RECLAMATION

Managing Water in the West

Water Operation and Maintenance Bulletin

No. 232

In This Issue . . .

Development of Standing Operating Procedures for Canals

Basic Pump, Motor, Mechanical, and Electrical Maintenance

U.S. Department of the Interior
Bureau of Reclamation

March 2013

This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Bureau of Reclamation personnel and water user groups in operating and maintaining project facilities.

The *Water Operation and Maintenance Bulletin* and subject index may be accessed on the Internet at: **www.usbr.gov/assetmanagement**.

Although every attempt is made to ensure high quality and accurate information, the Bureau of Reclamation cannot warrant nor be responsible for the use or misuse of information that is furnished in this bulletin.

For further information about the
Water Operation and Maintenance Bulletin, contact:

Kenneth Schwairy, Managing Editor
Bureau of Reclamation
Technical Service Center (86-68360)
PO Box 25007, Denver, CO 80225-0007
Telephone: (303) 445-3015
FAX: (303) 445-6483
Email: KSchwairy@usbr.gov

***Cover photograph*:** San Luis Canal – Central Valley California.

Water Operation and Maintenance Bulletin

No. 232 – March 2013

CONTENTS

Available on the Internet at:
www.usbr.gov/assetmanagement

DEVELOPMENT OF STANDING OPERATING PROCEDURES FOR CANALS

by: Charlie Swanson, P.E., Bureau of Reclamation, Technical Service Center, Instrumentation and Inspections Group, 86-68360

Most of the sections discussed in this article were previously presented in Water Operation and Maintenance Bulletin No. 231, dated December 2012.

The Bureau of Reclamation (Reclamation) does not require Standing Operating Procedures (SOP) for canals, but some operating offices and operating entities have found benefit in developing such documents. Currently, there is no written guide for developing a canal SOP. However, Reclamation's Standing Operating Procedures Guide for Dams, Reservoirs, and Power Facilities (SOP Guide) can be used as an initial starting point. Many of the section headings are similar and can be applied toward SOP content for a canal.

This article provides general information about the subject content for canals only, covering Chapters I through V and related appendices. Due to the wide variety of canal systems, both in design and complexity, it is impractical to discuss all canal systems within this article. (It should be noted that this article **excludes** the discussion or information about the content of an applicable Emergency Management Plan [EMP], Emergency Action Plan [EAP], and/or a Communications Directory, including related references and documentation.)

The following chapters were developed, in recent past, for an SOP for one of Reclamation's canals. The decision for including these particular chapters was made by the author and field personnel. For this canal SOP, there were five chapters and related appendices:

Chapter I	General Information
Chapter II	Structural
Chapter III	Mechanical and Electrical
Chapter IV	Structural Behavior Instrumentation
Chapter V	Operations
Appendix A	Structures List
Appendix B	Forms and Reports
Appendix C	Drawings

The decision was made to separate the structural features from the mechanical and electrical features because not all structures have mechanical and electrical equipment.

SOPs reflect that each canal and their operation and maintenance (O&M) procedures are detailed. The SOP is a unique document for each canal, as no two canals are the same. In addition to operating personnel, the SOP will likely be used by many other offices, including regional and area offices, operating agencies, and the Technical Service Center (Denver). The SOP includes operating procedures for the equipment (gates, valves, generators, etc.) and maintenance requirements for the canal, mechanical equipment, and electrical equipment.

For Reclamation canals, detailed information may be available in the Designers' Operating Criteria (DOC). *Note*: DOCs may not have been written for all Reclamation canals.

Key operating personnel/supervisors and related Reclamation offices are responsible for reviewing the SOP to ensure all the information is current. Suggested changes to the SOP should be provided to the issuing (area/regional) office for revisions. Recommendations are sometimes made during onsite field examinations to revise the SOP, and these recommended revisions should be made in a timely manner.

Chapter I – General Information

The section headings (A. through N.) in this chapter are similar to those used for a dam SOP and are applicable for a canal SOP. The section headings provided below are provided for your consideration when developing a canal SOP. A brief description about each of these sections is provided below.

A. Purpose of the Project

Briefly identify the canal system, state the authorized purpose of the project, and note the benefits.

B. Location and Access to Key Control Structures

Include a brief description of each key control structure along the canal as well as the canal milepost location and distance to the nearest town. Key control structures include the headworks, check structures, siphons, wasteways, etc. Each key control structure should start with a numbered heading.

C. Assignment of Responsibility

Clearly identify all areas of responsibility in the chain of command with respect to canal O&M. A summary of typical maintenance/ inspection duties should be included with frequency headings shown (e.g., Daily, Weekly, Monthly, Quarterly, Semiannually, Annually, Every 3 Years, Every 6 Years, As Necessary, etc.).

D. Attendance, Communications, and Warning Systems

1. Attendance

   Include a statement about the attendance at the canal, indicating full time, part time, or unattended. For part-time and unattended canals, provide the times and/or frequency of the site visits. Also include the frequency of visits to the canal. If there is a residence associated with the canal, the operating personnel's residence location and distance to key control structures should be included.

2. Communications

   Identify and describe the primary and backup means of communication along the canal and provide the location(s) of the communication equipment.

3. Warning Systems

   Briefly describe the warnings system(s) equipment installed for the canal. If no warning system equipment is installed, then state that "No warning system equipment is currently installed for the canal."

E. Cooperation with Other Agencies

Identify and briefly describe the relationship among the operating organization and other agencies (e.g., National Weather Service, U.S. Geological Survey, Natural Resources Conservation Service, State and local governments, municipalities, water districts, etc.).

F. Data Reporting

Identify the usual data reports that are required as part of the O&M of the canal. Examples of data reports include, but are not limited to, daily reports (water surface elevations and deliveries), weekly reports, monthly reports, landslide reporting (if applicable), facility examinations, examination of inaccessible features, etc.

G. Operating Log

Include a statement of purpose for the Operating Log that is maintained for the canal and state the storage location of the Operating Log. A typical list of logbook entries should be provided in this section.

H. Public Safety and Health

Safety of the public is of primary concern; safety instructions and protection shall comply with all applicable regulations. Canals are not intended for recreational use, and appropriate warning signs should be posted that warn the public of hazards. Provide a list of the nearest medical facilities and/or law enforcement agencies, potential hazardous areas not discussed in Section I (Restricted Areas), safety equipment along the canal, and other pertinent information concerning public health or safety.

I. Restricted Areas

Identify all areas along the canal from which unauthorized persons are restricted and explain the purpose of the restrictions, fences, barriers, and/or signs.

J. Emergency Management and Facility Security Plans

State in general terms the need for security regulations and plans for protecting the canal. Reference to a separate EMP or EAP, as applicable, should be made to address specific procedures in case of an emergency event. Otherwise, specific emergency management and notification procedures pertinent to the canal should be outlined and included in this section.

K. Distribution of Standing Operating Procedures

The SOP must have a limited distribution, as these are controlled copies and must be kept in a secure location. At least one copy must be located at or near the canal headworks/control structure(s) or a nearby office. All controlled copies of the SOP should be distributed to other designated offices as deemed necessary by the issuing office. To ensure that all copies of the SOP are kept current, a record of their location must be maintained. The record should be kept in the SOP by including the Letter of Transmittal, showing the complete distribution list, and identifying the control number assigned to each office. This will ensure that revised pages are furnished to all official copyholders whenever revised instructions are distributed.

L. Revisions to Standing Operating Procedures

Identify the office that is authorized and responsible for issuing all revisions to the SOP. A record of all revisions must be kept with the SOP. Clear and concise instructions for making the revisions should be included in the transmittal memo to avoid any confusion.

M. Supporting Documents

Examples of specific documents include, but are not limited to, contracts, Memoranda of Understanding, Memoranda of Agreement, Designers' Operating Criteria, Design Summaries, Examination Reports, Final Construction Reports, Oil Spill Prevention and Countermeasure Plans, etc.

N. Reference Material

List all manuals, publications, bulletins, and other reports that may assist personnel in performing specific O&M duties for the canal.

Chapter II – Structural

The section headings for Chapter II can vary depending on the structural features along the canal. An example is provided to illustrate the possible section headings for canal structures. The section headings should include only the specific structures.

A. General Description of Canal System

In addition to the written description of the canal, the table shown below can be used to summarize the pertinent engineering data for the canal and appurtenant features. The table shown is an example of engineering data for the canal and key control structures along the canal as necessary.

Table II-1. Engineering Data for __________ Canal

Water Supply – Diversion Point	
Canal design capacity	_______ ft^3/s (_________ million gallons per day)
Normal delivery	_______ ft^3/s
Length	(length usually provided in miles)
Bottom width	_______ feet
Side slopes	___H:1V
Water depth	________ feet
Canal invert slope	______ (decimal format)
Headworks:	Provide location, canal milepost, latitude and longitude, nearest town, cross streets, etc., as necessary
Check structure(s):	Provide location, canal milepost, latitude and longitude, nearest town, cross streets, etc., as necessary
Siphon(s):	Provide location, canal milepost, latitude and longitude, nearest town, cross streets, etc., as necessary
Wasteway(s):	Provide location, canal milepost, latitude and longitude, nearest town, cross streets, etc., as necessary
Terminus:	Provide location, canal milepost, latitude and longitude, nearest town, cross streets, etc., as necessary

This list should include key control structures (same as those shown in Chapter I, Section B) and location from upstream to downstream.

B. Canal Maintenance and Inspection

1. Inspection and Maintenance
2. Inspections Following Earthquakes

C. Check Structures, Turnouts, Wasteways, Siphons, and Tunnels[1]

1. Check Structure
2. Turnouts
3. Wasteways
4. Siphons
5. Tunnels
6. Structure Locations

[1] This is an example of structures that may be constructed along the canal reach that should be included in the SOP (delete or revise as necessary).

Table II-2. Structure Locations

Location/Canal Milepost	Structure	Purpose/Crossing	Pipe Size
1.2 to 1.7	Tunnel	Crossing under highway	18 feet wide by 19 feet high

The table above is provided only as an example.

7. Inspection and Maintenance

D. Canal Bridges

1. Location

Table II-3. Bridge Locations

Location/Canal Milepost	Owner	Bridge Type	Load Capacity	Road Location/Structure Identification No.
0.125	Reclamation	Concrete		
10.55	State	Steel		

The table above is provided only as an example.

2. Maintenance

E. Operating Roads

Briefly describe the operating (O&M) roads associated with the canal and include a description of the roadway surfacing, gates, drains, maintenance, etc. The SOP should include on which side of the canal the road is located.

Chapter III – Mechanical and Electrical Equipment

A. O&M Instructions for Headworks

1. General Description
2. Slide Gates, Motor-Operated Lifts, and Controls
    a. Description
    b. Operation[2]
    c. Maintenance
    d. Gate Exercising and Testing

[2] If there are gates of more than one size, additional subsections may be needed to differentiate the operating procedures.

3. Flow Measurement Equipment (if applicable)
    a. Flowmeter
    b. Level Monitor

4. Automated Control System (i.e., SCADA)
    a. Description
    b. Operation
    c. Maintenance

B. O&M Instructions for Check Structures

1. General Description/Locations
2. Radial Gates, Hoists, and Controls
    a. Description
    b. Operation
    c. Maintenance
    d. Gate Exercising and Testing

3. Level Monitor
    a. Description and Operation
    b. Maintenance

C. O&M Instructions for Turnout Structures

1. Description/Locations

Table II-4. Turnout Structure Locations

Milepost	Gate Size (inches)	Gate Quantity	Status	Customer
3.56	30 by 30	1	Active	
8.24	48 by 48	2	Inactive	

The table above is provided only as an example.

2. Customers (Water Users)
3. Maintenance of Customer-Owned Facilities and Equipment
4. Slide Gates, Motor-Operated Lifts, and Controls
5. Flowmeters

D. O&M Instructions for Wasteway Structures

1. Description/Locations
2. Operation
3. Maintenance
4. Gate Exercising and Testing (if applicable)

E. O&M Instructions for Auxiliary Equipment[3]

1. Generators
2. Air Compressors
3. Trashracks
4. Stoplogs
5. Flap Gates
6. Roadway Gates
7. Ladders
8. Staff Gages
9. Buoy Lines
10. Life Rings

F. Electrical Systems and Equipment

1. Description
2. Operation
3. Maintenance

G. Preventive Maintenance Schedules (or similar)

1. Preventive Maintenance Summary Report
2. Job Plan

H. Safety Procedures

1. Hazardous Energy and Control Procedures
2. Logbook Entries
3. Operations Associated with Contractors or Non-Reclamation Personnel
4. Confined Spaces
5. Evacuation Procedures
6. Hand Tools and Portable Power Tools
7. Personal Protective Equipment
8. Ropes, Chains, and Accessories
9. Materials Handling, Storage, and Disposal
10. Equipment and Motor Vehicles

I. Protective Coating

1. Inspection
2. Maintenance

[3] This is not meant to be a complete list of auxiliary equipment (delete or revise as necessary).

Chapter IV – Structural Behavior Instrumentation

Structural behavior instrumentation for canals often varies based on the need for monitoring performance/conditions along the canal. In some cases, there could be some instruments that are "abandoned" and/or "on standby," in which case, **all** pertinent information about the instruments should still be included in the SOP.

The following is an example of subject headings that may be used in Chapter IV.

A. Instrumentation and Reading Schedule

Describe the types and number of each type of structural behavior instrumentation installed along the canal. It is suggested that a list of all instruments installed along the canal is shown even if the instruments are abandoned, destroyed, on standby, etc. Also, include the total number of instruments installed and whether they are currently being monitored or not to inform the users of the SOP not only of what instrumentation is installed along the canal but the current status of each instrument type.

B. Responsibilities

Describe the responsibilities of personnel/offices associated with the reading and maintaining of structural behavior instrumentation along the canal.

1. Operator/Operating Office
2. Area Office
3. Regional Office
4. Technical Service Center

C. Description of Each Type of Instrument

The instrumentation listed below is provided as an example of structural behavior instrumentation installed for monitoring a canal. The author/users should also include a detailed description of instrumentation installations and references to applicable drawings.

1. Seepage Monitoring Points
2. Observation Wells
3. Piezometers
4. Measurement Points

Within each type of instrument description in this section, subsections should include the location(s), monitoring, and maintenance of each instrument. Regardless of whether the instrument is actively monitored, “standby,” or “abandoned,” it is helpful to know about the history of the instruments installed along the canal. If an instrument has been abandoned, a statement should be included that provides an explanation.

D. Seismic Monitoring/Strong Motion Program

Seismic monitoring equipment may be installed at or near the canal alignment. When seismic monitoring equipment is installed and operational, a description of the instrument(s), location(s), and maintenance requirements should be provided.

When no seismic monitoring equipment is installed near the canal alignment, a ground-motion sensor could be used to provide post-earthquake ground-shaking information. Knowing the location of the earthquake epicenter, the earthquake magnitude and distance relationship table (if developed) can be used to estimate if the canal site has experienced a horizontal ground acceleration of 0.05g or greater.

Chapter V – Operations

Section headings (A. through N.) are typically included in Chapter V. A brief description of each of these sections is provided below. More detailed information about each of these sections is discussed in the SOP Guide.

A. General

Provide information about the design flow capacity, normal water deliveries (range), water surface elevations (maximum, minimum) at key control structures, and type of controls at control structures (automated, manual, etc.). Include a description of designed operational intent of the canal system. For emergency situations, provide reference to canal system drawdown procedures, as outlined in the EMP or EAP, as applicable, or expand procedures in section B. below.

B. Filling Schedule and Drawdown Procedures

Provide specific information regarding the rate of filling or rate of drawdown to prevent damage to the canal or the canal lining. If observations are needed during filling or drawdown procedures, provide the location(s). Expand and include canal system drawdown procedures if not already referred to in a separate EMP or EAP document.

C. Water Delivery Orders and Scheduling

Provide information about the water delivery orders and scheduling procedures for the authorized office.

D. Water Conservation Plan

Provide the necessary information regarding the water conservation plan for the canal.

E. Power Restrictions

Provide information about any power restrictions.

F. Landslide Surveillance

Landslide surveillance procedures have been established for Reclamation projects. The procedures require the identification, annual examination, and preparation of data and/or data reporting of landslide areas by the regional geologist or designated representative. As a result of these and other examinations, operating procedures and appropriate schedules of landslides must be established for specific canals.

Include detailed information, such as locations of landslides or potential landslides that may be activated by drawdown, and include a map in the SOP appendix showing landslide locations.

Except for reporting procedures and operating instructions, all information and instructions related to landslides and landslide surveillance should be given in the SOP section. Inspection requirements relative to landslides should be described in SOP Chapter I, Section F (Data Reporting) and referred to in this section. Operating requirements resulting from landslide conditions should be included in SOP.

Special instructions for O&M personnel may be developed as a result of the annual examination of landslide areas, and other information should include, but not be limited to, maintaining posted warning signs of landslide areas; identifying names and locations of persons and entities in established locations who would be affected by either slow or sudden movement of a critical landslide, and who could benefit from establishment and implementation of related emergency communication procedures; maintaining and observing landslide monitoring instruments; measuring landslide areas by land surveying; examining and reporting on critical landslide areas between annual examinations as directed by the regional geologist; adhering to special limitations on canal drawdown rate; and immediately reporting unusual landslide activity.

Landslide surveillance should describe landslide observations and measurements to be made following an earthquake and should refer personnel to the EAP (if available) for reporting procedures.

G. Water Quality Program (Prevent of Pollution of Water)

Describe and identify operating personnel's pollution abatement responsibilities to prevent or reduce further pollution, inventory and locations of possible oil and hazardous material sources, and sources of oil and hazardous substance cleanup.

At facilities where emergency plans for dealing with accidental pollution have been published, the SOP should include the plan or the document in which it is described, and the document should be referenced in this section. References should also be made to other pertinent documents containing information about temporary corrective measures to perform in the event of oil and/or hazardous material incidents and a reference made for contacting the National Response Center.

H. Fish and Wildlife Considerations

Provide reference to all contracts and agreements with other agencies for the benefit of fish and wildlife. Explain any requirements and how the agreements affect operations. These requirements might include minimum water surface elevations, minimum release rates to meet downstream flow, etc. Endangered plants or species may also be included in this section.

If applicable, include detailed information about the Memorandum of Understanding/Memorandum of Agreement with Federal, State, and/or local fish and game agencies.

I. Recreation Management Plan

State whether or not a recreation management plan has been established along the canal alignment. If a plan has been published, identify the agreement establishing the plan, the agency responsible for operating the plan, and how the plan affects operations.

J. Off-Road Vehicle Regulations

Identify regulations regarding off-road vehicle use for protecting public lands. Identify the Federal Register issue establishing the regulations, indicate the agency responsible for operating the plan, and state if and how the plan affects canal operation or operating personnel responsibilities.

Maps designating roads and trails for off-road vehicle use, as well as maps indicating prohibited areas, should be included in the SOP appendix.

K. Hydropower Release Criteria (include if applicable)

This section may be useful when hydroelectric plants are non-Reclamation and operated by others. For canals serving as forebays to hydroelectric plants, this section should state the basic criteria used in determining the time and quantity of hydropower releases and should indicate the relation of releases to other canal operating functions and criteria. When the only canal function is hydroelectric, or when operation is coordinated to maximize power generation consistent with other authorized project operation purposes, the criteria may be referenced here and included in Chapter I, Section M (Supporting Documents).

Clearly state the reporting requirements, release range, and power demands before effecting sudden or large releases of water. Also describe warning signs, devices, etc., to alert people downstream of increased releases.

L. Operating Criteria for Other Functions (include if applicable)

Operating criteria for other canal functions not appropriately included in other SOP sections may be described here. Where appropriate, this section may include reviews of canal operating criteria for downstream pollution abatement, structure protection during periods of the year, and control of silt deposition in the reservoir.

M. Outgrants

An outgrant is any pertinent legal agreement or contact, such as licenses, leases, easements, permits, etc., that should be identified and recognized in the O&M of the canal system.

Describe the procedures for authorizing outgrants along the canal. The approving office should be identified in this section as well as the requirements for approving outgrants.

If a section within Chapter V is not needed, sometimes it is best to state "Not applicable" or "No information is available at this time" rather than deleting the heading. The decision to keep the section heading or delete the heading should be made on a case-by-case basis.

Appendix A – Structures List

Include a complete list of all structures along the canal alignment that shows the canal milepost (location), structure type, features, description, etc.

Appendix B – Forms and Reports

Include common forms and reports that are used for reporting information about operations/maintenance for the canal.

Forms in the SOP generally include, but are not limited to, "Telephone Report of Water and Power Interruptions and Facility Failure," daily operations report forms, sample pages of the Operating Log, inspection checklists, preventive maintenance summary reports, job plan reports , etc.

Appendix C – Drawings

Include drawings relating to the canal and appurtenant features. There is no need to include all design and specification drawings, as this would make the SOP too large.

Additional appendices may be added to meet the needs of the operating agency. Additional appendices may include aerial maps, rodent control plans, rating tables, etc.

Summary

In general, no two SOPs will be exactly the same, but there may be similarities. Each canal SOP is unique for many reasons/factors: location, operating entity, purpose, operating equipment, control structures, design, length, appurtenant structures, instrumentation, etc. Information in this article may be helpful whether developing a new SOP or updating an SOP as a completely republished document.

The following points should be considered when developing/revising an SOP:

- For a canal with multiple operating organizations, it is recommended that a separate SOP be developed for each operating entity.

- For an extremely long canal, a separate SOP is recommended to cover shorter reaches of the canal.

- There are too many possibilities of features and equipment for a canal to include them in this article. The SOP author(s)/users should use their best judgment when organizing the contents in each chapter. This applies mostly to Chapters II and III.

- Information from the DOC should be incorporated into the SOP instead of just making a reference to the DOC.

- Chapters II, III, and IV should be tailored to meet the requirements of the structures and equipment installed for the canal.

- Digital photographs of the canal and appurtenant features, equipment, and controls for equipment operations can be beneficial and should be included in the SOP. There is no standard as to where photographs are located in the SOP. The decision for placement of photographs in the document should be made by the (Reclamation) office having jurisdiction of the canal. Consider having the photographs included within the SOP section where the feature is discussed in the text. This can be done with word processing software.

- Drawings should be included in the SOP as a means of providing additional information to supplement the text. Drawings that are referenced in the text of the SOP should be included if available. Consider including drawings in Appendix C of the SOP. A complete set of the construction drawings should not be included, but rather only drawings that represent the key features, mechanical equipment, installation, general electrical drawings, etc. Note that any drawings provided in the SOP are not to be used for construction purposes.

- Computers and word processing software now make it possible to embed digital photographs and other digital (tiff or jpeg) images into the document. Word processing software also makes it easier to update and maintain an SOP.

References

Standing Operating Procedures Guide for Dams, Reservoirs, and Power Facilities, dated August 1996, revised reprint June 2001.

Water Operation and Maintenance Bulletin No. 231, U.S. Department of the Interior, Bureau of Reclamation, dated December 2012.

BASIC PUMP, MOTOR, MECHANICAL, AND ELECTRICAL MAINTENANCE

by: Gary Cawthorne and John Shisler

Effective and efficient operation of large-scale pumping projects requires a comprehensive regular preventive maintenance program. On many irrigation projects, there is almost no redundancy in pumping installations; therefore, keeping pumps operating is of primary importance. Good maintenance is essential for optimum operations, protecting a capital investment, avoiding costly breakdowns, and avoiding expensive down time.

A pumping unit consists of the pump, motor, switchgear, and often the transformers and substation equipment. A failure in any of these components will force the pump out of service. Maintenance of each of these components will be examined here. Basic maintenance procedures for pumps, motors, and associated equipment will be stressed. Sound maintenance procedures applied to pumps and electrical equipment are really quite simple. Good mechanical knowledge and common sense, applied in a timely manner, will be sufficient in most situations.

Pumps driven by electric motors are extremely reliable. The A&B Irrigation District in southern Idaho provides one example. Their annual budget for maintaining 198 pumps, motors, switchgear, 400 distribution transformers, and substation equipment is less than the budget for maintaining the district's mobile equipment that consists of 32 pickups, 9 trucks, and 24 pieces of heavy equipment. The fact that electrical equipment is so reliable can undoubtedly contribute to failure because it can continue operating in substandard, poorly maintained conditions, thus giving a false sense of security that leads to further neglect of proper maintenance procedures and eventual catastrophic failure.

A valuable resource for information on electrical and mechanical maintenance, known as the Facilities Instructions, Standards, and Techniques (FIST), has been developed by the Bureau of Reclamation. These documents give detailed information on electrical and mechanical maintenance techniques. FIST documents can be found on the World Wide Web at: http://www.usbr.gov/power/data/fist_pub.html, or you can Google "Reclamation FIST." They were originally intended for hydrogeneration facilities, but are an excellent resource for the water community as well.

Pump Maintenance

There are many different pump manufacturers, producing many types, sizes, and models of pumps for various uses. These include vertical turbine, horizontal centrifugal, end suction, axial flow, and other types. Many installations combine different types of pumps, such as centrifugal booster pumps, with deep well pumps. Regardless of the type or size, the major components and maintenance items are similar for all types of pumps.

Lubrication

This is one of the most obvious areas of concern. Always use the proper type of lubricant and in the proper amounts. Too little lubricant will cause excessive wear and lead to a mechanical failure. Excessive lubrication can also cause failure through overheating. Always insist on top quality lubricants and resist the temptation to economize by using lower-graded materials.

Packing or "Stuffing Box"

Drive shafts and pump sleeves can be high maintenance items. Overtightening of packing can severely damage shafts and sleeves. Packing should be replaced periodically, especially if there has been a history of installing extra rings of packing to stop leaks. Pump sleeves with wet lantern-ring packing can wear very rapidly. Maintenance costs in this area can be significantly reduced by flame spraying the sleeves with stainless steel or other materials and carefully selecting the replacement packing. An example is a large pumping plant near Rupert, Idaho. Before changing the packing system, the impeller shaft sleeves had to be removed and repaired annually. The retrofit consisted of metalizing the sleeves with stainless steel and installing grease impregnated wood-metal packing manufactured by the Raines Corporation. One of the 70-cubic-foot-per-second, 500-horsepower impellers was removed after 16 years of service, and the sleeves were only worn 0.002 to 0.004 inch. The five large pumps in this plant are continuing to operate without any significant wear on the sleeves.

Excessive Vibration

Modern vibration meters are very useful for determining the normal vibration pattern of a unit. Any change or worsening of the normal pattern is always a sign of trouble and, unless corrected, will almost certainly lead to damage or failure.

Foreign Materials

The most common problem affecting pumps, pumping from surface sources, is floating trash and aquatic vegetation. Even small amounts of small-sized trash will reduce pump output. Foreign material such as trash, sticks, rocks, plastic, and even rodents and reptiles are often picked up by pumps. Screening should be provided to prevent entry of foreign materials into the pump. Adequate screening will help to eliminate damage to the equipment and substandard performance. Air introduced into a pump is also a foreign material and can cause damage to the system; any vortices entering the pump should be eliminated.

Cavitation

Cavitation can be caused by improper pump selection or operating the pump outside the range of designed head conditions, especially operating with less than the recommended net positive suction head. A sharp crackling sound coming from the pump while it is running is a very good indication that cavitation is occurring. This sound is similar to rocks passing through the pump. It is frequently heard while filling an enclosed system or when the pump is throttled. When cavitation damage is occurring within the pump, very serious damage can be done in a short length of time. Pumps should never be operated over long periods of time while cavitation is occurring.

In large pumping plants, the pumps and motors should be inspected every 3 years; however, experience may dictate more frequent inspections. All interior parts of the pumps and motors should be inspected, wearing ring bearing clearances measured, and the entire system thoroughly inspected for damage. Cavitation damage and/or impeller wear will usually start any place within the pump where water abruptly changes direction.

Applying coatings to the impellers and pump interiors may reduce friction and wear and increase output. Check with coating manufacturers and others individuals who have experience using different kinds of coatings. This information can greatly help in determining which types of coatings to use.

Low Pump Discharge

Perhaps the most common complaint by water users is: “The pump is not pumping as much water as it used to.” It is essential to know if the complaint is valid. The past operating history of the pump and motor must be known to determine if a pump is not operating properly. To obtain an operating history, measure the quantity of water being pumped by using a reliable water measurement device such as an in-line flow meter.

Keeping a record of the pump parameters and operation conditions can greatly assist in determining problems with a pump. Documenting bearing temperatures, unit voltage, current draw, flow output, inlet elevation, and, where possible, vibrations on a regular basis can prevent pumping unit failures. Very reliable measurements can be obtained by using a good amperage meter or a watt-hour meter to measure the amount of electrical energy being used by the motor. A permanent record should be kept of all these measurements. Then, when trouble arises or a complaint is made, solid verifiable information will be available. This information will be invaluable when helping to troubleshoot and make the critical decision to remove and repair the pump. Comparing a one-time reading taken during a crisis with motor and pump nameplate data is totally inadequate; knowing the unit's past operating history is absolutely essential.

Remember that if no other data are available, the amperage or watt-hour meter readings will provide an excellent reference regarding the operating condition of the pump. An electric motor, in normal circumstances, will use only the amount of electricity required to operate the pump. If wear between the pump impeller and wearing ring increase and efficiency decreases, the power consumption will also decrease.

Most cases of low pump discharge are caused by excessive wear at the pump "seal." This seal is not to be confused with the shaft seal or packing gland. The pump seal is the interface between the rotating impeller and the pump case. All pumps have one or more seals, and they are usually fitted with replaceable wearing rings. Normal wear increases the annular clearance between the pump impeller and wearing rings. On large pumps, the clearances should be measured and recorded during the annual inspection.

A pump that is low on discharge can be repaired at any good machine shop. Satisfactory repairs can be made by boring out the wear rings, if there is sufficient material remaining, or replacing them if they are severely worn. The impeller sealing surface, or skirt, is then built up by flame spraying or metalizing with stainless steel or other materials. The impeller skirt is then machined to proper tolerances. Recommended tolerances between the impeller and the wearing rings are as follows: for a 6-inch-diameter impeller, 0.014 to 0.016 inch; for an 8-inch-diameter impeller, 0.016 to 0.018 inch; for impellers above 8 inches in diameter, add 0.001 inch for every additional inch of diameter. For larger impellers, follow the original factory specifications. While the pump is disassembled, the bowl shaft and pump case bearings should be replaced along with any other worn or damaged parts. After the repairs are completed, the pump will perform as good as new.

Badly damaged and broken impellers can be repaired by modern welding and flame-spraying techniques. Repairing older, large impellers is generally much less expensive than purchasing replacements.

Electric Motor Maintenance

In keeping with the theme of simplicity and basic maintenance requirements, four primary areas of consideration concerning electric motor, switchgear, and transformer maintenance will be addressed. These areas could be termed "key requirements," and strict adherence to them will eliminate most problems, as most electrical failures are a result of neglecting one or more of these requirements.

Keep it Clean

Dirt and oil provide an environment for moisture to collect and remain in contact with energized parts and insulating materials. Dirt, oil, and moisture remaining in contact with the motor windings may not allow for proper cooling of the motor, and it might reduce the insulating properties of the insulation. These contaminants can also introduce abrasive materials into moving parts, thus increasing wear.

Keep it Tight

Probably the most common cause of electrical failures is a loose connection. Electric current flowing across a loose connection generates heat, causing insulation failure, brittle wires, fires, explosions, etc. A regularly scheduled program to inspect and tighten all electrical connections within the system should be followed.

Infrared cameras and remote temperature sensors are excellent tools for diagnosing trouble spots caused by loose connections and other discrepancies. They have the advantage of inspecting the system remotely, while it is in operation, and pinpointing trouble spots before a failure can occur. Many service shops offer inspections using these cameras at an attractive price. Besides pointing out potential problems, they also provide peace of mind by visually showing normal operating conditions. These cameras are one of the best diagnostic tools available.

Keep it Dry

Water and electrical equipment simply do not mix. Irrigation sprinkler systems should never be allowed to spray directly onto pump motors and electrical equipment. Moisture greatly reduces insulation resistance, which could cause the motor to short. Moisture can cause problems for moving parts as well due to corrosion and other contaminants being attracted to the moisture.

Keep it Cool

Heat is a major enemy of insulating material, especially in older motors and wiring. Studies have shown that the life of an electric motor is doubled for each 18-degree Fahrenheit reduction in operating temperature. Sunshades for motors, reflecting paint, ventilating fans, and, if feasible, separate air-conditioned enclosures for pumping plant switchgear are effective measures to reduce temperatures.

A program of regular insulation resistance testing should be followed. The use of a hi-pot tester “Megger” will give reliable measurements of the condition of the entire electrical system. However, it is extremely important that the tests be performed at the appropriate voltage for the motors. It is best to use the manufacturer’s operation and maintenance manuals to determine this voltage. A good rule of thumb is to use the rated voltage, times 2, plus 1,000. Many potential problems can be detected before they become major failures by doing these tests. A permanent record of these tests and other maintenance procedures must be kept so that trends can be followed. Quite often the readings of a Megger may not look bad, but the trend may show that the unit is starting to degrade. Maintaining trend records will allow personnel to evaluate and plan for a replacement or some form of corrective maintenance.

One of the best maintenance procedures on large motors is a thorough visual inspection. Special attention should be paid to the stator coils. The condition of the insulating varnish should be inspected; it should have a good gloss and not be cracked or crazed. Slot sticks should also be firmly in place. Make sure the coil ties, at the end turns, are tight and that there is no looseness at all, especially in the area where the coils enter the stator iron. Looseness, and the resultant movement, in this area is the source of the majority of motor failures.

While inspecting synchronous motors, the slip rings, commutators, and brushes should be carefully examined. A smooth dark-colored patina on these components is normal. The excessive use of brush seating sticks is not a good practice. Abrasive particles from the stick can become embedded in the brushes, causing serious damage to the commutator. Badly worn commutators or slip rings should be resurfaced, cleaned, and repaired. Never clean slip rings unless they are badly pitted, scored, or burned. The slip rings naturally build up a layer of carbon within the pores of the metal surface, which will help lengthen the life of the brushes and promote good current flow to the motor. When necessary, new brushes should be installed and properly seated. To seat brushes, the use of a seating stone is not recommended – because there is such tight access, damage to the motor is likely. Furthermore, a seating stone will produce an abrasive dust, which can seriously damage the motor. Therefore, removing this dust prior to motor operation is required. Never use an emery cloth or emery paper for seating brushes, as the dust from both is conductive, and the particles are very abrasive. Particles from an emery cloth or paper can embed themselves in the brushes and cause scoring on the slip rings. Using 80-grit sandpaper is actually the recommended medium for seating brushes. This method will ensure proper curvature of the brush face and 100-percent contact with the commutator or slip ring. After seating all brushes, the machine should be vacuumed and cleaned to ensure all contaminates have been removed from the brush area. For larger motors, it is a good idea to regularly swap the polarity of the slip rings, which will help solve the problem of excessive brush wear.

In harsher climates, during the nonirrigation season, motors located outside should be winterized. Snow shields should be installed to cover the ventilation openings in the motors. The shields should be painted a bright contrasting color so that the motor will not be operated with them in place. Overfill the bearing oil reservoirs to submerge the bearings and prevent rusting. Replace the bearing oil in the spring or more often if conditions warrant. Pumps frequently operate continuously for the entire season without changing bearing oil. Use a good grade of oil and avoid the temptation to economize.

Electric motors operating in the typical outdoor environment should be reconditioned on a regular basis. The reconditioning procedure consists of a thorough steam cleaning and oven drying. The motor stator is then dipped in an insulating varnish and baked again. It is then reassembled and given a fresh coat of paint. While the motors are disassembled for reconditioning, this is an excellent opportunity for a thorough inspection, making sure all mechanical parts are in peak operating condition. Any problems in the electrical components, such as cracked leads, loose slot sticks, end turns, and coil ties, can be repaired or replaced. The rotors should also be carefully inspected, making sure there are no cracked squirrel cage bars, broken fan blades, or loose components.

Approximately 80 to 90 percent of motor failures occur because of a failure of mechanical components within the pump-motor system. Bearing failure is probably the most frequent. The mechanical failure can then involve the motor windings, leading to complete failure and a very costly complete motor rewind.

The interval between scheduled reconditioning should be determined by the number of motors involved and budgetary considerations. A 5-year interval has proven to be very satisfactory and relatively inexpensive. With this type of program, it is well documented that failure rates of motors can be reduced to less than 2 percent from all causes.

Switchgear Maintenance

Circuit breaker switchgear is one piece of equipment within our facilities in which maintenance has historically been ignored. Within the switchgear, as in no other piece of equipment, the failure of a small, seemingly insignificant component can force a pump out of service. Furthermore, many breakers rarely operate, so the contacts can become pitted, and the mechanical parts of the breaker become stiff. This will lead to the breaker not being able to operate as designed when needed, which is a very perilous situation for both the equipment and personnel. One of the most dangerous pieces of equipment in any facility is the 480-volt station service switchgear. In many situations, simply operating the breaker, open and closed, can help this problem. For larger breakers, regular maintenance is required. Compressed air should not be used to blow dirt out of switch gear cabinets, as this can drive dirt into delicate mechanisms. A vacuum cleaner should be used instead.

Breaker maintenance should be performed at least once every 3 years. Special attention should be given to the contact points and the trip element. When the contactor closes, the points should come together simultaneously and have equal spring tension. Any contact points that are badly pitted, burned, or worn should be replaced. Spare contact points and main holding coils for all the makes and sizes of contactors being utilized in the facility should be available within the facility's warehouse. A special test set is required to test the trip element. This test is very important because there will be no sign that a trip element has failed, and in the case of a fault, the breaker will never trip. We worked at a plant where breaker maintenance was never performed on the switchgear, and the first time the trip elements were checked, 7 out of 16 trip elements were bad, and the breakers would never have tripped.

Transformer Maintenance

One of the best indicators of what is going on inside a distribution transformer is the insulating oil. A dissolved gas analysis (DGA) is one of the most important tests that can be performed on a transformer. Annual DGA tests of oil samples can tell you a whole myriad of information such as if there is excess heating or if there is arcing inside the transformer. It is an excellent indication of the health of the transformer as well as a very good indicator that things are starting to go bad. A DGA test for transformers is a simple, inexpensive test. The company that performs the analysis of the oil will produce a valuable report that will show the results of the analysis as well as any problem trends that are developing. They will trend the DGA results since testing began with that company. The most difficult part of performing this test is obtaining the sample because it is critical that the sample be drawn so that it is not contaminated with gases and moisture from the outside air.

Transformer oil may be contaminated with polychlorinated biphenyls (PCBs), which may occur even though the nameplate states the transformer is filled with mineral oil. Contamination can occur during manufacture and transportation of the insulating oils. All transformer oils should be tested for the presence of PCBs, certified, and labeled. Repair facilities will also require test results or testing for PCBs before undertaking repair work.

Safety

All of the maintenance procedures we have discussed are easy to accomplish while the switchgear is de-energized. If working the unit hot is necessary, it becomes much more complex and dangerous. Only highly qualified personnel should attempt to work on energized equipment, and then it should only be done in extreme situations. Today, arc flash hazards have become the trend. Arc flash hazards can occur any time work is being performed on live equipment, and appropriate personal protective equipment (PPE) must be worn. Appropriate PPE includes flash resistant clothing, hoods, face shields, safety glasses, ear plugs, insulated gloves, and leathers. The National Fire Protection Association standard 70E is a standard for electrical safety that includes a great deal of information on protecting personnel from arc flash hazards.

Conclusion

As stated initially, most of the procedures outlined here are basic, quite simple, and cost effective. Experience has shown that, almost without exception, when the cause for a failure has been determined, it can usually be traced to neglecting one or more of the requirements and procedures discussed here. The majority of electrical mechanical breakdowns can be prevented by a vigorous, ongoing, comprehensive, preventive maintenance program.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Darrel Krause, Bureau of Reclamation, ATTN: 84-57000, PO Box 25007, Denver, CO 80225-0007; (303) 445-2941; email: DKrause@usbr.gov

Kenneth Schwairy, Bureau of Reclamation, ATTN: 86-68360, PO Box 25007, Denver, CO 80225-0007; (303) 445-3015; email: KSchwairy@usbr.gov

James Dean, Pacific Northwest Region, ATTN: PN-3200, 1150 North Curtis Road, Boise, ID 83706-1234; (208) 378-5398; email: JDean@usbr.gov

Paul Caruso, Mid-Pacific Region, ATTN: MP-4300, 2800 Cottage Way, Sacramento, CA 95825-1898; (916) 978-5224; email: PCaruso@usbr.gov

Scott Foster, Lower Colorado Region, ATTN: LC-6600, PO Box 61470, Boulder City, NV 89006-1470; (702) 293-8144; email: SFoster@usbr.gov

Rick Scott, Upper Colorado Region, ATTN: UC-1000, PO Box 11568, Salt Lake City, UT 84147-0568; (801) 524-3726; email: RScott@usbr.gov

Dave Nelson, Great Plains Region, ATTN: GP-2400, PO Box 36900, Billings, MT 59107-6900; (406) 247-7630; email: DENelson@usbr.gov