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Electrical Design of Pumping Stations

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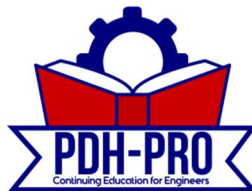
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Module 1: Pump Drive Selection

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the trade-offs between electric motors and internal combustion engines based on reliability and site-specific constraints.
- **Conduct** a life-cycle cost analysis that accounts for installation, operation, maintenance, and rehabilitation expenses.
- **Calculate** estimated maintenance costs using standard percentage benchmarks relative to station capacity.

Executive Summary: The selection of a pump drive is governed primarily by **reliability** under worst-case flood conditions. While cost is a significant factor, it is secondary to ensuring the station operates when needed. If reliability requirements do not dictate a specific drive type, you must perform a comprehensive annual cost comparison—including installed, operating, and replacement costs—to determine the most economical solution.

Design Fundamentals: Drive Selection

When designing flood-protection pumping stations, you typically choose between two drive types: **electric motors** or **internal combustion engines**. Your selection process must rigorously investigate two factors: reliability and cost.

Reliability Considerations

Reliability is the primary criterion. You must assess performance under the worst conditions expected during the station's operational life.

- **Power Source Availability:** Review power company records to determine the frequency of outages and the utility's repair capabilities.
- **Grid Redundancy:** For large stations, assess the feasibility of sourcing power from two different grids to prevent total failure during a single-source outage.
- **Equipment Complexity:** While motors and engines are generally reliable, their accessories often fail. Consider the skill level of operating personnel; equipment requiring specialized external service will significantly increase downtime.



Drive Configurations

- **Internal Combustion Engines:** **Must** use gear drives as part of the system.
- **Electric Motors:** Can use direct drives or gear drives.

💡 Design Tip: Using gear drives with electric motors allows you to select higher-speed motors, which are often less expensive, and permits greater variation in pump speed than direct drives.

Cost Analysis Framework

If reliability analysis allows for either drive type, you must proceed with an annual cost comparison.

Installed Costs

Calculate these on an annualized basis over the project's life.

- **Equipment:** Construction costs of all mechanical and electrical units.
- **Power Supply:** Substation installation and transmission line construction costs.

Operating Costs

Operating costs combine energy consumption and manpower.

- **Pumping Duration:** Do not guess. Obtain pumping time estimates from hydrology period-of-record routing studies.
- **Energy Pricing:**
 - **Standard Stations:** Use current utility price schedules or market fuel prices.
 - **Large Stations:** Conduct a study of future energy costs over the project life.


⚠️ Constraint: Ensure your calculation includes both **energy used (kWh)** and **demand (capacity) charges**. Demand charges can constitute a major portion of the total cost.

Maintenance Costs

Maintenance includes manpower and materials for preventative and major repairs. Unless the station utilizes specialized equipment, estimate these costs as a percentage of the installed equipment cost.

Table 10-1: Maintenance Cost Estimates

Station Size	Maintenance Cost (% of Installed Cost)
0.025 m ³ /s (1.0 cfs)	0.5%
15 m ³ /s (530 cfs)	5.0%

 **Calculation Note:** For station sizes falling between these values, determine the percentage proportionally (interpolation). Unusual or specialized equipment requires a separate additional cost estimate.

Rehabilitation and Replacement Costs

For a standard 50-year station life, plan for major equipment (pumps, drivers, switchgear) to be rehabilitated or replaced at least once, typically between years 20 and 40.

- **Rehabilitation Estimation:** Estimate rehabilitation costs at **35% to 45%** of the replacement cost, depending on equipment condition.
- **Total Replacement Cost:** This must include:
 - Equipment costs.
 - Engineering and structural modification costs (since replacement in-kind is rare).
 - Removal costs and rental equipment required during the swap.

Checkpoint Quiz

1. When evaluating electric power reliability for a pumping station, which source of data is most critical?

- a) The manufacturer's Mean Time Between Failures (MTBF) for the motor.
- b) Power company records of outages and repair capabilities in the area.
- c) The station's backup generator capacity.
- d) National averages for grid stability.

Answer: (b). The text explicitly states that the reliability of the electrical power source should be determined from power company records of outages in that area.

2. You are designing a station with a capacity of 10 m³/s. How should you estimate the annual maintenance costs?

- a) Use a flat rate of 5.0% of the installed cost.
- b) Use a flat rate of 0.5% of the installed cost.
- c) Calculate a proportional percentage between 0.5% and 5.0% based on the size.
- d) Maintenance costs are negligible for electric motors.

Answer: (c). Percentages for intermediate station sizes (between 0.025 m³/s and 15 m³/s) are determined proportionally.

3. In a life-cycle cost analysis, what components must be included in the "Operating Costs" calculation for an electric drive?

- a) Only the kilowatt-hours (energy) consumed.
- b) Energy consumed (kWh) plus demand (capacity) charges and manpower expenses.
- c) Installation costs of the substation divided by 50 years.
- d) The cost of renting backup equipment.

Answer: (b). Operating costs include energy and manpower. It is critical to include both the energy used (kWh) and demand charges, as demand charges can be a major part of the cost.

Module 2: Pump and Station Hydraulic Tests

Learning Objectives

By the end of this section, you will be able to:

- **Distinguish** between factory pump tests and station hydraulic model tests, identifying when each is required.
- **Evaluate** pump performance curves to ensure they meet the specific Corps of Engineers criteria for cavitation and unstable ranges ("dog legs").
- **Identify** the critical parameters for sump model design, including the maximum allowable swirl angle and velocity deviation.

Executive Summary: Testing is the primary mechanism for verifying that pumping equipment meets design specifications before construction is complete. While factory tests focus on the pump's individual mechanical performance (head, capacity, efficiency), station model tests are crucial for assessing how the pump interacts with the civil structure. For large pumps ($>14 \text{ m}^3/\text{s}$) or complex layouts, physical hydraulic models are mandatory to prevent adverse flow conditions like vortexing.

Testing Fundamentals

Before a station is built, two distinct types of testing verify the design:

1. **Pump Tests:** Conducted on the equipment itself (full-size or model) to verify performance ratings.
2. **Station Tests:** Physical hydraulic models of the substructure to assess flow conditions.

Pump Tests

Pump performance is verified at the manufacturer's facility, as field testing is often cost-prohibitive or technically impossible.

Types of Tests

- **Full-Size Tests:** Typically limited to pumps with capacities less than $2 \text{ m}^3/\text{s}$ (**75 cfs**) due to facility size limitations.
- **Model Tests:** Used for larger pumps. The model must be geometrically similar and have the same specific speed as the prototype.

Performance Verification

- **Scope:** All flood-control pumps must be tested. For identical pumps, only one unit requires testing.



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