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CONDUCT OF MAINTENANCE (P950)
OPERATIONS AND MAINTENANCE MANUAL
OPERATIONS & MAINTENANCE CRITERION

TITLE: CENTRIFUGAL HORIZONTAL, CENTRIFUGAL VERTICAL, AND VERTICAL TURBINE PUMPING SYSTEMS

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The information contained in this document conforms to the official definition (including its specific exclusions) of the Construction and Facilities Engineering (CONST) Designated Unclassified Subject Area (DUSA), therefore it is exempt from classification and sensitive information review requirements.

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RECORD OF REVISIONS

Revision No.	Date	Description
0	07/25/01	Initial issue. Includes Department of Energy Lessons Learned from 1993 to present.
1	6/25/10	This revision also includes the incorporation of all formatting changes addressed in Revision 3 of the O&M Criterion 101 Writer's Guide. This revision reflects current organizational structure and responsibilities, corrections, clarifications and examples.

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CRITERION 412

CENTRIFUGAL HORIZONTAL, CENTRIFUGAL VERTICAL, AND VERTICAL TURBINE PUMPING SYSTEMS

1.0 PURPOSE

This Criterion establishes minimum requirements and best practice recommendations for the operation and maintenance of centrifugal horizontal and vertical pumps.

This document addresses the requirements of P 315, *Conduct of Operations Manual,* and P 950, *Conduct of Maintenance*, by defining the minimum operations and maintenance criteria for structures, systems, and components that they cover. The Criterion lists requirements that are based on codes, standards, contract commitments, lessons learned, or business cases. It also lists recommendations based on industry practices, operational experience, or business case. Guidance for implementation of the requirements and recommendations is also provided.

2.0 SCOPE

Los Alamos National Laboratory (LANL) facilities have over 5,000 fluid pumping systems. This Criterion addresses LANL facility and programmatic non-positive displacement fluid pumps that are either horizontally or vertically mounted centrifugal pumps. Typical applications for these pumps are

- circulation of heating or cooling water,
- removal of water or sewage within sumps or lift stations,
- feeding water to boilers,
- boosting line pressure for potable water,
- producing a vacuum, and
- transferring fluids.

Positive displacement pumps and specialty vacuum pumps such as root blowers, cryogenic, vane, scroll and ion getter pumps are not included in the scope of this document. Requirements for fire pumps are contained in Criterion 723, *Fire Pumps,* and detailed motor requirements are in Criterion 510, *Electrical Motors*.

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

AHJ	Authority Having Jurisdiction
CFR	Code of Federal Regulations
DOE	Department of Energy

DSA	Documented Safety Analysis
FOD	Facility Operations Director
GPM	Gallons Per Minute
HP	Horsepower
LANL	Los Alamos National Laboratory
ML	Management Level
MM	Maintenance Manager
MSS	Maintenance and Site Services
MSS-MP	Maintenance and Site Services, Maintenance Programs
NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Suction Head Required
OEM	Original Equipment Manufacturer
OM	Operations Manager
ORPS	Occurrence Reporting and Processing System
PM	Preventive Maintenance
PMI	Preventive Maintenance Instruction
PSI	Pounds Per Square Inch
SKF	Svenska Kullagerfabriken AB
SSC	Structure, System, and Component
TSR	Technical Safety Requirements
VIT	Vertical Industrial Turbine

3.2 Definitions

Absolute Pressure- The sum of the gauge pressure and atmospheric pressure.

Cavitation- Occurs when pressure in suction line falls below vapor pressure of the liquid, vapor bubbles are formed and move along with the stream. When these vapor bubbles reach a region of greater pressure, they collapse causing local high pressures and local high velocities. This creates noise and vibration and will cause pitting damage in the interior of the pump.

Centrifugal Pump- A machine consisting of a set of rotating vanes enclosed within a housing or casing. The vanes impart energy to a fluid through centrifugal force.

Critical- A system or equipment in which cannot tolerate an unscheduled outage.

Gauge Pressure- The difference between a given pressure and that of the atmosphere.

Head- Energy per pound of fluid. Commonly used to represent the vertical height of a static column of liquid corresponding to the pressure of a fluid at the point in question.

Management Level (ML1, ML2, ML3, ML4)- ML designation is used to grade the structures, systems, equipment, and components and associated activities based on their importance to the protection of the public, environment, and workers, security, and the Laboratory mission. See AP-341-502, *Management Level Determination* for definitions of each ML level.

Mechanical Seal- Composed of precision lapped fixed and stationary seals along with o-rings, spring and a gland ring that is compression fitted in order to prevent leakage of the liquid. Mechanical seals are installed in the pump's stuffing box.

Net Positive Suction Head Available (NPSHA)- The inherent energy in a liquid at the suction connection of a pump, i.e., the energy available to push liquid into the suction connection of a pump.

Net Positive Suction Head Required (NPSHR)- Amount of energy required to push liquid into a pump without cavitation. The NPSHR is established by the pump manufacturer through testing.

Packing- A soft semi-plastic material cut in rings that snugly fits around the shaft sleeve to form a seal and allow minimal liquid leakage for cooling purposes.

Pressure- The force exerted per unit area of a fluid. The most common unit for designating pressure is pounds per square inch (psi).

Pumping- The addition of energy to a fluid to move it from one point to another.

Pumpage- That which is raised by pumps. The work done by a pump.

Vertical Turbine Pump - A vertical pump designed to meet a wide range of applications where the capacities may be up to 70,000 GPM, produce a head up to 1948 psi and require a driver unit up to 5,000 HP.

4.0 RESPONSIBILITIES

4.1 MSS-Division Leader (MSS-DL)

Receives and approves or rejects, in conjunction with the Authority Having Jurisdiction (AHJ), requests for variances from this Criterion. The MSS-DL maintains the record of decision for all variance requests.

4.2 MSS-Maintenance Programs (MSS-MP)

Responsible for the technical content, monitoring the applicability and the implementation status of this Criterion. MSS-MP will assist organizations that are not applying or meeting implementation expectations or will elevate concerns to the appropriate level of LANL management.

4.3 Facility Operations Director (FOD)

Responsible for implementation of this O&M Criterion for identified systems/equipment within their facility boundaries.

4.4 Operations Manager (OM)

Responsible to the FOD for implementing operation portions of this Criterion and for coordinating transfer of systems/equipment to the Maintenance Manager for maintenance activities. The OM with concurrence of the FOD will prioritize implementation within budget allocations.

4.5 Maintenance Manager (MM)

Responsible to the FOD and the MSS-Division Leader for implementing the maintenance portions of this Criterion and for coordinating the transfer of systems/equipment to the Operations Manager at the conclusion of maintenance activities. The MM with concurrence of the FOD will prioritize implementation within budget allocations.

4.6 Authority Having Jurisdiction (AHJ)

The AHJ is the Point of Contact for the Mechanical Chapter of the LANL Engineering Manual. The AHJ is responsible for providing a decision on specific technical questions regarding the systems or equipment relevant to this Criterion.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 Precautions

This section is not intended to identify all applicable precautions necessary for implementation of this Criterion. However, all applicable precautions should be contained in the implementing procedure(s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards and precautions that may not be immediately obvious.

1. Isolate and bleed pumps prior to disassembling, as a water, air or steam pocket under pressure may be present.
2. Never work on pumps while they are running. Packing adjustments are the only allowed adjustments while the equipment is running.
3. Make sure all guards are in place before returning the equipment to service.
4. When testing pumps after repairs, high-pressure liquid may leak from the pump piping, gaskets or seals.
5. When returning large pumps to service, start them deadheaded (discharge valve closed or nearly so) to prevent water hammer in the system. Bleed the air from the pump cavity if a bleed valve is attached to the top of the pump casing.

5.2 Limitations

The intent of this Criterion is to identify the minimum requirements and recommendations for structures, systems, and components (SSCs) operation and maintenance across the Laboratory. Each Criterion user is responsible for the identification and implementation of additional facility specific requirements and recommendations based on their authorization basis and unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, manufacturer O&M requirements and guidance, etc.)

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities should implement the requirements of Department of Energy (DOE)

Order 433.1A, *Maintenance Management Program for DOE Nuclear Facilities* as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or the Code of Federal Regulations (CFR) as applicable.

Nuclear facilities, certain high hazard facilities and explosives facilities may have additional facility specific requirements beyond those presented in this Criterion which are contained in the Documented Safety Analysis (DSA), Technical Safety Requirements (TSRs), or facility safety plans, as applicable.

6.0 REQUIREMENTS

Minimum requirements for all users are specified in this section. Requested variances to these requirements shall be prepared and submitted to MSS-MP for review and approval. The MSS Division Leader approves or denies variances. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgment, safety matters, and operations and maintenance experience drive the requirements contained in this section.

Note: Discovery of SSC with a degraded or non-conforming condition is a triggering input to the Operability Determination and Functional Assessment process defined in AP-341-516, R1 *Operability Determination and Functionality Assessment*. Degraded or non-conforming conditions include, but are not limited to, failed equipment or components, unsatisfactory readings, code or standard violations and fire protection impairments. Personnel performing tests or inspections under this O&M Criterion are not responsible nor authorized to perform the Operability Determination. Any degraded or non-conforming condition discovered under this O&M Criterion shall be communicated to the FOD Representative for input to the AP-341-516, R1 process. While that process may not apply in Low Hazard Non-Nuclear and Office facilities, the same concept applies. The FOD organization is responsible to determine the response (taking equipment out of service, establishing fire watches, limiting operations, etc.) to SSC degraded and non-conforming conditions.

6.1 Operations Requirements

No requirements identified.

6.2 Maintenance Requirements

6.2.1 Sanitization

Tools and parts used in the repair of domestic water pump internals must be cleaned in a solution of chlorine bleach (5.25% sodium hypochlorite).

Basis: LANL Construction Specifications, Section 22 0816, requires sanitizing to prevent microbiological contamination of potable water.

7.0 RECOMMENDED AND GOOD PRACTICES

The information provided in this section is recommended based on acceptable industry practices and should be implemented by each user based on the unique application and operating history of the subject systems/equipment.

7.1 Operations Recommendations

7.1.1 Readings Log

A weekly log of gauge readings should be part of the operations inspections. Subtracting the suction from the discharge reading will yield the system differential pressure drop at the flow the pump is producing. Referencing this number to the pump performance curve will give system flow. Multiply PSI by 2.31to determine feet of head.

7.1.2 Pumps Run Dry

Do not run pumps dry because this can damage the seals.

7.1.3 Stuffing Box Leaks

Pumps with a packed stuffing box should normally leak in the range of 40 to 60 drops per minute in order to provide adequate cooling and prevent damage caused by heat.

Basis: Gould Pumps, *Pump Case Manual*

7.1.4 Deadheading

Use extreme caution when deadheading a centrifugal pump. (Running the pump with the discharge valve closed.) Heat build up in the fluid can cause damage. (See ORPS Report ORO-LMES-Y12, site 1998 0039).

Basis: Engineering judgment. In closed circulation systems for heating or cooling, pressure gauges installed on suction and discharge openings of a pump will provide information as to the condition of the pumping system and aid in diagnosing system problems. Trending system flow via gauge readings will warn of approaching problems. For example, increasing differential pump pressure = restriction in pumping system; decreasing differential pressure = pump wear, increased capacity.

7.2 Maintenance Recommendations

7.2.1 Semi-Annual

7.2.1.1 Inspection and Lubrication

Set up and maintain inspection and lubrication plans. A lubrication plan will

1. Locate and list all lubrication points,

2. Pumps with a packed stuffing box should also be lubricated. The choice of stuffing box lubricant depends on the pumpage, temperature and pressure.

Basis: *Gould Pump Case Manual*, Gould Pump

3. State type, amount, and frequency of lubrication required.

Utilize equipment manufacturer's recommendations, equipment manuals, or lubrication vendor references for specific lubricants, application method, amount, and frequencies. Appendix A provides additional information on lubrication systems for centrifugal pumps.

With further analyses and well-kept records, different types of lubricant, and/or optimized lubricant intervals improve a lubrication program. Improper greasing techniques shorten bearing and motor life. The thorough cleaning of grease relief ports, grease fittings, and grease gun nozzles prior to lubrication is necessary to allow for proper lubrication flow and for preventing introduction of contaminants. Maintaining cleanliness of lubricant and preventing introduction of contaminants into the lubricant is a very common problem. Utilizing cartridges rather than bulk lubricant can prevent some contamination problems. The free flow of grease is important to prevent damage to motor bearings. Grease guns are capable of producing high pressures that can literally drive seals and shields out of the bearing. Mixing of incompatible greases will cause bearing failures. Refer to Table 7.2-1 below.

Table 7.2-1: Grease Compatibility Chart

	Aluminum Complex	Barium	Calcium	Calcium 12-Hydroxy	Calcium Complex	Clay	Lithium	Lithium 12-Hydroxy	Lithium Complex	Polyurea
Aluminum Complex		I	I	C	I	I	I	I	C	I
Barium	I		I	C	I	I	I	I	I	I
Calcium	I	I		C	I	C	C	B	C	I
Calcium 12-Hydroxy	C	C	C		B	C	C	C	C	I
Calcium Complex	I	I	I	B		I	I	I	C	C
Clay	I	I	C	C	I		I	I	I	I
Lithium	I	I	C	C	I	I		C	C	I
Lithium 12-Hydroxy	I	I	B	C	I	I	C		C	I
Lithium Complex	C	I	C	C	C	I	C	C		I
Polyurea	I	I	I	I	C	I	I	I	I	

Note: It is necessary to remove old lubricants from bearings that are not compatible with introduction of new type grease.

Basis: DOE Order 430.1A, *Life Cycle Asset Management* and University of California Appendix E, *Definitions Of Preventive, Predictive, And Corrective Maintenance To Assure Asset Availability For Planned Use.*

7.2.1.2 Pumps

Perform the following lubrication and inspections as per the manufacturer's lubrication schedule.

1. Add lubricating oil or grease to bearings
2. When refilling constant level oilers, refill the reservoir only when it is half full or less. This will prevent adding a small amount of lubricant to the oil sump each time the constant level oiler reservoir is removed.

Basis: Machinery Lubrication Magazine

3. Inspect for leaks
4. Adjust/replace packing as necessary
5. Check bearings for noise or temperatures above 160F
6. Examine coupling for wear
7. Inspect gauges for breakage
8. Examine area under couplings for bits of metal/rubber and other evidence of wear
9. Check mounting bolts for looseness and vibration.
10. Pumps over 20 horsepower may benefit from routine vibration analysis for early detection of looseness, wear, or misalignment. Recommended frequencies for analysis are 12 weeks for critical system pumps and every 6 months for non-critical systems.
11. Velocity is the most prevalent external measure of a pumps mechanical condition. General guidelines for peak overall velocity in inches per second assuming pumps not mounted on vibration isolators (pump speed 600 to 60,000 rpm):

CENTRIFUGAL PUMPS	GOOD	FAIR	ALARM 2	ALARM 1
Vertical Pumps (12' - 20' height)	0 - 0.375	0.375 - 0.600	0.600	0.900
Vertical Pumps (8' - 12' height)	0 - 0.325	0.325 - 0.500	0.500	0.750
Vertical Pumps (5' - 8' height)	0 - 0.250	0.250 - 0.400	0.400	0.600
Vertical Pumps (0' - 5' height)	0 - 0.200	0.200 - 0.300	0.300	0.450
General Purpose Horizontal Pump (Direct Coupled)	0 - 0.200	0.200 - 0.300	0.300	0.450
Boiler Feed Pumps	0 - 0.200	0.200 - 0.300	0.300	0.450

Hydraulic Pumps	0 - 0.125	0.125 - 0.200	0.200	0.300

7.2.1.3 Pump Motors

See Criterion 510, *Electric Motors*

7.2.1.4 Sump Pits, Receiver Tanks

1. Test alarms, float switches and alternators.
2. Lubricate float rods and mechanical linkage.

Basis: LANLs maintenance experience and manufacturer's technical bulletins.

7.2.1.5 Strainers, Check Valves, Screens, Solenoid Valves

1. Blow down strainer
2. Remove and clean screens
3. Verify flow/operations of check valves
4. Verify solenoid valve operation

Basis: LANLs maintenance experience and manufacturer's technical bulletins.

7.2.2 Annually

7.2.2.1 Motors

See Criterion 510, *Electric Motors*

7.2.2.2 Pumps

1. Change pump oil unless otherwise specified by the manufacturer
2. Ensure that replacement oil is compatible with the oil specified by the manufacturer
3. When using a constant level oiler, ensure that the oil level sight gauge on the pump is within the predetermined fluid levels for the pump's oil sump.
4. For the side-mounted constant level oiler, verify that the constant level oiler is properly installed on the side of the pump facing the direction of the shaft rotation where the bottom of the bearing pushs the oil towards the oiler. This protects the oiler from oil sump surge that can occur during start-up and cause the oiler to overfeed.

Basis: LANLs maintenance experience and manufacturer's technical bulletins and *Machinery Lubrication Magazine* articles.

7.2.3 General

7.2.3.1 Mechanical Seals

It is highly recommended that the mechanical seal be replaced whenever a pump is disassembled. The price of the seal is small compared to disassembly cost and downtime. Seal replacement at this time can also eliminate a future repair. Pumps with mechanical seals that handle hot water or light hydrocarbons near the vapor pressure should have either a bypass or external flush lines provided at the seal surfaces. Ensure that these bypass or flush lines are not plugged and operating correctly.

Basis: LANL maintenance experience and Gould Pumps, *Pump Care Manual*

7.2.3.2 Bearings

Since removal of a bearing is a potential source of damage and contamination, avoid removing an undamaged bearing from the pump shaft during repairs.

Basis: SKF Bearing Maintenance Handbook

8.0 GUIDANCE

8.1 Operations Guidance

No implementing guidance available.

8.2 Maintenance Guidance

8.2.1 Pump Maintenance Guides

Preventive Maintenance Instruction (PMI) 40-25-006, *Vacuum Pump Equipment Maintenance and Repair*, and PMI 40-40-007, *Centrifugal Pumps Maintenance and Repair* contain acceptable procedures for pump maintenance, provided the procedures have been reviewed and approved by MSS-MP.

8.2.2 Troubleshooting

For troubleshooting, the major categories of pump problems are as follows:

1. Pump selection or capacity – These problems can caused by design error in selecting a pump with insufficient head (or too much head), or unexpected restrictions in the system such as a plugged strainer, partially closed gate valve, air lock or clogged impeller, pipe, or heat exchanger.
2. Motor overload or overheating – These problems can be caused by binding of the pump's rotating parts, excessive equipment room temperature, oversized impeller, voltage not within 10% of name plate, unbalanced three-phase power, wrong size wiring, or wrong fuse protection.
3. Mechanical seal leaks – Mechanical Seal leaks can be caused by improper installation, pump to motor misalignment, abrasive material in pumped liquid, cracked seal seat, or absence of liquid between seal faces.

Note: A mechanical seal acts as a check valve to prevent liquid leaking out or air leaking into the pump. The seal also acts as a bearing slider since there is motion between the rotating carbon washer and the stationary seal. Bearings must be lubricated, and in this case the pumped liquid seeps between the carbon and seal forming a thin liquid film, which acts as a lubricant. This is why you should never run pumps dry! Mechanical seals also require great care in installation. If the seal surfaces are damaged or misaligned, the pump will leak.

4. Stuffing box packing not leaking – Adjust the packing gland to ensure that the product leaks from the packing at a rate of 40 to 60 drops per minute.
5. Vibration – Misalignment is the most common cause of vibration. Other causes can be loose footings or strains due to pipes supported by the pump, cavitation, impeller wear, or imbalanced hydraulic forces.
6. Cavitation – When cavitation occurs, ensure that the system NPSHA is within the design specifications. Verify that the pump is operating within the designed flow and head rating.

8.2.3 Spare parts for conventional centrifugal pumps

Conventional Pump Design (Mechanical Seal Or Packing)
1. Radial bearings (antifriction)
2. Thrust bearings (antifriction)
3. Mechanical seal or packing
4. Sleeve
5. Shaft
6. Inducer (if applicable)
7. Bearing housing seals
8. Case gaskets
9. Sleeve gaskets
10. Shims for bearings
11. Thrust bearing lock washer
12. All other locking tabs
13. All other gaskets
14. Coupling bolts & gaskets

8.2.4 General tools and lifting equipment

1. 5-ton Drott or Carry Deck picker and lifting accessories like slings and shackles.
2. Work bench with a vise and 3-ton overhead lifting capability.

3. Millwright hand tools (e.g., socket set, open end wrenches, hammers, punches, chisels, screwdrivers, files).
4. Impact wrenches and sockets.
5. Bearing induction heater with thermocouple.
6. Press (10-ton minimum).
7. Bench grinder and sander.
8. Hand drill and bits.
9. Taps and dies.
10. Abrasive paper or pads.
11. Solvents or degreasers.
12. Lint free towels for mechanical seals.

8.2.5 Maintenance and technical manuals

1. Original Equipment Manufacturer (OEM) pump maintenance and operation manual
2. Pump performance curve
3. Pump material of construction
4. Pump process data sheet
5. Pump parts list with OEM part numbers
6. OEM pump data sheet
7. Pump cross-sectional drawing
8. Coupling installation manual
9. Process schematic drawing
10. Coupling drawing
11. Mechanical seal materials of construction
12. Seal flush schematic
13. Mechanical seal parts list with OEM part numbers
14. Auxiliary equipment drawings, data sheets, and replacement parts information

9.0 REQUIRED DOCUMENTATION

Maintenance history shall be maintained for centrifugal pumps to include, as a minimum, the parameters listed in the Table 9-1 below:

Table 9-1: Maintenance History Documentation Parameters				
Parameter	**ML 1**	**ML 2**	**ML 3**	**ML 4**
Manufacturer's Name Plate Data	**Required**	**Required**	**-**	**-**
Maintenance Activities				
Repair / Adjustments	**Required**	**Required**	**Required**	**Required**
PM Activities	**Required**	**Required**	**-**	**-**
Equipment Problems				
Failure Dates	**Required**	**Required**	**-**	**-**
Failure Root Cause	**Required**	**Required**	**-**	**-**
Inspection Results				
Inspection Date	**Required**	**Required**	**-**	**-**
SSC Condition	**Required**	**Required**	**-**	**-**
'-' indicates documentation is not required.				

Basis: Documentation of the parameters listed in Table 9-1 above satisfies the requirements of P 950, Section 3.5.15 which states, "A maintenance history and trending program is maintained to document data, provide historical information for maintenance planning, and support maintenance and performance trending of facility systems and components"

10.0 REFERENCES

The following references, and associated revisions, were used in the development of this document.

10.1 AP-341-502, R1 *Management Level Determination*

10.2 AP-341-516, *Operability Determination and Functionality Assessment*

10.3 *Bell and Gossett Hydronic Specialties*, September 1966

10.4 Goulds Pumps, *Installation, Operation, and Maintenance. Vertical Industrial Turbine (VIT) Pump*

10.5 Goulds Pumps, *Pump Care Manual*

10.6 *IRD Mechanalysis Criteria for Overall Condition Rating*

10.7 ITT Bulletin No. TEH-966, *Analysis of Hydronic System Problems*, September 1966

10.8 *LANL Construction Specifications*, Section 22 0816, 8/13/09, Disinfection of Potable Water Piping

10.9 *Machinery Lubrication Magazine*, Constant Level Oilers-Seven Mistakes to Avoid When

Installing, Applying and Refilling

10.10 *Machinery Lubrication Magazine*, Effective Constant Level Lubrication

10.11 O&M Criterion 510, Revision 0, *Electric Motors*

10.12 P 315, *Conduct of Operations Manual*

10.13 P 950, *Conduct of Maintenance*

10.14 PMI 40-25-006, *Vacuum Pump Equipment Maintenance and Repair*, 20 November 1996

10.15 PMI 40-40-007, *Centrifugal Pumps Maintenance and Repair*, 30 June 1998

10.16 *Pump Handbook* , Second Edition, Karassik, Krutzcch, Fraser, and Messina, (Section 12-6)

10.17 *Pump Operation and Maintenance*, John R. Aymer (Chapter 12-15)

10.18 *SKF Bearing Maintenance Handbook*, 1996

10.19 *World Class Maintenance Management,* (Chapter 6), Terry, First Edition

11.0 APPENDICES

Appendix A. *Pump Maintenance Handbook,* Exploring Bearing Lubrication Options