CENTRIFUGAL FIRE PUMP ACCEPTANCE TESTS

INTRODUCTION

The purpose of a fire pump acceptance test is to determine:

- Within the accuracy of the calibrated test instruments, that the pump meets the manufacturer's certified characteristic curve;
- The installation complies with NFPA 20, as interpreted by PRC.14.2.1;
- The installation complies with AXA XL Risk Consulting accepted plans and specifications;
- The following equipment will operate properly when needed:
  - Power supply (electricity, fuel or steam);
  - Controller panel;
  - Drivers (motors, engines or turbines);
  - Accessories (relief valves, right angle drives, flexible couplings, alarms and interlocks);
  - Suction supplies;
  - Pump house (construction, heat, lighting, access and ventilation);
  - Startup inspection and maintenance.

POSITION

Witness an acceptance test for all new, rebuilt or relocated pump installations. Review pertinent portions of NFPA 20 and AXA XL Risk Consulting interpretations concerning fire pumps prior to each test. The presence of the manufacturer's representatives of major components is highly recommended.

The pump manufacturer's representative or the installing contractor is responsible for conducting the acceptance test. Do not allow an acceptance test to proceed until a representative of the pump manufacturer has inspected and pre-tested the installation, made any adjustments to variable speed engine governors, and has provided a certified shop-test characteristic curve for the specific pump.

Inspect the equipment to determine compliance with the accepted plans and specifications. Discuss any deviations with the installing contractors, and make arrangements for correction. Correct discrepancies that may affect the results prior to testing. Have performance deficiencies corrected.

Compare the flow test results with the certified curve as data for each flow point is collected. If significant discrepancies are disclosed, measure that point again to confirm the accuracy of the data.

Speed Readings

Measure the pump speed with an accurate speed indicator. The accuracy of built-in engine tachometers may be questionable. For test purposes, direct-reading digital tachometers are preferred, although stroboscopic speed indicators can be used. Contact-type speed indicators have been found to give inconsistent test results and their use should be avoided.

For vertical turbine pumps, be sure to account for gear ratios in the right angle drive.

Pump Pressure Readings

Use recently calibrated gauges during the test. Check the recently calibrated gauges against the gauges installed on the pump. If the installed gauges are inaccurate, have them recalibrated or replaced. Most suction gauges are of the compound type and can easily be checked for accuracy using positive pressure. With open suction sources like ponds or rivers, measure the actual static-lift distance and compare it with the vacuum reading on the gauge when the pump is operating under shut-off conditions. The results should be the same. If not, adjust the gauge or apply the gauge correction factor to the results. Clearly identify all recorded results by the appropriate units of the measuring instrument; this is especially true with suction gauges where suction pressures may be expressed in different units.

At many plants, the fire pump suction water supply is stored in aboveground steel tanks providing a moderate positive head on the fire pump. Read the discharge and suction pressure for a horizontal pump at gauges located at the center line of the pump on the casing. For a vertical turbine pump only, the discharge pressure is normally recorded from a gauge located at the discharge head fitting. In some special cases, a vertical turbine pump may be fed by a pressurized suction pipe. If so, provide a suction gauge and record its reading. Measure the distance from the water level to the centerline of the pump. Make proper allowances for any elevation difference.

Flow Readings

Conduct flow tests from the pump header with the discharge valve to the underground piping shut. This arrangement will prevent the test from being affected by conditions outside the pump house. Follow proper impairment procedures using the AXA XL Risk Consulting's RSVP* impairment system as described in Section 1 of *OVERVIEW*.

The preferred method of determining the flow during these tests is to measure the flow through Underwriter playpipes with a pitot tube. This method produces accurate results if done with care.

Since hose lines are used only to aid in the disposal of water, the length of the lines is incidental. Long hoses restrict the discharge from the nozzle, which is reflected in more pressure at the pump. Nozzles attached directly to the test header outlets are satisfactory, if they do not jeopardize safety or cause undue property damage.

Measure the water flow from each nozzle by using a good quality pitot tube. Flow is determined by knowing the nozzle orifice size and the pitot reading for each orifice. Flow measurements can be determined by using appropriate flow tables. (See PRC.14.1.2.1.2.A.)

Start the flow test under a churn or shut-off condition with no water being discharged other than from the properly adjusted circulating relief valve. A flow adjustment of approximately 25 gpm (95 L/min) can be made to allow for flow through the circulation relief.

Increase the flow rate by adding one or more hose streams at a time until the pump is operating at 150% capacity or more. When planning the test, estimate that under normal operating pressures, a 1⅛ in. (30 mm) tip will deliver about 250 gpm (945 L/min) and a 1¾ in. (45 mm) tip about 500 gpm (1890 L/min). Obtain sufficient readings at approximately 250 gpm (945 L/min) increments to plot a good curve.

All listed centrifugal fire pumps in the U.S., except "special fire service" pumps, are designed to produce at least 150% of rated capacity at 65% rated pressure. The pump manufacturer guarantees the flow and pressure only at shut-off, 100% and 150% of rated capacity points on the certified shop-test curve. Select flows as close as possible to these conditions. It is unnecessary to throttle the discharge valve to obtain exact flows. The exact flow results would probably change when adjusted for rated speed.

Do not use a flow meter in lieu of hose streams when making an acceptance test. The accuracy of a flow meter depends on proper installation, initial adjustment and periodic recalibration. The initial adjustment and calibration is usually determined by flowing water through the pump header and confirming the results with the meter. On large pump installations or in instances where it is difficult to dispose of water from Underwriter playpipes, the use of flow meters may be accepted for subsequent tests.

Test Duration

Run the fire pump continuously for at least 1 hr to prove that bearings and packing boxes are in good condition and will not overheat. Adjust packing glands on horizontal pump shafts so that water drips freely or runs in a thin stream to cool, lubricate and provide an air seal. Some pumps have small valves in tubing lines that cool the bearings; keep these valves wide open and control waterflow to the bearings by tightening or loosing the packing. For vertical turbine pumps, ensure that the lubricating system is operating properly and within manufacturer's specifications.

Precautions

Make sure the pump is not operated when dry or unprimed, and is not allowed to churn without some circulation relief. The closely fitted wearing rings can overheat and seize, damaging the pump. In the past, shutting off the circulating relief during the test has been condoned. It is not recommended because it could result in extreme damage to the driver if it is not reset. Where variable speed drivers are installed, check the engine cooling water frequently.

In some cases, the disposal of the water used for testing becomes a problem. The following methods (in order of AXA XL Risk Consulting preference) are available for disposal of water:

- Hose streams from the pump header to a nozzle stand discharging into the yard or back to a grade level pond or stream;
- Hose streams from the pump header to a nozzle stand discharging into the suction tank;
- Large, calibrated nozzle discharging into the suction tank;
- Discharge through a flow meter into the top of the suction tank.

If fire hose is used, be sure the nozzles are adequately secured so they cannot work loose. Hose must be in good condition to maintain its integrity during the test. Replace any hose that shows signs of possible failure. Request documentation on the most recent hydrostatic test of the fire hose if there is any doubt. Aim nozzles so that discharged water will not cause damage or injury.

Because of possibility of personal injury, provide adequate ladders, platforms and guard rails when manually discharging water back into a suction tank.

During the test, run variable speed drivers (engine or turbine) under governor control. Each flow and pressure measurement must be corrected mathematically to the rated speed. Observe the action of the governor and have the pump manufacturer's representative adjust the governor, if necessary, to provide rated pump speed at the maximum pump load as shown on the manufacturer's certified curve.

Adjustments

A small amount of water will be flowing when engine-driven pumps take cooling water from the pump discharge. However, account for it by approximating the flow at 0.2 gpm/hp (0.001 L/min/kW) or by timing the flow into a container of known volume.

In order to compare the pump's performance with the manufacturer's certified curve, the net pressure must be determined and corrected to rated speed. The net pressure is the total amount of energy the pump imparts to the water and may be determined as follows:

$$P_n = P_d - P_s + \Delta P_v + \Delta P_e$$

where:

P_n = net discharge pressure

P_d = discharge pressure

P_s = suction pressure

ΔP_v = change in pressure due to the velocity head

ΔP_e = change in pressure due to the elevation head

ΔP_v may be determined graphically using the velocity head graph shown in Figure 1. This is done by determining the velocity head at the pump suction and at the pump discharge and subtracting the two readings. It can also be determined by using the following equation:

$$\Delta P_v = 0.001123\, Q_m^2 \left(\frac{1}{D_d^4} - \frac{1}{D_s^4} \right) \quad \left(\Delta P_v = 2.24975 Q_m^2 \left(\frac{1}{D_d^4} - \frac{1}{D_s^4} \right) \right)$$

where:

P_v = velocity pressure psi (bar)

Q_m = measured flow gpm (L/min)

D_s = suction pipe diameter in. (mm)

D_d = discharge pipe diameter in. (mm)

Horizontal Pump

If the pump discharge and suction flange openings (point of gauge attachment) are at the same elevation, there is no change in elevation head. This is usually the case for most horizontal pumps.

If the pump discharge and suction flange openings (point of gauge attachment) are of the same size, there is no change in velocity head. If the pump discharge flange opening is smaller than the pump suction flange opening, there is an increase in velocity energy as the water passes through the pump. This change must be credited to the pump.

Vertical Turbine Pump

The design or nameplate pressure is calculated using the vertical distance from the pump suction flange to the water level; there is no suction gauge. The discharge gauge is usually on the discharge end of the pump casting. Since this gauge is not at water level, the pressure lost due to elevation of the gauge must be added to the gauge reading to arrive at the true net pressure. The friction loss between water level and discharge gauge is generally negligible. ΔP_e for the vertical turbine pump can be calculated from:

$$\Delta P_e = Z \times 0.433 \quad (\Delta P_e = Z \times 0.00981)$$

where:

ΔP_e = change due to the elevation head psi (bar)

Z = elevation distance from discharge gauge to water level ft (m)

In general, ΔP_v is due exclusively to velocity induced at the pump discharge outlet, therefore, the second term of the equation containing D_s is zero.

When a vertical turbine pump takes suction from a pressurized water main, calculate the net pressure as for a horizontal pump, and make the necessary adjustments for the elevation differences. This situation is not commonly encountered.

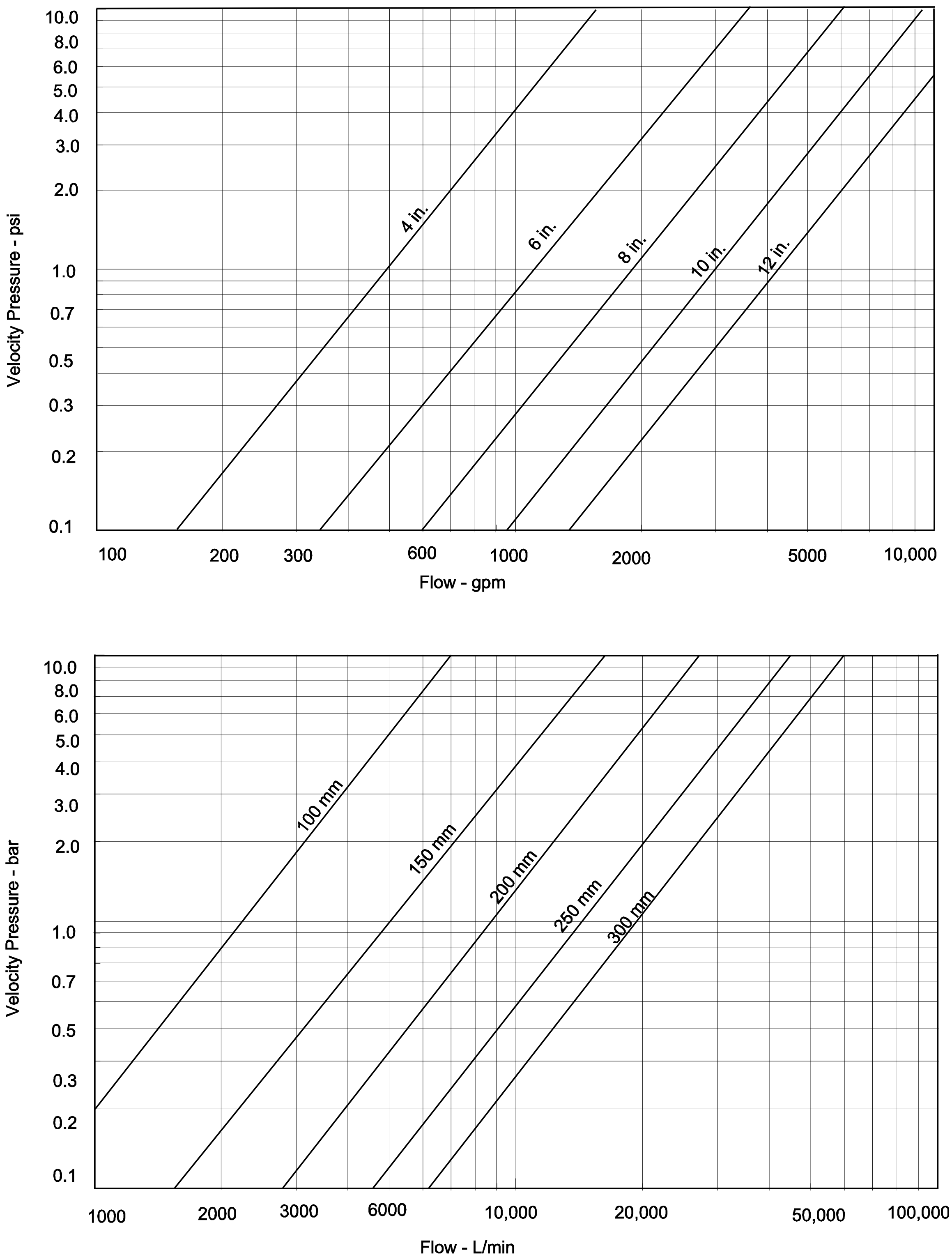

Figure 1. Velocity Pressure vs Flow.

After determining the net pressure, correct the flow and pressure readings mathematically to the nameplate speed conditions of the pump. The flow is directly proportional to the speed, and pressure is proportional to the speed squared.

$$Q_c = Q_m \times \frac{N_r}{N_m}$$

where:

Qc = corrected flow

Q_m = measured flow

N_r = rated speed

N_m = measured speed

$$P_c = P_n \times \left(\frac{N_r}{N_m}\right)^2$$

where:

P_c = corrected net pressure

P_n = net pressure

Electric Driven Pumps

The electric power supply must be dependable, especially under the adverse conditions that may reasonably be anticipated in a fire. Install wiring in accordance with NFPA 20 and PRC.14.2.1 from the source of the electric power in a manner to reduce the possibility of interruption from fire, lightning or other destructive forces. Check the electrical system details against the AXA XL Risk Consulting reviewed drawings of the fire pump installation. Maintain a one-line diagram of the pump's power supplies at the fire pump controller.

Motors should run smoothly without excessive vibration. The voltage should not exceed 110% rated voltage of the motor and should not drop more than 5% below the rated voltage of the motor when the pump is being driven at rated conditions. NFPA 20 requires the provision for amperage and voltage readings to be taken during testing.

Start and stop the motor 10 times in succession (5 manual and 5 automatic). Run the pump for at least 5 min each time to allow the motor windings to cool. The actual load on the pump is incidental. The motor and control equipment should not overheat during the test. If the circuit breaker trips while trying to start, investigate the reason for failure immediately and correct the condition, otherwise, the pump installation should not be accepted.

Stop and then restart the pump once, when operating at peak electrical load or about 140 – 150% of flow capacity. The motor in-rush current will be the same as before but will last longer, since the pump will come up to speed more slowly. The motor should not overheat or open circuit breakers during this test.

Engine Driven Pumps

Internal combustion engines should run smoothly without excessive vibration. The engine must have sufficient power to drive the fire pump after appropriate corrections are made for elevation, temperature and gear reduction, as specified in NFPA 20. After the pump has been flow-tested satisfactorily, adjust the waterflow for the peak power requirement, which is about 140% – 150% capacity and run the pump for 15 min – 20 min to demonstrate that the engine will not overheat under this condition. Cooling water should discharge to a safe location with no possibility of flooding the pump room even during a power failure. Check the cooling water flow rate for any deterioration during the test.

After the engine has been thoroughly warmed for about 30 min, start and stop it 10 times in succession (5 manual and 5 automatic). In addition, start the pump once using the manufacturer's emergency starting procedures, which should be on the engine per NFPA 20 requirements.

Adjust and set the engine-speed governor to maintain rated pump speed at rated pump load. This differs from NFPA 20, which suggests that the governor be set at the maximum pump load or approximately 140 – 150% of rated pump capacity. The governor must control the speed with no more than a 10% variation between maximum pump load and shut-off conditions (churn).

Set the overspeed trip at approximately 120% of rated pump speed. This setting may be checked by using the manufacturers recommended procedure for testing the overspeed device. This information is typically found in the Operation and Maintenance Manual for the engine. See PRC.14.2.1.3. It is important that the setting not be so low as to shut the engine down on the temporary overspeed that may occur when the engine starts. Remember that this device must be reset manually after each overspeed shutdown. Some industrial engines are wired to shut down automatically when they overheat or when the lubricating oil pressure is low. This is not acceptable for fire pump service; instead, warning alarms indicating these conditions must be provided.

Refill the diesel fuel supplies at the completion of testing.

Steam Turbines

Steam turbines probably will not be used in new installations. Turbines of solid-wheel construction can usually be cold started. However, the bladed turbines cannot usually be started suddenly unless steam is constantly bled into the casing to keep it hot. In either case, it is advisable to obtain the turbine manufacturer's approval before attempting starts from a cold condition. The turbine manufacturer's representative should be present at the acceptance test.

Record the steam-pressure readings at both the turbine inlet, and at the stream chest. A steam strainer is usually built into the turbine valve. Steam friction loss should not exceed 10% between these two points. A somewhat greater friction loss is not objectionable if the pump can still be driven at rated speed while carrying maximum pump load.

A steam turbine driven pump requires a reliable steam supply **at all times**. Therefore, boilers must continue to operate regardless of conditions within the plant. If electric auxiliaries are used, arrange the electric supply to the boiler room the same as that for an electric fire pump. In some cases, automatic emergency generators are provided in the boiler room to take over in case of outside electric power failure. Also, protect the boilers and steam piping against possible fire damage.

Adjust and secure the turbine speed governor to maintain rated pump speed at maximum pump load, or approximately 140% – 150% of rated pump capacity. It must control the speed with no more than an 8% variation between maximum pump load and shut-off conditions (churn):

- With normal steam pressure and with the hand valve closed;

OR

- With steam pressure down to 80 psi (5.5 bar), or 70% of full pressure where this is in excess of 120 psi (8.3 bar) and with the hand valve open.

The turbine overspeed trip device should shut off steam to the turbine at approximately 120% of rated turbine speed. Check this setting by having the turbine manufacturer's representative carefully overspeed the turbine, when required. It is most important that the setting not be so low as to shut the turbine down on a temporary, moderate overspeed.

TESTING OF ACCESSORIES

Confirm the installation and setting of the main relief valve conforms to NFPA 20. To prevent overheating, adjust the circulating relief valve to open approximately 5 psi (0.34 bar) below the minimum shut-off (churn) pressure. When the cooling water for an internal combustion engine driver is taken from the discharge side of the pump, no circulating relief valve is needed. Size the circulating relief valve according to NFPA 20.

A horizontal pump and driver require a flexible coupling in the shaft between them to compensate for any slight misalignment and to provide shaft-end clearance to compensate for heat-induced shaft expansion. This is usually a simple loose-pin coupling, but in some cases, extremely flexible industrial couplings are used. Ensure that the coupling is of substantial construction and will reliably perform its intended function. Do not use a flexible coupling to compensate for gross misalignment of pump and driver shaft.

The pump installer is responsible for aligning the pump and driver according to the pump manufacturer's recommendations. Otherwise, the shaft and bearings may be damaged. If there is any doubt whether this was done correctly, remove the pins and check the coupling halves for alignment. A rough check can be made by moving the sleeves on the pins by hand. These should not be tight on the pins. A dusting of sleeve material on the base plate after a period of running indicates that misalignment is making the material grind out. NFPA 20 gives additional information concerning alignment.

Check the controller features according to PRC.14.2.1.3.

Test all panel alarms and alarms transmitted to a remote location where personnel are available at all times including:

- Pump running;
- Loss of operating electric power;
- Low fuel supply;
- Low steam pressure;
- Controller main switch in other than “automatic” position;
- Low lubricating oil pressure;*
- High engine temperature;*
- Failure of engine to start (overcrank);*
- Engine overspeed;*
- Overspeed shutdown device not reset;*
- Battery failure;*
- Loss of ac current to battery chargers and controllers monitored as the loss of charger dc output on the load side of the over current protective device;*
- Discharging of relief valve (flow switch);
- Flow in flow meter bypass;
- Low temperature in pump room;
- Low temperature in suction supply;
- Phase reversal (electric only);
- Suction supply water level below normal;
- Suction supply water level near depletion.

* on engine controllers.

If these alarms have a common audible signal, each condition should also be visually indicated at the pump house.

Fire Pump Suction Supply

Flexible couplings are rubber gasketed fittings used in suction piping. These couplings can slip if they are not restrained. They must be properly secured, especially if the pipeline changes direction.

Where possible, operate all pumps taking suction from a single suction source simultaneously at maximum flow to ensure that the fill pipes and suction pipes are unobstructed and properly sized to maintain an adequate water flow.