatic systems—compressed air with bottled nitrogen back-up and hydraulic starting systems. Many of the larger engines, above 200 hp, offer two ports for starters, so that two types of starting systems can be used. This having been said, most experienced engine users agree that if the unit does not start within the first three to five seconds, the likelihood of starting at all is just about nil. For this reason, it is very important to pay close attention to the starting cycle of the unit during the weekly exercise sessions. Remedy any difficulties or malfunctions at once.

Although relatively uncommon, some systems also use motors, especially when the firewater pumps are also used for water lift or washdown services. Whether they are more reliable remains an open discussion. The simple fact of their predominance as drivers has made them more acceptable. Like other major components of fire pump systems, motors are available in UL/FM and CSA listed varieties from a wide range of manufacturers. While still not widely accepted, the most recent revision of NFPA 20 (January 1998) now requires fire pump motors to be UL listed.

Controllers

Controllers were the last major component of fire pump systems to receive certification by various listing agencies. Unlike other components, however, they come with a wide range of options and even provide remote system contacts for the other pump, driver and other options that may need to be incorporated into the control scheme.

A few areas in the design and specification of the controller should be reviewed carefully. The first is area classification. Unusual as it may seem to designers and specifiers who are unaccustomed to it, standard drivers and controllers are not rated for any National Electrical Code (NEC) area classification. Depending on the manufacturer, they can add this as an option or build a custom controller that meets a specific area's classification. Meeting a Division I or II classification usually involves adding a Z-purge system, which can be expensive relative to the cost of the controller (typically increasing cost by up to 50%), but this is currently the most cost-effective method to meet these requirements. Custom controllers, a very expensive alternative, will generally incorporate hermetically sealed or NEMA 7 enclosures for all potentially arcing devices. In addition, diesel engine control sensors and battery start systems are not intended for a classified area. Electric motors must also be specified for the area.

Pneumatic engine controllers with air start systems are an obvious alternative when area classification becomes an issue. Although not commercially available as UL/FM listed units, it is generally agreed that they are inherently explosion-proof because they have no electrical components. Custom built electric controllers, however, can meet the area classification requirements of any facility. Controllers incorporating PLC logic are also available as standard commercially available, but not as UL/FM listed units, or pneumatic controls as custom built units.

Custom manufactured controllers are becoming more common, especially in the HPI/CPI markets to meet NEC area classifications. It is important to note, however, that while these units may consist entirely of UL (or other) listed components, this does not convey a UL listing to the controller. Thus, the controller does not meet the UL218 requirements. This may appear to be a subtle differentiation, but local codes and regulations, as well as insurance requirements, may require sacrificing an area classification for a UL/FM listing.

Instrumentation

Fire pump systems are not process systems. Thus, much of the advanced instrumentation applied to process systems is relatively uncommon in the world of fire pumping. However, some systems include transmitters and other "smart" devices that provide additional information to the user. Carefully review the purpose and function of these devices to determine their value under the anticipated operating conditions and to insure that they provide valuable information without contributing to needless complication. Unlike a process system, where almost every eventuality can be understood, evaluated and prepared for, the full array of conditions under which a fire pump system will be used is almost impossible to imagine. Controls should be as simple and straightforward as possible, lest they fall victim to the law of unintended consequences.

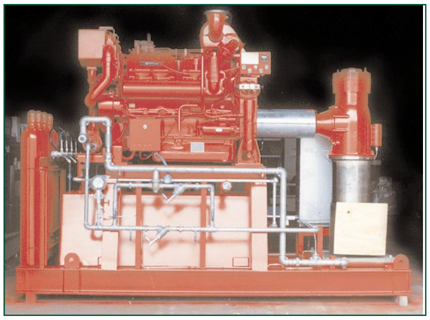

Photo 4. A 570 hp V-12 diesel engine driver for all nickel aluminum bronze fire water pump producing 3500 gpm at 180 psi.

Industry Standards

Two major organizations are the primary promulgators of standards for fire pump systems, and their roles, far from being conflicting, are complementary.

National Fire Protection Association

The National Fire Protection Association, through its NFPA 20 Standard for the Installation of Centrifugal Fire Pumps, provides the most complete set of provisions for the design and installation of various components as well as the overall system. The NFPA 20 sets standards for design and construction of all the major components in the fire pump system, including minimum pipe sizing tables, electric motor characteristics, performance testing, and periodic testing and system design. NFPA 20 further attempts to develop a safety standard or level of performance for centrifugal fire pump systems to provide a reasonable degree of protection for life and property. Under these provisions, alternate arrangements and new technologies are permitted—and in fact encouraged.

The National Fire Protection Association does not, however, certify or evaluate compliance with its various specifications and guidelines.

NFPA 20, while the source of some performance requirements, is best known for its detailed design provisions for all components commonly found in fire pump systems. Unlike many industry standards that address only the design, manufacture and testing of specific components, NFPA 20 is a veritable 'how-to' manual for the engineer or user who needs to develop guidelines and specifications for fire water systems. Taken as a complete document with referenced texts, this standard alone will assure the purchase and installation of a reliable fire pump system. Take care in developing additional specifications, whether stand-alone or ancillary, to avoid conflicts with NFPA 20. Because of the detailed nature of this specification, add-on requirements can frequently have the effect of actually diminishing the standards.

Here again it is important to keep in mind the function of the equipment in a fire pump system. Contrary to the design considerations in process units, fire pump systems should be designed to operate reliably under the most adverse conditions for as long as required, but typically this is only a matter of hours. In a process unit, systems are designed to protect themselves with various shutdowns and monitors. Fire pump systems are designed to protect the plant and personnel even if that means operating to destruction. In other words, three hours into a fire fighting event, the vibration level of the diesel engine driver is of no significance so long as the pump continues to deliver adequate flow.

NFPA 20 includes pump design guidelines for vertical shaft turbine pumps, horizontal (both end-suction and split-case) and vertical in-line pumps. It also includes standards for motors, both horizontal and vertical, right angle gears and diesel engine drives.

Additionally, the guidelines are an excellent resource for auxiliary and ancillary equipment found in most fire water pump systems. For example, the diesel engine specifications include not only requirements for the engine itself, but also the fuel supply, exhaust system and control system operation.

Underwriters Laboratories

Underwriters Laboratories (UL) reviews equipment and systems from a performance orientation. The organization provides an independent, third party evaluation of manufacturers for a variety of components, but for fire pump systems the primary specifications for our consideration are UL448 for pumps, UL1247 for diesel engines and UL218 for controllers.

In certifying equipment to these standards, UL reviews construction design, materials of construction and overall performance. These reviews assess the ability of the equipment to perform the task for which it is to be rated. Following initial certification, UL maintains an ongoing surveillance program to insure continued adherence to design and performance criteria. UL field representatives make unannounced visits to all manufacturers displaying the UL label. If team members encounter problems or questions, they may schedule more frequent visits.

UL standards are among the most stringent in the industry, and equipment certification is necessarily very specific. So what happens when a listed product is modified to meet customer specifications or site specific requirements? If the change is clearly an upgrade to the existing listed design and not a major change in the product, UL will frequently certify the modification without re-testing. Major modifications, of course, must go through the complete certification process. The manufacturer is responsible for initiating changes to the listing.

UL448 sets the standards for certification of centrifugal pumps for use in fire water systems. As previously noted, UL448 is based on the ability of the unit to perform under the conditions of service required and according to the manufacturer's specifications with regard to total differential head (TDH), capacity, and efficiency or power requirement. Materials of construction are reviewed for strength and corrosion resistance. Each unit or size to be certified is given an operational performance test and is also hydrotested to twice the manufacturer's published Maximum Allowable Working Pressure. This is a substantial increase over pump industry standards of 150% hydrotest pressures.

After certification, UL448 requires that each unit bearing the UL mark be tested successfully for hydrostatic integrity and hydraulic performance.

Diesel engines fall under the scrutiny of UL1247. Again, the emphasis is on performance. Certification requirements include extended testing on dynamometers as well as speed control. Because of the importance of driver speed in centrifugal pump applications, speed control and overspeed shutdown operation are critical areas. Units are also tested for their ability to start under a wide range of conditions, both hot and cold.

After certification, each production unit shipped must be subjected to a dynamometer test including performance checks of the speed control and overspeed shutdown systems.

Engine and motor controller specifications are covered by UL218, which is written and administered by the Industrial Controls section of Underwriters Laboratories. While this section is closely aligned with UL's primary purpose to review equipment for fire and shock hazards, the critical nature of fire pump controllers makes performance an important concern of this standard. These units are reviewed for safety, of course, but the importance of starting a fire water pump under emergency conditions warrants a different philosophy in certifying the controllers.

Controllers are inspected with special attention to their ability to signal—that is, to notify remote personnel of any abnormal conditions in the controller system—as well as to be able to accept remote instructions for starting. Diesel engine controllers, besides providing a starting signal to the engine, must also provide charging current for the batteries, perform a weekly starting and run test of the engine and driven equipment train, as well as provide visual and audible indication of various engine failures. These include failure of the engine to start, shutdown from overspeed, battery failure, battery charge failure and other abnormal conditions. Diesel engine controllers also include pressure recorders to sense pressure in the fire protection system and confirm unit performance on demand or during weekly tests.

Electric motor control requirements also focus on the ability of the unit to start the motor drive. This overriding concern is demonstrated in unit design, for fire system controllers are different from standard motor controllers. This is perhaps best demonstrated by their use of either a listed fire pump circuit breaker or a non-thermal instantaneous trip circuit breaker with a separate motor overcurrent protective device for protection against overcurrents and short circuits. Another difference between these and standard controllers is that once a fire pump controller is under emergency conditions, it is prevented from shutdown except when it is under a condition more threatening than the fire or until conditions return to normal standby.

Surprisingly, UL lists no fire pump controllers for installation in hazardous (classified) locations. To meet Division I or II requirements, controllers must be custom designed with a suitable hazardous location protection method. They must either have a purge system or be explosion proof. Custom designs, of course, will incorporate either NEMA 7 components or enclose elements in explosion-proof boxes. The X and Z-purge systems are the most common.

For international installations, the problems are compounded because no harmonized IEC (International Electrotechnical Commission) standards exist that address fire pump controllers This situation, however, is being addressed by a joint working committee of the NFPA and UL that is developing an IEC standard that will incorporate NFPA 20 and UL218 requirements. At present, the committee has developed a draft specification and submitted it to the IEC for inclusion as a new work item proposal (NWIP). Following acceptance as a NWIP, the IEC will convene a group to review and comment on the standard for development as an IEC publication. Given the importance of international markets, this move will be an appreciated step for U.S. based manufacturers.

Conclusion

Fire pump systems are designed to protect life and property. In this area, specifiers, owners and operators need to change their perspective on equipment, controls and operation. Performance and reliability must be the priority in design, purchase and maintenance. While site specifications and purchaser requirements certainly must be considered, simpler is usually better. The ability of the system to perform reliably under the most severe conditions, for the protection of life and property, must be the driving consideration. n

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