# Chapter 8
# Engines and Gears

## 8-1. General

Internal combustion engines used for pump drivers are of the diesel or gas-fueled type. Engine drives offer the advantage of variable speed, which may be a benefit when compared with other types of pump drives that operate at essentially constant speed. Selection criteria for internal combustion engines and electric motors are provided in Chapter 10.

## 8-2. Engines

Engines of the two- or four-cycle type are used for pump drives. Natural gas engines are preferred where a dependable natural gas supply is available; otherwise, diesel-operated engines should be used. Skid-mounted engines should be used when possible with all the auxiliaries except fuel tank, mounted thereon. Engines for flood control pumping service should be rated in accordance with the Diesel Engine Manufacturer Association. All rating should be based on continuous duty operation. The engine should be rated 10 percent in excess of the maximum operating requirements that would include the maximum pump horsepower requirement and losses through the drive system. The engine should also be capable of operation at 110-percent full-load rating at rated speed with safe operating temperatures for periods of 2 hours in 24 hours. Engine speed should be as indicated in the table below.

| Engine Horsepower Rating | Maximum Speed - RPM |
|---|---|
| 1,050 kilowatt (kW) (1,400 horsepower (HP)) and over | 900 |
| 450 kW (600 HP) to 1,050 kW (1,400 HP) | 1,200 |
| Less than 450 kW (600 HP) | 1,800 |

*a. Cooling systems.* Two basic types of cooling systems are radiator and heat exchanger. Selection criteria include engine size, space availability, raw or sump water supply, initial cost, operation and maintenance cost, and environmental concerns. A radiator system may have the radiator mounted on the engine base or remotely mounted. The radiator will always be located where an adequate supply of cooling air is available. For larger engines, the physical size of the radiator may make it an impractical choice. The selection of the fan and radiator location would include the noise level, heat produced, and size requirements. The heat exchanger cooling system will be the closed type. It can be an elaborate system with raw or canal water supply pumps, a shell and tube heat exchanger, and a traveling water screen (screen the raw water to the supply pumps) to cool the engine's jacket water. It could also be a simplified submerged pipe type. This type circulates engine jacket water through pipes submerged in the pump sump. Selection will be based on engine cooling requirements and the recommendation of the engine manufacturer. Some problems associated with heat exchanger cooling are freezing climates, foul cooling water, rejecting heated raw water to the canal, and engine testing restrictions when the sump or entering ditch is dry.

*b. Control equipment.* All engines will be designed for manual starting. Manual and automatic control devices should be of the types regularly furnished by the engine manufacturer for similar service. Automatic engine shutdown is required for engine overspeed. Visual and audible alarms and automatic engine shutdown (as a minimum) should occur for high jacket water temperature, high lubricating oil temperature, low lubricating oil pressure, gear reducer high lubricating oil temperature, or gear reducer low lubricating oil pressure. The type of speed control devices will depend upon the desired scheme of operation, but a governor to maintain speed and a suitable speed indicator should be provided in all cases. Consideration can be given to an engine shutoff method for low sump water elevation. Engine controls are generally located adjacent to the engine. Redundant remote read-out of critical engine, pump, and gear parameters may be located in an operating office for large pumping stations. The control system should be designed so that the engines can be started and operated when the electric power to the station is interrupted and automatic engine shutdown should not occur due to minor fluctuations in commercial power. A control system for engines less than 300 kW (400 HP) rating can be equipped with a rechargeable battery system for its operation. Larger sized engines will require a separate engine-generator to provide electrical power for the control system. The controls should permit operation of the engine's jacket water pump to allow cool down of the engine if required by the engine manufacturer. If the jacket water pump is engine driven, then an auxiliary motor driven jacket water pump should be considered for cool down, if required. A means needs to be furnished to manually shutoff the intake air supply to the engine to provide for critical shutdown. Crankcase explosion relief valves should be provided for diesel engines.

*c. Engine equipment and auxiliaries.*

(1) Clutches. Engines less than 450 kW (600 HP) may be equipped with a manual clutch mechanism, which allows the engine to be started and operated without running the pump. This permits testing of the engine without regard to water levels that may not allow pump operation.

(2) Flexible drive shafts. Flexible drive shafts eliminate the need for critical alignment of the engine to the gear reducer. The drive shaft consists of a center section with a flexible joint on each end. One of the flexible joints incorporates a splined slip joint that permits longitudinal movement to occur. The drive shaft manufacturer's published rating at the maximum engine speed should be at least 1-½ times the maximum torque of the pump that usually occurs at its maximum head condition. A drive shaft minimum length of 900 millimeters (36 inches) is desirable to allow for intentional or accidental misalignment. A vertical difference of approximately 15 millimeters (0.5 inch) (for 900 millimeters (36-inch) shaft length) should be provided between the engine output shaft and the gear input shaft to provide continuous exercise for the flexible joints. There are other types of engine-to-gear connections, such as direct through flexible couplings. This can be investigated if site conditions prevent the use of the drive shaft described above.

(3) Starting system. The engine starting system should be pneumatic except for small engines. The air system should contain a reservoir of sufficient size to permit two starts of each unit without recharge by the air compressor. The time for the air compressor to recharge the reservoir should not exceed 2 hours. Two air compressors should be provided for reliability. Unless a standby generating unit is provided for the station, one of the air compressors should be engine driven so that the air pressure can be built up during electric power outages.

(4) Prelubrication. Engine manufacturer's should be consulted as to any requirements for a prelubrication pump. Factors that are normally used to determine the need for prelubrication requirements are engine size and the expected period of time between operations.

## 8-3. Fuel Supply System

*a. Fuel oil.* The type of fuel oil used should be recommended by the engine manufacturer for the type of environment the engine will operate in. An adequate supply of fuel oil is required to ensure station operation without the need for emergency replenishment. The volume of the storage tank system should provide for a minimum of 2 days of continuous operation of all units operating at maximum horsepower. The volume provided may be increased for those stations that are remote or of such a size that quantities required would not permit ready replenishment. The location and type of fuel storage should be determined after review of the applicable local, state, and national Environmental Protection Agency (EPA) regulations.

*b. Natural gas.* Stations equipped with engines operating on natural gas supplied from a utility system need to be provided with a stored gas backup system if reliability of the source could cause the station to be out of operation for more than 24 hours. The volume of the gas storage system should provide for a minimum of 2 days of continuous operation of all units operating at maximum load. The storage usually consists of one or more pressure tanks above ground. All gas tanks should be installed with foundations attached to the tanks, which preclude floating of the tank in case of flooding. A station with natural gas-operated engines must be provided with devices capable of measuring air content for explosive conditions and indicating this condition with alarms both inside and outside the station. The ventilating system must be suitable for operating in an explosive atmosphere and capable of being turned on from outside the station. The sump should be ventilated in a similar manner. All installations need to be designed and installed in accordance with the National Fire Protection Association (NFPA).

## 8-4. Gear Drives

Most applications for pumping stations will use a vertical pump with a right-angle gear to transmit power from the horizontal engine shaft to the vertical pump shaft. Gear drives may also be used with horizontal electric motors driving vertical pumps. This permits the use of less expensive high-speed horizontal drive electric motors. Horizontal pump installations may use chain drive or parallel shaft gear reducers. The gear units should have a service factor of 1.25 when driven by an electric motor and 1.5 when driven by an engine. The service factor should be based on the maximum horsepower requirement of the pump. Right-angle drives should be of the hollow shaft type to permit vertical adjustment of the pump propeller at the top of the gear. All right-angle gear drives should be designed to carry the full vertical thrust from the pump. The gear unit should be equipped with an oil pump directly driven from one of the reducer shafts and be capable of delivering sufficient oil to all parts when operating at less than rated speed. The transmission of power through the gear produces significant heating of the lubricating oil, and some means must be provided to reject this heat. The heat removal can be accomplished by placing an oil cooler in the engine's cooling water system or by using a separate oil radiator placed in the air stream from the engine-driven fan or located with its own fan. Engines that use heat exchangers should also use a similar system for cooling the reduction gearing. All gears should be equipped with a thrust-bearing temperature thermometer, an oil pressure gage and temperature thermometer, and oil level indicators. Automatic shutdown of the pumping unit and visual and audible alarms should be provided for high thrust-bearing temperature, high oil temperature, or low oil pressure. When cold weather operation is expected, oil heaters should be used in the gear to reduce oil thickening between operational periods. A backstop device should be attached to the low or intermediate shaft of the gear reducer to prevent reverse rotation of the pump and engine.