CRITERION 412

CENTRIFUGAL AND TURBINE PUMPING SYSTEMS

SIGNATURES

William S. Radzinski	25 July 01	FWO-SEM	667-2116
William Radzinski Criterion Author	Date	Group	Phone Number
David B. McIntosh	7-25-01	FWO-SEM	667-3616
David McIntosh Maintenance Engineering Team	Date	Group	Phone Number
M. S. Harris	7/25/01	FWO-SEM	667-9769
Mitch S. Harris Office of Institutional Coordination	Date	Group	Phone Number
S. Subbaswamy	7/25/01 10/25/01	FWO-FMS	667-1262
Sam Subbaswamy Facility Management Services	Date	Group	Phone Number

RECORD OF REVISIONS

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1.0 PURPOSE

This Criterion establishes minimum requirements and best practice recommendations for the operation and maintenance of centrifugal and turbine pumps. This document addresses the requirements of LIR 230-05-01, (Ref. 10.1) "Operations and Maintenance Manual."

The implementation of these requirements and recommendations satisfies DOE Order 430.1A, (Ref. 10.2) "Life Cycle Asset Management," Attachment 2 "Contractor Requirements Document," Paragraph 2, Sections A through C, which in part require UC to "…maintain physical assets in a condition suitable for their intended purpose," and employ "preventive, predictive, and corrective maintenance to ensure physical asset availability for planned use and/or proper disposition." Compliance with DOE Order 430.1A is required by Appendix G of the UC Contract.

2.0 SCOPE

LANL Facilities have over 5000 fluid pumping systems. This Criterion addresses LANL facility and programmatic non-positive displacement fluid pumps that are either centrifugal or turbine. 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, line pressure boosters 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, and detailed motor requirements are in Criterion 510. (Ref. 10.15)

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

CFR	Code of Federal Regulations
DOE	Department of Energy
LIG	Laboratory Implementing Guidance
LIR	Laboratory Implementing Requirement
LPR	Laboratory Performance Requirements

NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Such Head Required
O&M	Operations and Maintenance
PPE	Personal Protective Equipment
PP&PE	Personal Property and Programmatic Equipment
RP&IE	Real Property and Installed Equipment
SSC	Structures, Systems, and Components
UC	University of California

3.2 Definitions

Absolute Pressure. The sum of the gage pressure and atmospheric pressure.

Cavitation. When pressure in suction line falls below vapor pressure, vapor is formed and moves along with the stream. The collapse of vapor bubbles (cavitation) creates high velocity, noise and vibration which damages pumps.

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.

Gage 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.

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.

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.

4.0 RESPONSIBILITIES

4.1 FWO-Systems, Engineering and Maintenance (SEM)

4.1.1 FWO-SEM is responsible for the technical content of this Criterion and assessing the proper implementation across the Laboratory.

4.1.2 FWO-SEM shall provide technical assistance to support implementation of this Criterion.

4.2 Facility Manager

4.2.1 Responsible for operations and maintenance of institutional, or Real Property and Installed Equipment (RP&IE) under their jurisdiction, in accordance with the requirements of this document.

4.2.2 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that may be assigned to the FM in accordance with the FMU-specific Facility/Tenant Agreement.

4.3 Group Leader

4.3.1 Responsible for implementing operational and maintenance surveillance programs including the preparation and maintenance of required procedures and documentation for PP&PE under their jurisdiction that is covered by 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. A compilation of all applicable precautions shall 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/precautions that may not be immediately obvious.

5.1.1 Isolate and bleed pumps prior to disassembling, as a water, air or steam pocket under pressure may be present.

5.1.2 Never work on pumps while they are running. Packing adjustments are the only allowed adjustments while the equipment is running.

5.1.3 Make sure all guards are in place before returning the equipment to service.

5.1.4 When testing pumps after repairs, high-pressure liquid may leak from the pump piping, gaskets or seals.

5.1.5 When returning large pumps to service, start them dead headed or nearly so to prevent water hammer in the system.

5.2 Limitations

The intent of this Criterion is to identify the minimum generic requirements and recommendations for SSC operation and maintenance across the Laboratory. Each 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, vendor 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 shall implement the requirements of DOE Order 4330.4B (Ref. 10.3) (or 10 CFR 830.340, Maintenance Management, when issued) 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 CFR identified above.

6.0 REQUIREMENTS

Minimum requirements that Criterion users shall follow are specified in this section. Requested variances to these requirements shall be prepared and submitted to FWO-SEM in accordance with LIR 301-00-02 (Ref. 10.4), "Variances and Exceptions to Laboratory Operations Requirements," for review and approval. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgement, safety matters, and operations and maintenance experience drive the requirements contained in this section.

6.1 Operations Requirements

No requirements identified.

6.2 Maintenance Requirements

6.2.1 Tools and parts used in repair of domestic water pump internals must be cleaned in a solution of house bleach (5.25% sodium hypochlorite – Clorox™).

Basis: LANL Construction Specifications, Section 15470 requires sanitizing. (Ref. 10.11) Sanitizing is necessary to prevent microbiological contamination of potable water.

7.0 RECOMMENDATIONS 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 his/her unique application and operating history of the subject systems/equipment.

7.1 Operations Recommendations

7.1.1 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 (multiply by 2.34 to determine feet of head) to the pump performance curve will give system flow.

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

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

Basis: Engineering Judgement. 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 (Ref. 10.14).

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

- Locate and list all lubrication points,
- 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.

Table 7.2-1. Grease Compatibility Chart

Grease Compatability 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	

I=Incompatible C=Compatible B=Borderline

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 (Ref. 10.2) (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

The following lubrication and inspections should be performed for every centrifugal or turbine pump requiring lubrication per manufacturer's specifications:

- Lubricate oil or grease bearings
- Inspect for leaks
- Adjust/replace packing as necessary
- Check bearings for noise or temperatures above 160F
- Examine coupling for wear
- Inspect gages for breakage
- Examine area under couplings for bits of metal/rubber and other evidence of wear
- Check mounting bolts for looseness and vibration.

- 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.
- 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

Basis: LANLs maintenance experience and manufacturer's technical bulletins. (Ref. 10.10, 10.16 and 10.17)

7.2.1.3 Pump Motors

See Criterion 510. (Ref. 10.15)

7.2.1.4 Sump Pits, Receiver Tanks

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

Basis: LANLs maintenance experience and manufacturer's technical bulletins. (Ref. 10.10 and 10.8)

7.2.1.5 Strainers, Check Valves, Screens, Solenoid Valves

- Blow down strainer
- Remove and clean screens
- Verify flow/operations of check valves
- Verify solenoid valve operation

Basis: LANLs maintenance experience and manufacturer's technical bulletins. (Ref. 10.14, 10.10 and 10.8)

7.2.2 Annually

7.2.2.1 Motors

See Criterion 510. (Ref. 10.15)

7.2.2.2 Pumps

Change pump oil unless otherwise specified by the manufacturer

Basis: LANLs maintenance experience and manufacturer's technical bulletins. (Ref. 10.10 and 10.8)

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.

Basis: LANL maintenance experience.

7.2.3.2 Bearings

Never reuse a bearing that has been removed using a gear puller.

Basis: LANL maintenance experience.

8.0 GUIDANCE

8.1 Operations Guidance

No implementing guidance available.

8.2 Maintenance Guidance

8.2.1 Provided they have been reviewed and approved by FWO-SEM, PMI 40-25-006, "Vacuum Pump Equipment Maintenance and Repair" (Ref. 10.12), and PMI 40-40-007, "Centrifugal Pumps Maintenance and Repair"(Ref. 10.13) contain acceptable procedures for pump maintenance.

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

- 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.

- 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.
- Seal Leaks – 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 from 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.
- 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.
- Cavitation – This is the formation of gas bubbles in a flowing liquid. The bubbles form when pressure falls to around vapor pressure. All liquids absorb air at the free surface; the amount absorbed being determined by the pressure on the surface. Cavitation can be very damaging to the pump and restrict flow since the bubbles act as a fluid valve.

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

- 5-ton Drott or Carry Deck picker and lifting accessories-slings and shackles.
- Work bench with a vise and 3-ton overhead lifting capability.
- Millwright hand tools (e.g., socket set, open end wrenches, hammers, punches, chisels, screwdrivers, files).
- Impact wrenches and sockets.
- Bearing induction heater with thermocouple.
- Press (10-ton minimal).
- Bench grinder and sander.
- Hand drill and bits.
- Taps and dies.
- Abrasive paper or pads.
- Solvents or degreasers.
- Lint free towels for mechanical seals.

8.2.5 Maintenance and technical manuals

- OEM pump maintenance and operation manual
- Pump performance curve
- Pump material of construction
- Pump process data sheet
- Pump parts list with OEM part numbers
- OEM pump data sheet
- Pump cross-sectional drawing
- Coupling installation manual
- Process schematic drawing
- Coupling drawing
- Mechanical seal materials of construction
- Seal flush schematic
- Mechanical seal parts list with OEM part numbers
- Auxilliary 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 Documentation Parameters

MAINTENANCE HISTORY DOCUMENTATION PARAMETERS				
PARAMETER	**ML 1**	**ML 2**	**ML 3**	**ML 4**
Manufacturer's Name Plate Data	**X**	**X**		
Maintenance Activities				
Repair / Adjustments	**X**	**X**	**X**	**X**
PM Activities	**X**	**X**		
Equipment Problems				
Failure Dates	**X**	**X**		
Failure Root Cause	**X**	**X**		
Inspection Results				
Inspection Date	**X**	**X**		
SSC Condition	**X**	**X**		

Basis: Documentation of the parameters listed in Table 9-1 above satisfies the requirements of LPR 230-07-00, Criteria 2, (Ref. 10.5) which states; "Maintenance activities, equipment problems, and inspection and test results are documented."

10.0 REFERENCES

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

10.1 LIR 230-05-01.0, Operation and Maintenance Manual.

10.2 DOE O 430.1A, Attachment 2 "Contractor Requirements Document" (Paragraph 2, Sections A through C), a requirement of Appendix G of the UC Contract.

10.3 DOE Order 4330.4B, Maintenance Management Program, Section 3.4.9.

10.4 LIR 301-00-02.0, Variances and Exceptions to Laboratory Operation Requirements.

10.5 LPR 230-07-00, Maintenance History, Performance Criteria [2].

10.6 LIR 230-04-01.0, Laboratory Maintenance Management Program.

10.7 LPR 230-09-00.0, Inventory and Categorization of Facilities.

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

10.9 World Class Maintenance Management, (Chapter 6), Terry, First Edition.

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

10.11 LANL Construction Specifications, Section 15470, 30 June 1997.

10.12 PMI 40-25-006, Vacuum Pump Equipment Maintenance and Repair, 20 November 1996.

10.13 PMI 40-40-007, Centrifugal Pumps Maintenance and Repair, 30 June 1998.

10.14 Bell and Gosset Hydronic Specialties, September 1966.

10.15 O&M Criterion 510 Revision 0, Electric Motors.

10.16 ITT Bulletin No. TEH 966, Analysis of Hydraulic System Problems, September 1966.

10.17 IRD Mechanalysis Criteria for Overall Condition Rating.

11.0 APPENDICES

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

APPENDIX A

PUMP MAINTENANCE HANDBOOK,
"Exploring Bearing Lubrication Options"