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Approved American National Standard

ANSI

American National Standard for

Rotodynamic (Centrifugal and Vertical) Pumps

– Guideline for Condition Monitoring

ANSI/HI 9.6.5-2009

Hydraulic Institute

6 Campus Drive
First Floor North
Parsippany, New Jersey
07054-4406
www.Pumps.org

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Sponsor

Hydraulic Institute

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Approved October 13, 2009

American National Standards Institute, Inc.

American National Standard

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Foreword (Not part of Standard)

Purpose and aims of the Hydraulic Institute

The purpose and aims of the Institute are to promote the continued growth and well-being of pump manufacturers and further the interests of the public in such matters as are involved in manufacturing, engineering, distribution, safety, transportation and other problems of the industry, and to this end, among other things:

a) To develop and publish standards and guidelines for pumps;

b) To collect and disseminate information of value to its members and to the public;

c) To appear for its members before governmental departments and agencies and other bodies in regard to matters affecting the industry;

d) To increase the amount and to improve the quality of pump service to the public;

e) To support educational and research activities;

f) To promote the business interests of its members but not to engage in business of the kind ordinarily carried on for profit or to perform particular services for its members or individual persons as distinguished from activities to improve the business conditions and lawful interests of all of its members.

Purpose of Standards and Guidelines

1) Hydraulic Institute Standards and Guidelines are adopted in the public interest and are designed to help eliminate misunderstandings between the manufacturer, the purchaser and/or the user and to assist the purchaser in selecting and obtaining the proper product for a particular need.

2) Use of Hydraulic Institute Standards and Guidelines is completely voluntary. Existence of Hydraulic Institute Standards does not in any respect preclude a member from manufacturing or selling products not conforming to the Standards.

Definition of a Hydraulic Institute Guideline

A Hydraulic Institute Guideline is not normative. The guideline is tutorial in nature, to help the reader better understand the subject matter.

Comments from users

Comments from users of this guideline will be appreciated, to help the Hydraulic Institute prepare even more useful future editions. Questions arising from the content of this guideline may be directed to the Hydraulic Institute. It will direct all such questions to the appropriate technical committee for provision of a suitable answer.

If a dispute arises regarding contents of an Institute publication or an answer provided by the Institute to a question such as indicated above, the point in question shall be sent in writing to the Technical Director of the Hydraulic Institute, who shall initiate the Appeals Process.

Revisions

The Standards and Guidelines of the Hydraulic Institute are subject to constant review, and revisions are undertaken whenever it is found necessary because of new developments and progress in the art. If no revisions are made for five years, the standards and guidelines are reaffirmed using the ANSI canvass procedure.

Units of measurement

Metric units of measurement are used and corresponding US customary units appear in brackets. Charts, graphs, and sample calculations are also shown in both metric and US customary units. Since values given in metric units are not exact equivalents to values given in US customary units, it is important that the selected units of measure to be applied be stated in reference to this guideline. If no such statement is provided, metric units shall govern.

Consensus

Consensus for this guideline was achieved by use of the Canvass Method. The following organizations, recognized as having an interest in the standardization of rotodynamic pumps, were contacted prior to the approval of this revision of the guideline. Inclusion in this list does not necessarily imply that the organization concurred with the submittal of the proposed guideline to ANSI.

Bechtel Power Corporation
Black & Veatch
City of Atlanta
GIW Industries, Inc.
Grundfos Pumps USA
J.A.S. Solutions Ltd.
John Crane Inc.
Kemet Inc.
Malcolm Pirnie
Patterson Pump Company
Peerless Pump Company
Pentair Water
Powell Kugler, Inc.
TACO, Inc.
The Conservation Fund
Weir Floway, Inc.

Committee list

Although this guideline was processed and approved for submittal to ANSI by the Canvass Method, a working committee met many times to facilitate its development. At the time it was developed, the committee had the following members:

Chairman: E. W. Allis, Peerless Pump Company

Committee Members	Company
R. B. Erickson	Flowserve Pump Division
J. Anspach	John Anspach Consulting
D. Rusnak	Flowserve Pump Division
A. Hobrastch	National Pump

9.6.5 Rotodynamic (Centrifugal and Vertical) Pumps for Condition Monitoring

9.6.5.0 Scope

This guideline is for rotodynamic (centrifugal and vertical) pumps, including both sealed and sealless pump designs as stated in each section.

9.6.5.0.1 Purpose

This document is intended to give the pump user a tool for condition monitoring of the pumps in their systems, but does not directly address process management systems.

9.6.5.0.2 Use of this document

It is the user's responsibility to identify the need for implementing pump condition monitoring practices. The user is also responsible for identifying those parameters they wish to monitor. *This document does not require any monitoring be done*, but will provide information relevant to making such decisions, and provides suggestions for carrying out the monitoring process.

This guideline discusses the indicators that can be monitored or reviewed on rotodynamic pumps to identify pump failure modes. Common means of measuring those indicators have been defined. Control limits have been recommended, where appropriate, for those indicators whose limits are not defined in other Hydraulic Institute Standards. ANSI/HI 9.6.4 contains default initial field alarm and trip vibration measurement setting recommendations that may be used until a baseline can be established and the recommendations contained herein may be applied.

There are a number of potential failure modes for rotodynamic pumps. For each failure mode there can be several possible causes. To anticipate the occurrence of each cause, one or more of the following 14 indicators may be monitored or reviewed. The failure modes, causes, and indicators are listed in Appendix A. The inverse, namely indicators, causes, and failure modes, are listed in Appendix B.

There are definitions included in Appendix C to clarify terms used in this standard.

In addition to those indicators listed below, changes in pump sound can sometimes be used to indicate some changes in pump performance. However, interpretation of change in sound is usually subjective in nature.

Various failure modes can be characterized by the following observations and processes.

- Power absorbed
- Temperature rise
- Corrosion/Erosion
- Leakage
- Pressure (suction, discharge, differential)
- Vibration
- Periodic lubricant analysis
- Shaft position
- Rate of flow

- Maintenance inspection
- Speed (rpm)
- Bearing wear
- Preinstallation hydrostatic test
- Design review

When monitoring a pump, it is important to establish a baseline to which all future measurements can be compared. This applies to both new and reconditioned equipment. Trending is more important than the absolute level of the indicator. Soon after the pump is put into service, a baseline should be established. The indicators that one chooses to monitor at an established frequency can then be compared to the baseline. The change and rate of change of the trended indicator will give the user indications of the pump's current state, and how much longer it will continue to operate.

9.6.5.0.3 Monitoring frequency

The frequency at which an indicator should be monitored is determined by the severity of the consequences of failure (severity level) and the probability of failure.

The severity level indicates the consequences of failure. There are three factors considered: safety, environmental, and economic.

- Safety consequences include those effects on immediate employees as well as others in the community
- Environmental consequences may involve local regulations and national or company standards
- Economic consequences include the costs of lost production and correcting the failures

Table 9.6.5.0.3a suggests three levels for each factor: low, medium, and high. Users should assign a severity level for each factor based on its circumstances. The severity level for an application is determined by the highest individual level.

Table 9.6.5.0.3a — Severity levels

Safety Consequences	Low	Medium	High
Environmental Consequences	Low	Medium	High
Economic Consequences	Low	Medium	High

In determining the probability of a pumping system failure, the following factors should be considered:

- Historical data
- Indicator levels at start-up
- Recent trends
- Corrosive/erosive character of liquid

- Equipment redundancy
- Operating proximity to best efficiency point (BEP) rate of flow

It should be recognized that the probability of failure may be revised at any time, particularly if trends change.

The user should categorize the probability as low, medium, or high.

By entering Table 9.6.5.0.3b, a monitoring frequency can be determined. The user should consider monitoring more frequently than monthly for pumps that are rated as "High" probability of failure and "High" severity level. The frequency should be determined based on the user's evaluation of specific risks and consequences of failure. For critical applications, the frequency may range from twice a month to continuous monitoring. The use of installed monitoring equipment should be considered for these applications. The installed monitoring equipment should provide alarm indication based on set operating parameters. The monitoring equipment may also be set up to periodically record and store operating parameters. These data are useful for reviewing pump condition trends and evaluating and scheduling service.

Table 9.6.5.0.3b — Frequency of monitoring

	Probability of Failure		
Severity Level	Low	Medium	High
Low	Annually	Annually	Semiannually
Medium	Annually	Semiannually	Monthly
High	Semiannually	Monthly	Twice a month to continuous

9.6.5.0.4 Control limits

Separate control limits are recommended for alarm and shutdown conditions.

Alarm limit is defined as the indicator value at which one wants to be notified of changes (either increase or decrease) in the measured indicator level. The alarm limit for each indicator should be set as a change from the baseline value and not from established commissioning acceptance levels. The pump does not need to be shut down, but more detailed and/or increased frequency of monitoring should be instituted.

The *shutdown limit* is defined as the indicator value at which the unit needs to be shut down and secured immediately. Continued pump operation at indicator levels in excess of the shutdown limit will shorten the mean time between failures of the unit and greatly increase the likelihood of a catastrophic pump failure.

The alarm and shutdown limits suggested in this document are guidelines. The best knowledge base for each pump installation is the user's experience and knowledge. Experience may warrant higher or lower alarm/shutdown limits, depending on the design of the equipment, system requirements, past indicator history, and failure record.

In subsequent sections of this document, each indicator is discussed. Each section includes an introduction discussing the reasons for monitoring, methods of monitoring, frequency of monitoring, and control limits.

Appendix B contains a cross-reference between indicators, causes, and failure modes.

9.6.5.1 Power monitoring

9.6.5.1.1 Introduction

Monitoring the power consumed by a pump can give advanced indication of the following failure modes: rolling element bearing failure, coupling failure, shaft breakage, and hydraulic performance degradation.

9.6.5.1.2 Means of power monitoring

There are several ways of monitoring the power used by a pump. Some of the instrumentation/systems are outlined below.

Torque meter: The most direct method is to install a torque meter with integral speed pickup between the driver and the pump. This system will directly sense the speed and torque required by the pump. Some torque meter readouts will even calculate the actual power transmitted.

Power meter: This measurement is useful if the pump is driven by an electrical motor, either directly coupled to the pump or through a gearbox, belt, or hydraulic coupling. Electrical transducers are typically installed in the electrical motor starter to measure voltage, current, and phase angle. Multiplying them results in the power supplied to the motor. This approach will not only monitor the power increase or decrease in the pump as parts deteriorate or drag, but also indicates if anything is happening to the general health of the electrical motor and/or the gearbox, belts, or hydraulic coupling.

Electrical current: Similar to a power meter, but only the motor current is monitored. The line voltage and power factor are assumed to remain constant, allowing one to calculate the power supplied to the motor. While this method monitors the condition of the pump and motor, it is susceptible to error caused by variations in the electrical supply grid.

Strain gauges: Strain gauges applied to either the pump shaft near the coupling, or the drive output shaft, with proper telemetry or slip ring equipment, will give an indication of the torque required to drive the pump. This approach is similar to using a torque shaft except that a longer baseplate is not required to accommodate the length of the torque shaft. Some accuracy is sacrificed. If the pump speed is constant or known, the power required by the pump can be calculated.

Caution must be used when applying electrical power monitoring techniques to pumps exhibiting "flat" power curves, i.e., where power changes very little over the operating range. In these cases, setting alarm points can be difficult due to the detection of small power changes resulting from operating point changes and discriminating them from power changes due to other causes, such as temperature changes in the motor or pump and normal process fluctuations.

Measurement practice: Monitoring the pump power usage alone will only indicate whether or not the power is changing. Power changes can also result from changing the hydraulic operating conditions and mechanical or hydraulic deterioration.

Along with power measurements, the operating condition of the pump needs to be monitored, or as a minimum, the pump must be operated at the same conditions when data are recorded.

To adequately monitor the operating condition of the pump; rate of flow, total head, net positive suction head available (NPSHA), and pumpage viscosity and specific gravity need to be measured. When variable-speed devices are used, speed should also be measured.

Once it has been determined that changes in the power consumed by a pump are not the result of changes in its operating conditions, then the changes can be attributed to a pump failure mode. Note that flow rate, operating speed, fluid density, and viscosity are all operating conditions that will impact the absorbed power. Further study of the changes in power and other failure causes will be required to determine the exact mode of failure.

9.6.5.1.3 Power monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.1.4 Power control limits

Before selecting alarm and shutdown limits, the accuracy, repeatability, and stability of the power measurements must be evaluated. Similarly, the accuracy, stability, and repeatability with which the pump's operating condition can be set also must be evaluated. Consideration should also be given to the power level, with higher-power pumps requiring tighter tolerances.

The following control limits are recommended:

Alarm — 5% to 10% change from baseline

Shutdown — 10% to 30% change from baseline

The above levels should not fall below the normal minimum power required by the pump or above the normal maximum power levels.

9.6.5.2 Temperature monitoring

9.6.5.2.1 Introduction

Temperature is a relatively simple and inexpensive parameter to monitor. It can be used to monitor the following failure modes: bearings, seal faces, corrosion, NPSHA variation, cooling-loop blockage, decoupling of magnetic couplings, and motor-winding insulation breakdown.

9.6.5.2.2 Means of monitoring temperature

Thermocouple probes or strip resistance temperature detectors (RTDs) are primarily used for monitoring. When monitoring temperatures at locations where there can be rapid changes (e.g., vaporization of cooling flow or bearing rubs), special care must be taken. Temperature at the source of heat input may be up to several hundred degrees higher than measured temperature of liquid, gas, or metal a short distance away. There is also a time delay between temperature rise at the hot spot as heat flows toward the measurement spot. With proper attention to locating the sensor near the heat input, and minimizing the thermal inertia of the sensor and heat transfer path, temperature changes (temperature rise) can be used as an indicator of machine condition.

9.6.5.2.3 Specific applications of temperature monitoring

9.6.5.2.3.1 Motor-winding temperature

Motor insulation deteriorates faster at higher temperatures. Temperature is dependent on load, frequency of starts, and cooling effectiveness. Winding temperature is more often measured by thermocouples located at the center of the end turns. Strip RTDs and thermistors are also used as alternate sensor methods. Motors are often fitted with thermostats that shut off power when a preset temperature is reached.

9.6.5.2.3.2 Temperature-sensitive liquids

Temperature sensors are used to measure temperature of liquids to ensure that the material is maintained in the liquid state. For high-freezing-point liquids, care must be taken to locate the sensor in the least heated area and allow time for temperature stabilization. For polymerizing liquids, the sensor must be mounted in potential hot spots (areas of high liquid shear or near external heat inputs).

9.6.5.2.3.3 Rolling element bearing temperatures

Rolling element bearing temperatures can be measured by one of three methods:

- Thermocouples or tip-sensitive RTDs immersed in lube oil active flow areas to measure lubricant temperature.
- Thermocouples or tip-sensitive RTDs touching the outside raceway of the bearing.
- Sensors attached to or touching the outside surface of the bearing housing. This is the least reliable method of measurement and is not recommended.

9.6.5.2.3.4 Liquid film bearing and seal faces temperatures

Temperatures of contacting surfaces of sleeve bearings, thrust bearings, and mechanical seal faces can change rapidly when the liquid film is not supporting the load correctly. For hydrodynamic radial bearings, even thermocouples installed in drilled holes as close to the radial bearing surface as possible are often too slow in showing excessive temperature rise to be able to shut down before bearing failure. Use of proximity probes to detect radial shaft position and motion is preferred. For thrust bearings and mechanical seal faces, thermocouples located very near the contact surfaces can frequently detect distress before failure.

9.6.5.2.3.5 Pumped liquid temperature rise

Measurement of liquid temperature at suction and discharge can indicate temperature rise accurately when rate of flow is sufficient to avoid recirculation and suction heating (above 10% or so of BEP flow). At lower rates of flow, fluid mixing from discharge to suction can result in relatively low indicated temperature rise. In these cases, the suction temperature may have increased so that NPSHA has been reduced and flashing may be occurring. Locating the suction thermocouple 20 diameters or more upstream will also avoid suction recirculation heating error. Significant increase in temperature rise across the pump indicates a drop in flow that is likely to cause flashing.

9.6.5.2.4 Sealless pump liquid temperature

Avoidance of liquid flashing in the bearing area of sealless pumps is critical because the bearings are liquid lubricated. Reduced cooling flow can result in an increase in cooling-liquid temperature and flashing. Slow increases in temperature can be detected by well-placed thermocouples. Rapid increases may not be sensed quickly enough to avoid bearing damage.

Liquid is also often used as a coolant in the magnetic gap between the inner magnet and the containment shell. If flashing occurs, heat removal capacity is greatly reduced and excessive heating may take place. The flashing of highly volatile liquids inside a sealless pump can cause rapid expansion that leads to distortion of internal components that can result in failure.

9.6.5.2.4.1 Sealless pump temperature damage

Magnets in magnetic couplings lose strength at elevated temperatures. If excessive heating occurs, the magnets will weaken until they are no longer strong enough to transmit the torque. Process liquid temperature changes as well as coolant-loop blockages may result in elevated coupling temperatures. Temperature sensors may be installed on the outside of the containment shell or in the containment shell cooling loop to monitor the magnetic coupling environment.

The following are some of the situations that may be encountered:

- Dry run: with no liquid to dissipate heat, temperature will rise rapidly.
- Running against a closed discharge valve, temperature will rise slowly.

- Decoupling of magnetic drive. In this case, the slippage of the inner magnet ring relative to the outer will generate eddy currents in the inner rotor and resulting heating can damage the magnets both thermally and mechanically. Coupling temperature will rise quickly.

- Internal flow holes blocked by solids/polymerized pumpage. Coolant temperature will rise at a rate depending on the amount of blockage.

- Solids between the inner magnet ring and the containment shell. Containment shell temperature will rise slowly.

- Internal and external rubbing on containment shell. Containment shell temperature will rise rapidly.

- Excessive temperature can damage the insulation of canned motor wiring.

9.6.5.2.5 Temperature monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.2.6 Temperature control limits

Alarm — 10% from baseline

Shutdown — 20% from baseline

These limits should be considered as initial guidelines. Specific process parameters may dictate more or less restrictive limits.

9.6.5.3 Corrosion monitoring

9.6.5.3.1 Introduction

Pumps may be monitored for corrosive attack to prevent pressure boundary failure, and corrosion monitoring is therefore an important aspect of maintaining a pump's reliability. Because of the difficulty in monitoring, potential for catastrophic failures, and the insidious effects of corrosion, it is imperative that proper materials are selected. Difficult or unusual pumpages may require the reselection or changes in materials based on the results of monitoring corrosion rates. Choosing the right materials for a service should be done by consulting with knowledgeable corrosion engineers, and, when done correctly, some of the burden for corrosion monitoring can be eliminated, or at least reduced.

9.6.5.3.2 Means of corrosion monitoring

9.6.5.3.2.1 Corrosion monitoring by visual/dimensional inspection

Visual inspection is the easiest and most economical method of monitoring corrosion, and most forms of corrosion can be detected by this method. However, stress corrosion cracking usually occurs without any visible signs, thus resulting in a sudden and sometimes catastrophic failure. Visual inspection of pump internals can reveal the degree of general corrosion occurring as well as signs of localized corrosion, such as pitting and crevice corrosion. Particular attention should be given to complete inspection of fasteners as corrosion often takes place in areas hidden from view. Pressure boundary leakage may expose nonwetted fasteners to corrosive pumpage.

Visual inspection can be supplemented with dimensional checks of key components, which can then be used to calculate the amount of general corrosion that the pump is experiencing.

Because most pump manufacturers provide a corrosion allowance in the design of their equipment, the amount of dimensional change over a given time increment can be projected into the remaining life of the pump.

9.6.5.3.2.2 Corrosion by electrical resistance (ER)

The basic principle of this method is the measurement of the increasing electrical resistance of a metal probe as its cross section is reduced by corrosion. The probe should be the same alloy as the pump. However, probes will typically be wrought alloys, whereas most pump components will be cast alloys, which can result in some small degree of error. ER probes can provide a reasonable degree of accuracy for general corrosion but they are not useful for localized forms of corrosion, such as pitting.

9.6.5.3.2.3 Corrosion by linear polarization resistance (LPR)

This method involves measurement of a current response to an applied potential through probes that are inserted in the system. There is commercially available equipment that can do this automatically. A small known pulse of DC voltage is supplied to a test electrode and the resulting current is measured. The current generated is proportional to the corrosion rate, which can be determined by electrochemical principles. Although there is a time lag involved with ER measurements, the advantage of LPR is that it can give instantaneous corrosion readings. To use LPR, a conductive liquid is required.

9.6.5.3.2.4 Corrosion by ultrasonic thickness measurement (UTM)

Although not as accurate as the other methods, UTM can also be used to monitor corrosion on a periodic basis. To use this method, a baseline reading should be obtained at a specific location on the pump casing or cover plate. Then a series of measurements can be made at this same location over time and the metal loss per unit time calculated. To use UTM, the metal surface must be bare metal (i.e., no paint). Temperature extremes may influence readings. One effect of temperature is choice of the couplant (material used to acoustically couple the sensor to the surface). High temperature will require a couplant other than water.

9.6.5.3.3 Corrosion monitoring frequency

The ER, LPR, and UTM methods lend themselves to continuous monitoring or frequent checks by use of small portable data acquisition devices.

The visual/dimensional checks are difficult to do on a very frequent basis because this method requires that the pump be shut down and opened in order to gather the data. The frequency of inspection by this method will then be determined by the importance of the pump. In the absence of experience, the first inspection by this method should be no longer than three months. The findings of these first inspections can then determine when subsequent inspections need to be made. Of course, data generated by this method should be obtained anytime a pump is opened for maintenance. Another sign as to when visual/dimensional inspection should be done is when a drop-off in pump performance is noted, i.e., rate of flow and total head. Corrosion monitoring is also recommended shortly after any significant process changes are made, such as temperature, concentrations, or any changes in corrosives being handled (unless experience dictates otherwise).

Also see Table 9.6.5.0.3b.

9.6.5.3.4 Corrosion parameter control limits

Pump casing or pressure boundary components are designed with a corrosion allowance. This corrosion allowance varies by component. Casings and rear cover plates may have up to 3 mm (1/8 in) allowance, while components such as sleeves and containment shells may be as low as 0.25 mm (0.01 in). The pump manufacturer should be consulted for specific corrosion allowances.

Alarm — 50% of corrosion allowance

Shutdown — 70% of corrosion allowance

9.6.5.4 Leakage monitoring

9.6.5.4.1 Introduction

Leakage from installed pumps is detected in a number of ways depending on the hazard posed by the liquid being pumped and the surrounding environment. Leakage is monitored to identify the failure of the seal or pressure boundry. These leaks may be in the form of liquid or vapor.

9.6.5.4.2 Means of monitoring leakage

9.6.5.4.2.1 Leakage by visual inspection

For less-hazardous liquids, leakage is often detected visually from joints or seal drains. Larger leaks of volatile light hydrocarbons such as propane may form ice deposits on the outside surface of the seal gland plate. Continued operation will cause the ice to melt and be replaced by carbon wear debris from the seal faces. Visual monitoring is commonly used for single seals and the outboard seal of a dual seal arrangement.

9.6.5.4.2.2 Leakage by sniffer inspection

Sniffers are used to detect minute leakage of volatile organic compounds (VOCs). Typical locations monitored are joints, connections, and seal drains. Concentrations can be measured to determine the severity of the leak. The proper sniffer must be used for the compound pumped.

The sniffer inspection method must be used for detection of VOC emissions from single seals.

9.6.5.4.2.3 Seal leakage in submersible pumps

Submersible pumps are typically fitted with a dual unpressurized seal system and a separate containment volume that accepts leakage accumulations from the outer seal. If this volume is allowed to fill up, the contained fluid will leak past the inner seal and into the submersible motor. Some motor designs have an additional interior cavity that will collect this leakage before any damage is done to the motor.

The two principal places for leakage monitoring are at the bottom of the motor (for vertical shaft motors) or in the seal barrier fluid containment volume. For reasons not discussed here, most designs place the leakage sensing device in the motor housing. Two sensor types dominate the market, the conductivity probe and the float switch. Leakage sensors installed in the seal oil chamber will respond sooner to leakage resulting from a mechanical seal failure, but because of the location, they are unable to detect water intrusion from other entry points in the equipment. A sensor installed in the bottom of the dry motor compartment can detect liquid intrusion from all possible areas, including from the top of the motor.

The float switch contains a small floating element that is loosely mounted on a pin or shaft. Under normal conditions, the float element remains at rest at the bottom. When liquid enters, the float will rise and this can be detected by several electrical methods. Although simple and reliable by design, float style leakage detectors are position sensitive and as a result are not usually used in submersible equipment that may be subject to inclined operation such as portable pumps.

The conductivity probe senses the conductance of an oil-water mixture, beyond a threshold water limit, that reaches the sensor. It works with a "relay" usually located in the control panel.

9.6.5.4.2.4 Leakage by pressure buildup

Leakage through the inboard seal of a dual unpressurized seal arrangement may be detected by a change in pressure in the seal reservoir containing the buffer fluid. This is accomplished by blocking off the reservoir from the flare (vent) for at least 10 minutes and noting the increase in pressure.

Pressure buildup in secondary containment areas of sealless pumps may also be used to indicate leakage past the primary containment.

9.6.5.4.2.5 Leakage by change in barrier fluid flow

Leakage through the inboard seal of a dual unpressurized seal arrangement may be detected by monitoring the gas/liquid flow from the seal to the flare system or collection system.

Leakage through the inboard seal of a dual pressurized seal arrangement may be detected by measuring the change in level of barrier liquid from the circulation system and reservoir.

The consumption of barrier gas through a dual gas barrier seal will vary with changes to pressure, temperature, and speed, and is therefore a poor indicator.

9.6.5.4.2.6 Double-walled system

For extremely hazardous fluids such as phosgene, double-walled pipe with double sealing flange surfaces and inert purge gas arrangement is used to minimize the chance of leakage to the atmosphere. Pumps with double-walled leakage protection are often used. Sniffers are used to detect the presence of any hazardous gas in the purge gas.

For liquids that do not flash when leaking into the lower-pressure collection areas, liquid detectors may be used to indicate leakage past the primary boundary into the collection area.

Table 9.6.5.4.2.6 provides an application guideline for the above methods.

Table 9.6.5.4.2.6 — Application guidelines for leakage monitoring systems' mechanical seals

Monitoring Method	Seal Arrangement				
	Single	Dual			
		Pressurized (Double)		Unpressurized (Tandem)	
		Inboard	Outboard	Inboard	Outboard
Visual	X		X		X
Sniffer	X				
Pressure buildup in seal reservoir				X	
Barrier fluid flow increase or change in reservoir level		X		X	

9.6.5.4.3 Leakage monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.4.4 Leakage control limits

Allowable leakage of hazardous materials is often established by government regulations. For monitoring purposes, the following limits are recommended:

Warning — 50% increase over baseline or government regulations, whichever is less

Shutdown — 100% increase over baseline or government regulations, whichever is less

9.6.5.4.5 Leakage control limits for gas seal consumption

Warning — three times baseline

Shutdown — five times baseline

9.6.5.5 Pressure monitoring

9.6.5.5.1 Introduction

Pump pressures may be monitored for at least two reasons. The pump or seal static pressure can be monitored to guard against an overpressurization of the casing that may cause the casing joint seal or mechanical seal to leak. Pressure may also be monitored as an indication of the operating point of the pump on the performance curve when operating speed and fluid density (or specific gravity) are known.

9.6.5.5.2 Means of pressure monitoring

Monitoring for pump performance is accomplished through the use of a pressure gauge or a pressure transducer. When monitoring pressure for hydraulic performance, both the discharge pressure and the suction pressure must be monitored or a differential pressure device can be used. Follow HI Standards ANSI/HI 1.6 *Rotodynamic (Centrifugal) Pump Tests* or ANSI/HI 2.6 *Rotodynamic (Vertical) Pump Tests* for tap location and design. Mounting gauges at other locations and/or with other tap designs will provide data that can be trended, but may have a very poor correlation to the manufacturer's published performance curve. This discrepancy is because of flow distortion and/or additional piping losses at the entrance and exit of the pump.

The mounting location of a gauge used to measure the hydrostatic pressure of a pump is less critical and should be on the discharge side of the pump before any valve. Mounting pressure gauges in the seal cavity of a pump should be discussed with the pump manufacturer to prevent disturbances in the flow field and/or formation of a collection point for debris.

Mounting a pressure gauge to a seal pressure reservoir should be done only after consulting with the reservoir manufacturer. If a pump is being used on the seal flush system to circulate the fluid through the seal cavity, the pressure gauge should be mounted between the discharge of the circulation pump and the seal cavity.

9.6.5.5.3 Pressure monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.5.4 Pressure control limits

Control limits will vary with the type of service that the pump is in and the shape of the pump head versus rate-of-flow curve. Typical control limits are:

Alarm — ± 5% from baseline values

Shutdown — ± 10% from baseline values

Process requirements may dictate more or less restrictive limits for alarm and shutdown levels.

If pressure monitoring is being used to monitor the overpressurization of the casing, seal pot, or seal cavity, a shutdown limit can be set at the manufacturer's maximum allowable working pressure for the unit.

9.6.5.6 Vibration monitoring

9.6.5.6.1 Introduction

Monitoring pump vibration is by far the most widely used method to determine the condition of pumps. Presently there are many manufacturers of equipment that will measure the vibration of rotating equipment. However, because many different failure modes can cause an increase in the pump vibration, it is difficult to pinpoint the failure mode by vibration alone. Bearing failure, seal leakage, coupling failure, shaft breakage, and hydraulic degradation are some of the failure modes that can be detected by vibration monitoring.

9.6.5.6.2 Means of vibration monitoring

Depending on the pump construction, there are different vibration sensors commonly used to measure vibrations.

Bearing housing vibrations: Pumps that have rolling element bearings are commonly monitored using an accelerometer or velocity transducer. The vibrations are usually measured on the bearing housings in the vertical, horizontal, and axial positions. For rolling element bearing equipped pumps operating between 500 and 5000 rpm, velocity is the preferred unit of measure, although displacement is sometimes used. If an accelerometer transducer is used, most vibration analyzers can integrate the signal to velocity.

Filtered high-frequency signal processing is a means to obtain early warning of rolling element bearing defects. When traditional vibration parameters (such as velocity and acceleration) are measured, bearing defects would not be detected until the latter stage of bearing failure when the vibration of a pump unit reaches a detectable level. This is because the normal amplitude of high-frequency vibration is relatively small compared to the amplitude of lower-frequency vibrations at pump running speed. The lower-frequency vibrations are normally analyzed to detect unbalance, misalignment, looseness, etc. Relying on lower-frequency vibration analysis may not leave sufficient time to schedule an economic repair or replacement of the bearing. The incipient bearing defect (microscopic cracks and spalls in the bearing) is typically unnoticeable without using the filtered high-frequency signal processing technique. The most meaningful use of this technique is to measure the baseline data at normal operating conditions and then trend future measurement data as discussed in the measurement practice section.

Shaft vibrations: On pumps (excluding sealless and submersible pumps) designed with sleeve bearings, vibration measurement is commonly taken using a proximity probe mounted on the bearing housing. On sealless and submersible pumps where access to the shaft is not readily available, bearing housing acceleration is more commonly taken. The probe's output is proportional to the displacement of the shaft with respect to the bearing housing. With most pumps that operate between 500 and 5000 rpm and have sleeve bearings, displacement is the preferred unit of measure. If velocity is required, many analyzers can take the displacement signal and differentiate it to obtain velocity. Two proximity probes are used on each sleeve bearing and are positioned 90 degrees from each other to obtain shaft orbits. Their orientation about the bearing is usually dependent on the bearing housing design. Normally they are either located in the vertical and horizontal position or equally displaced from the vertical axis (45 degrees to either side).

Vertical pumps: On vertical pumps, where the pumping element is submerged, a proximity probe is sometimes used to monitor shaft displacement. It should be located above grade adjacent to the shaft sealing element. Because accessibility is limited in this area, it is common practice to monitor bearing housing vibration just above ground level. Experience has shown that both measurements provide useful information on the pump condition.

Measurement practice: It is important that baseline and subsequent vibration measurements are taken at the same locations, using the same analysis procedures, and with the pump at the same operational conditions. Indelible ink markers, stickers, or drilled dimples can be used to identify the location of each vibration measurement point. The vibration analysis procedure (i.e., bandwidth, number of filters, type of filter, type of average, number of averages, pass filters, etc.) should be standardized. To ensure that the pump is operating at the same hydraulic condition, the rate of flow, speed, total head, power, NPSHA, pumpage temperature, and specific gravity should be recorded. If it is not possible to duplicate operating conditions, measurement results may need to be adjusted.

9.6.5.6.3 Vibration monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.6.4 Vibration control limits

Overall unfiltered vibration levels are most indicative of pump integrity. While acceptance levels at commissioning are beyond the scope of this document, the following standards provide guidelines: API 610, ANSI/ASME B73.1M and B73.2M, and ANSI/HI 9.6.4 *Centrifugal and Vertical Pumps, Vibration Measurement and Allowable Values*. Note: In addition to acceptance levels at commissioning, ANSI/HI 9.6.4 also contains alarm and trip values that differ from this document; however, those values are default levels for use when no baseline data is available and should not be confused with the recommendations contained herein.

The following control limits are recommended:

	Bearing Housing Vibration	Shaft Displacement
Alarm —	30% above baseline	80% above baseline
Shutdown —	50% above baseline	150% above baseline

9.6.5.7 Periodic lubricant analysis

9.6.5.7.1 Introduction

Periodic lubricant analysis is designed to measure three things:

- Wear rates of bearings or face seals
- Lubricant contamination levels
- Lubricant degradation

It is useful for monitoring the condition of a lubricant as a precursor to bearing or mechanical seal failure.

The following sections are intended to make it easy to understand the basics of what the tests measure and how to use that information.

9.6.5.7.2 Measuring metal particles from wear

Several techniques for measuring metal particles and evaluating wear mechanisms are available in industry today.

Typically, laboratories perform a spectrographic analysis for detection of up to 21 different metallic elements. These elements cover most, if not all, inorganic additives, contaminants, and wear metals. A spectrographic analysis indicates the presence of metallic elements, but not the amounts. Quantitative evaluations are obtained from particle-counting analyses. A particle-counting analysis will provide information on the number of particles in a sample within various size ranges and an analysis of the contaminants. A description of the methods and codes used can be found in ISO 11171 and SAE ARP 598. Lubricant analysis laboratories are also a good source of information. Some wear on metal parts, although not desirable, can be considered normal. Large amounts of metal contaminants usually indicate a serious machine problem. Different machine parts are made from different metals, so the presence of particular metals indicates which components are wearing. Common wear metals are iron, aluminum, chromium, copper, lead, tin, nickel, and silver.

9.6.5.7.2.1 Evaluating wear rates

The accurate diagnosis of wear rates can be accomplished through the use of an ongoing lubricant analysis program where the data have been trended over a period of time, accompanied by periodic machine inspection and wear documentation.

When no historical data are available for a machine and/or there are no other like machines in the database, an experienced data evaluator may review the laboratory data and make a value judgment about the wear situation of a specific sample.

When there are multiple machines of the same type, and/or when a machine has been sampled several times, data can be trended. Samples that have metallic content that is increasing at an unusually high rate or data that are statistically out of the normal range indicates that there is a problem with the machine.

The lubricant analysis should also measure certain metallic elements that are found as additives in the lubricant. The primary purpose of analyzing for the additives is to ensure that the appropriate additives are present and that there are no other inorganic additives that indicate that cross-contamination has occurred. Performing an analysis on the fresh unused lubricant will show which additives are there. Subsequent oil samples can be compared to this baseline.

Common additive metals are boron, zinc, phosphorus, calcium, barium, magnesium, molybdenum, and sulfur.

9.6.5.7.3 Measuring contamination of lubricant

Lubricating oil must be physically clean and chemically suitable to properly lubricate equipment. Contamination is commonly classified as organic or inorganic.

9.6.5.7.3.1 Organic contamination of lubricant

Organic contamination can be from the by-products of lubricant degradation or from external sources. Most often it is from lubricant degradation. If the organic contamination is from an external source, it is usually inherent to the operation and is readily identifiable, such as chlorinated hydrocarbons, process liquids, acids, diesel fuel, glycol, or freon. Organic contamination can increase or decrease the viscosity of the lubricant. The analyses most often performed to measure organic contamination are viscosity, acid number, infrared, and flash point.

9.6.5.7.3.2 Inorganic contamination of lubricant

Contaminants in the oil, such as dirt, dust, welding slag, etc., can be carried throughout the machine and cause severe abrasive wear.

Dirt and abrasives — Dirt and abrasives usually enter the machine through poor housekeeping practices or systems that are not properly sealed from the environment. Another source of the element silicon can be found in sealant and antifoam additives.

Fibers and debris — Debris in general is considered to be an inorganic contaminate. Debris can be found in the form of fibrous materials, such as rags or filter media breakdown.

There are a variety of laboratory techniques to measure "solid, inorganic" contamination. The most common method for measuring the concentration of these contaminates without regard for the actual make up of the debris is an automatic particle-counting instrument.

Water — Water is one of the most common contaminates found and in large quantities is the easiest to detect. Water can come from internal sources, such as leaks in cooling systems and condensation, or external sources, such as leaking seals. Usually the lubricant turns white in color and emulsifies.

9.6.5.7.4 Measuring lubricant degradation

Degradation characteristic of lubricating oils can be measured through viscosity, acidity, or antioxidant levels.

Measurable changes in viscosity or acidity are generally considered to be condemning limits for a lubricant, while the antioxidant level acts as an early-warning device for lubricant changes. Antioxidants are added to lubricants to protect the base oil from oxidizing. When these additives are "used up," the base oil is left unprotected and degrades at an accelerated rate allowing the formation of oxidation by-products harmful to the machine. As the antioxidant nears total depletion, the viscosity and acid number dramatically increase.

9.6.5.7.5 Lubricant sampling techniques

Acquiring a representative lubricant sample is extremely important to the overall success of a lubricant analysis program. Sampling points should be on the discharge side of the operating unit before the filter.

In noncirculating sumps, samples should be taken while the pump is operating (or immediately after shutdown) to ensure well-mixed lubricant is obtained. Samples should be withdrawn from within 12 mm (0.5 in) of the surface of an oil sump. A sample from the bottom of the sump will indicate the presence of free water. There are a variety of sampling techniques that can be used. Contact the laboratory for more information on special situations.

9.6.5.7.6 Lubricant monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.7.7 Lubricant control limits

Control limits will vary with the type of lubricant and parameter being monitored. Refer to the lubricant supplier or bearing or seal manufacturer for specific recommendations.

9.6.5.8 Shaft position monitoring

9.6.5.8.1 Introduction

A mechanical seal is a precision device that must be installed in mechanically sound equipment. One aspect of the pump being mechanically sound is that there not be excessive shaft runout or shaft deflection. Standards for shaft runout at the face of the seal housing and dynamic shaft deflection can be found in standards such as API 610 and ANSI/ASME B73.1. The purpose of these standards is to provide an environment that will maximize the life of the mechanical seal, thus preventing seal leakage.

Excessive shaft deflection or shaft runout can cause the rotating face of the mechanical seal to wobble against the stationary face. This may cause premature seal face wear, drive mechanism wear, secondary seal wear for pusher seals, seal spring failure, or bellows fatigue, all resulting in seal leakage.

9.6.5.8.2 How to monitor shaft position

A dial indicator can be used to measure shaft runout between the shaft and the seal chamber. Both the radial and axial runout can be measured as a means to confirm the acceptable accuracy of pump components and assemblies.

Dynamic shaft motion/position can be measured using a pair of proximity probes mounted 90 degrees apart and as close to the mechanical seal as possible. Proximity probes are not normally used to monitor shaft runout on pumps whose shafts are supported by rolling element bearings, but are used on shafts with sleeve bearings.

9.6.5.8.3 Shaft monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.8.4 Shaft control limits

Alarm — 50% above baseline

Shutdown — 100% above baseline

9.6.5.9 Rate-of-flow monitoring

9.6.5.9.1 Introduction

In some field installations, it may be difficult to accurately measure rate of flow. However, problems such as plugging of flow passages, air binding, excessive flow causing insufficient NPSHA, and increased internal pump clearances can be detected by flow monitoring using less accurate devices of sufficient sensitivity.

For example, in transfer applications, the rate of flow can be monitored based on the amount of time to transfer the pumpage or empty the vessel. From baseline measurements, increased amount of time to transfer or empty could be caused by corrosion, erosion, or some other damage/blockage to the pump.

9.6.5.9.2 Measuring rate of flow

Monitoring rate of flow may be accomplished by fixed in-line devices, such as rotameters, turbine flow meters, orifices, venturi meters, magnetic flow meters, or nutating disc meters. Noninvasive devices such as ultrasonic meters may also be used.

Those devices that cause losses or flow distortion should be placed on the discharge side of the pump. Manufacturer's directions should be followed to obtain the specified accuracy of the flow-measuring device. Particular attention should be given to the piping configuration immediately before and after the flow meter.

9.6.5.9.3 Rate-of-flow monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.9.4 Rate-of-flow control limits

Control limits will vary with the type of service the pump is in and the shape of the head versus rate-of-flow curve. Process controls must dictate these settings, however, the pump manufacturer's minimum flow requirements must also be observed and met. Rate of flow and absorbed power should be monitored in unison. Typical control limits are:

Alarm — 10% from baseline values

Shutdown — 20% from baseline values

9.6.5.10 Maintenance inspection

9.6.5.10.1 Introduction

Many potential causes of failure are best monitored by periodic inspections. Examples of such failure causes are

- Coupling failure
- Shaft breakage
- Erosion
- Hydraulic performance degradation

Inspections performed to detect these impending failures typically require disassembly. This section of the guideline only addresses those inspections that relate to the above failure causes. It should be recognized that additional inspections are often recommended by the equipment manufacturer, and can be found in the manufacturer's maintenance manual. Additionally, other recommended equipment checks can be found in the reference material, ANSI/HI 1.4 *Rotodynamic (Centrifugal) Pumps for Installation, Operation and Maintenance* and ANSI/HI 2.4 *Rotodynamic (Vertical) Pumps for Installation, Operation and Maintenance*.

9.6.5.10.2 Maintenance inspection practice

The failure modes and causes analysis indicates the following characteristics should be considered:

Coupling degradation

Shaft breakage
  Bending fatigue
  Torsional fatigue
  Torsional overload

Erosion

Hydraulic — Loss of head or rate of flow

Inspection practices may be different for each piece of equipment and are determined by the specific application. An analysis of the application, equipment, and environment will determine the items that should be inspected. A checklist for each application should be developed.

Following is a discussion of the above items, which will be helpful in developing a checklist.

9.6.5.10.2.1 Maintenance inspection of keys and keyways

Inspections can provide evidence of key/keyway damage. Keys should be inspected for evidence of offset (potential shearing), rounding of edges, and reduction in width or height.

There should be no evidence of any of the above. If evidence of overload is uncovered, replace the damaged key with one that meets the original equipment manufacturer's material specifications.

Keyways should be inspected for evidence of deformed groove sides and rounding of the corners. No damage is permitted. The manufacturer should be consulted for acceptable maximum groove width or minimum key width.

9.6.5.10.2.2 Maintenance inspection of coupling flexible elements

Elastomeric elements in couplings should be inspected for evidence of loss of bond between the elastomer and any metallic component (if applicable); cracking, tearing, and hardening of the elastomer; wear between mating parts; and permanent distortion. Evidence of a loss of bond is cause to remove the part from service. If wear or permanent distortion is found, the coupling manufacturer should be consulted for acceptable limits. Evidence of either is cause for review of frequency of inspection.

Metallic elements should be inspected for evidence of corrosion, wear between mating surfaces, and cracks. Corrosion and wear can be determined by visual inspection or mechanical measurements. Refer to the coupling manufacturer for recommended measurements and acceptable limits. Evidence of either is cause for review of frequency of inspection.

Evidence of cracks is commonly checked using dye penetrant or magnetic particle inspection. Indication of a crack is cause for removal of the part from service.

9.6.5.10.2.3 Maintenance inspection for shaft bending fatigue

Material failure due to bending fatigue can occur at any point on the shaft, or at any fastener. A bending fatigue failure will initiate in the area of highest bending stress. This usually occurs at the root of a change in section thickness, and in the area of highest bending loads. More common locations of failure are outboard of either bearing on an overhung impeller pump, near the impeller of a between-bearing pump, outboard of the inboard bearing of a between-bearing pump, and at the balance device (balance piston, balance disk) axial location points on the shaft of a multistage between-bearing pump.

Attention should also be given to areas of fretting or other damage that may cause stress risers and therefore initiation of fatigue sites.

If the impeller is secured with a thread, those threads should also be inspected.

Dye penetrant or magnetic particle inspection are common inspection methods. Any evidence of a crack is cause to remove the component from service.

9.6.5.10.2.4 Maintenance inspection for shaft torsional fatigue

A torsional fatigue failure of shafts occurs at a torsional stress riser location. The common location is at the root of a keyway. Dye penetrant or magnetic particle inspection are common inspection methods. Any evidence of a crack is cause to remove the component from service.

9.6.5.10.2.5 Maintenance inspection for torsional overload

A momentary torsional overload can produce permanent torsional deformation of a shaft. This is normally evident in the coupling area of the shaft. If the shaft has a keyway, it may be twisted. A friction drive coupling may show signs of scoring between the coupling and the shaft. Any evidence of overload is cause to remove the component from service.

9.6.5.10.2.6 Maintenance inspection for erosion

Damage from erosion occurs in regions of high velocity or impingement. Components typically damaged by erosion are casing sideplates or covers, casing discharge lips, casing volutes, impeller vanes, impeller shrouds, shafts, and shaft keyways. Damage is often found to be concentrated in areas where flow disturbances occur (i.e., hand hole cover and tap connections). Operation at off-design condition can cause flow recirculation in the impeller, resulting in localized damage at the inlet of the impeller vane. Very localized erosion may also occur in circumferential pockets, such as between a casing cover and the casing. Inspection for a known eroded area may be done by mechanical or ultrasonic measurement of the wall thickness. A dimensional change beyond the manufacturer's recommended wear limits is cause for removal of the component from service.

Because erosive damage may be localized, and may occur in unstressed areas, it is recommended that a mechanical inspection be conducted in addition to a hydrostatic test if the service is suspected, or known, to be erosive.

Because of the localized nature of erosive damage, other means of measurement of a closed pump, such as electrical resistance, linear polarization resistance, or ultrasonic measurement are not effective in monitoring erosion.

9.6.5.10.2.7 Maintenance inspection for hydraulic performance

A decrease in head and capacity may be indicated by comparison with previous tests or by direct measurement. Pump head or rate of flow may be reduced due to increased internal clearances or dimension changes. Increased clearances at wearing rings, or between semi-open or open impellers and mating surfaces, permit increased internal leakage and results in reduced head or rate of flow, or to scaling deposits on the internal fluid passages.

Clearance measurements and impeller diameter measurements are made mechanically. Wearing ring clearance measurements should be compared to the manufacturer's recommendation. If the clearances are excessive, the parts should be replaced.

During inspection check for scaling deposits on the internal fluid passages and remove if necessary. In the case of semi-open or open impellers, the manufacturer normally provides a means of resetting the clearance. If the wear is nonuniform, as determined using manufacturer's recommended methods, it may be impossible to obtain a uniform clearance and the worn parts must be retired from service.

9.6.5.10.3 Maintenance inspection frequency

The frequency of ongoing maintenance inspections depends on the application's historical records, as well as availability of the pump for inspection. Refer to Table 9.6.5.0.3b for recommended inspection intervals. Because service conditions may prevent removal at frequent intervals, when inspections are done, they should be thorough, with results documented and tracked to predict future equipment retirement.

9.6.5.11 Speed (rpm) monitoring

9.6.5.11.1 Introduction

Pump speed is monitored to check for speed changes that may cause loss of head or rate of flow, or to avoid operation near a critical speed. Also, excessive speed will cause the pump to draw more power and may cause the motor to be overloaded. There are two types of systems that drive pumps: constant speed and variable speed.

Constant-speed systems: It is unlikely that the motor speed will change significantly unless a major electrical problem has occurred. While the load of a rotodynamic pump varies with rate of flow, the changes in speed associated with the load changes are normally relatively slight (less than 2% of full load speed for NEMA Design B motors). However, changes due to high or low voltage, or loss of power to one phase on a three-phase motor, may be significant.

Variable-speed systems: These systems rely on speed change to control head and rate of flow. These systems can have the same problems as the constant-speed systems, but also can have unintended speed changes. These changes can be due to a faulty drive or speed control problem. It may be necessary, when possible, to block out certain speed ranges to prevent operation at or near rotor or structural critical speeds.

9.6.5.11.2 Speed measurement methods

Common methods of measuring speed are strobe light, revolution counter, tachometer, or electronic counter. Any of these devices should be able to measure within 0.1%.

9.6.5.11.3 Speed monitoring frequency

Refer to Table 9.6.5.0.3b.

9.6.5.11.4 Speed control limits

Alarm — 2% from baseline (constant speed)

Shutdown — 5% from baseline (variable speed)

The recommended control limits for variable-speed systems should only be considered initial guidelines. Process requirements may dictate more or less restrictive limits.

9.6.5.12 Bearing wear monitoring of plain bearings in sealless pumps

9.6.5.12.1 Introduction

Sealless rotodynamic pumps, both magnetic drive and canned motor, use a driven internal rotating mechanism (rotor), which may be immersed in the pumped liquid, to rotate the pump impeller. The rotor and liquid are separated from the environment by a surrounding containment device ("shell" or "can"). The sleeve bearings used to support the rotor are cooled and lubricated by the liquid within the containment device. Excessive wear or failure of these bearings due to insufficient lubrication, abrasives in the lubricant, or cavitation, could cause contact between the rotor and the containment device. This contact could result in failure of the equipment and leakage of the process liquid. Providing some means to monitor the condition of these bearings is therefore desirable.

9.6.5.12.2 Means of detecting bearing wear

9.6.5.12.2.1 Bearing materials

Typical materials used as sleeve bearings in sealless pumps are silicon carbide and carbon. Each of these materials exhibits different wear characteristics that can influence the monitoring frequency and detection method.

Silicon carbide: Silicon carbide bearings are more subject to sudden failure, such as breakage due to lack of lubrication (dry running) and overloading, than to exhibit significant wear ("wear out") under normal operating conditions. A progressive wear monitoring device may not detect significant wear prior to sudden failure.

Carbon: Carbon bearings can exhibit wear under normal operating conditions. A periodic monitoring plan using a progressive wear indicator can be useful in detecting normal wear prior to wear out or component contact. However, periodic monitoring will not detect bearing failure or component contact between monitoring periods.

9.6.5.12.2.2 Bearing wear detection methods

Detection of sleeve bearing wear in sealless pumps can be accomplished by visual inspection and dimensional verification during pump disassembly periods, or by instrumentation while the pump is in operation.

Instrumentation used to detect bearing wear falls into two categories, progressive wear monitoring and detection of component contact.

Progressive monitoring: Proximity sensing devices can be used to monitor the position of the rotor within the containment device. Positional changes of the rotor are then used to determine the direction and amount of bearing wear. This method permits excessive wear to be detected prior to contact between the rotor and the containment device or other part of the assembly (bearing holder) designed to prevent or limit rotor contact with the containment device. The proximity sensing device(s) should be selected to detect both radial and axial positional changes of the rotor. Rotor accessibility for proximity sensing, particularly in mag-drive pumps, result in these types of devices normally being incorporated into the pump by the manufacturer. Canned motor design pumps may provide accessibility to the rotating shaft for location of noncontacting-type proximity sensors. Progressive wear monitoring is not normally applied to bearings constructed from "nonwearing" materials.

Contact detection: Excessive bearing wear will allow positional changes of the rotor to cause contact (impacts or rubbing) between the rotor and the containment device or other part of the assembly (bearing holder) designed to prevent or limit rotor contact with the containment device.

Contact can be detected using a suitable acoustic detection device, power monitor, vibration sensor (accelerometer) conditioned to detect impacts and rubbing, containment shell temperature probe, continuity probe, or contact switch.

Application considerations for these devices are listed below.

Acoustic (sound) detection. An acoustic sensor can be used to detect sound produced by contact between the inner or outer magnet and the containment shell or other motion-limiting assembly. The initial contact, however, may be infrequent and the signal difficult to distinguish from other sounds, such as that produced by cavitation.

Power monitor. Rubbing of internal or outer components can cause the power required by the pump to increase. The increase in required power can be detected by a power monitor. However, the increase in power prior to a significant binding can be too small to distinguish from normal operational power changes.

Vibration sensor. Rubbing of internal components can also result in increased vibration levels detectable with vibration monitoring equipment. Initial intermittent contact may produce impact or ringing-type vibration signals more easily detected with higher-frequency vibration detection techniques.

Temperature probe. Rubbing contact between the rotor and containment shell can result in an increase in temperature at the rub point. The increase in temperature can be localized and minimal during the initial or infrequent contact, making it difficult to detect.

Contact or continuity switch. In some sealless pump designs, particularly canned motor pumps, direct access to the rotating shaft is available. In these cases, excessive wear can be detected by direct contact with an electrical switch or electrical continuity detection device. The continuity detection device may be activated by causing or interrupting a completed electrical circuit.

9.6.5.12.3 Bearing wear monitoring frequency

Refer to Table 9.6.5.0.3b. If a contact detection monitoring device is used, continuous monitoring must be performed.

9.6.5.12.4 Bearing wear control limits

Wear limits for sleeve bearings in sealless pumps are determined by the pump design and internal clearances. The pump manufacturer or its maintenance manuals should be consulted for allowable wear limits.

When contact-type wear monitoring devices are used, indication of contact requires immediate shutdown.

9.6.5.13 Preinstallation hydrostatic test

9.6.5.13.1 Introduction

A preinstallation hydrostatic test (hydrostatic pressure test) is performed to check for leakage. This leakage may be the result of a flaw in, or damage to, a pressure-containing housing; a damaged or improperly installed mechanical seal; O-ring; or gasket.

9.6.5.13.2 Means of conducting a preinstallation hydrostatic test

Refer to HI Standards ANSI/HI 1.6 *Rotodynamic (Centrifugal) Pump Tests* or ANSI/HI 2.6 *Rotodynamic (Vertical) Pump Tests* for information on hydrostatic tests.

9.6.5.13.3 Hydrostatic test monitoring frequency

A preinstallation hydrostatic test should be performed prior to installing the pump in the system or after any disassembly. If the pump does not meet the hydrostatic test requirements, corrective action must be taken. These actions may be as slight as correctly tightening bolts, or as extensive as replacing a major cast component. After corrective measures have been completed, the hydrostatic test should be repeated until the requirements are successfully met.

A hydrostatic test is usually performed by the OEM during the manufacturing process. One may also be performed by a repair facility, distributor, or other company assembling the pump. Certification may be provided with the original equipment documentation package. Any user should reconfirm his needs and expectations after consulting the OEM documentation package and IOM.

Subsequent tests can be performed either in the system or out of the system. When the testing is done with the pump in the system, determine what component of the system, when pressurized, has the lowest hydrostatic test pressure capability, and do not exceed that pressure during testing.

9.6.5.13.4 Hydrostatic test control limits

No leaks are permitted while the pressure is maintained. Pressure should be held for 10 minutes minimum.

9.6.5.14 Design review

9.6.5.14.1 Introduction

Pump applications in critical or hazardous service should be formally reviewed prior to initial startup, and after any major revamp or process change. A review should cover mechanical application, hydraulic application, and installation and operating procedures.

The review should address the above factors as related to safety as a minimum. It is strongly suggested that the review consider reliability and functionality issues as well.

9.6.5.14.2 Design review practice

Following is a guideline list of review items. This list is not necessarily complete for all applications. Users are cautioned to review their application and modify the list for their situation.

9.6.5.14.2.1 Mechanical application review

- Is wetted component metallurgy correct?
- Is the coupling selected properly?
- Is the mechanical seal of correct design?
- Is the seal properly flushed and vented?
- Is the pump design appropriate for the service?
- Do all shaft guards comply with applicable standards?

9.6.5.14.2.2 Hydraulic application review

- Is the impeller sized properly?
- Are there proper lengths of straight pipe at pump suction?
- Are temporary suction strainers removed or provided with a bypass?
- Are permanent suction strainers installed for the proper direction of flow?
- Are suction piping fittings designed to vent gases?
- Does sump design comply with ANSI/HI 9.8 *Pump Intake Design*?
- Are controls in place to prevent operation below the pump's minimum allowable rate of flow?
- Are controls in place to prevent operation above the pump's maximum allowable rate of flow?
- Is the motor properly sized for maximum power (over the full range of flows and specific gravity)?
- Is adequate NPSH margin provided under all operating conditions?

9.6.5.14.2.3 Installation review

- Is piping designed and installed to meet nozzle loads requirements? (ANSI/HI 9.6.2 *Allowable Nozzle Loads.*)
- Is piping supported?
- Is piping aligned?
- Are flange bolts properly tightened?
- Are pump and driver aligned?
- Is the baseplate grouted (if applicable)?
- Is the baseplate fully supported and leveled (if freestanding)?
- Are flush and drain lines connected?
- Are all guards in place and secure?
- Are all open ports plugged?
- Is lubricant provided to bearings?
- Are check valves dampened to prevent slam?

9.6.5.14.2.4 Operating procedures review

- Do startup procedures eliminate operation below pump's minimum allowable flow?
- Do startup procedures eliminate operation beyond pump's maximum allowable rate of flow?
- Do startup procedures ensure liquid is available to the pump?

- Do shutdown procedures eliminate operation below pump's minimum allowable rate of flow?
- Do shutdown procedures eliminate operation beyond pump's maximum allowable rate of flow?
- Do operating procedures ensure adequate NPSH is available to the pump under all operating conditions?

9.6.5.14.3 Design review frequency

A design review should be conducted prior to initial commissioning, and after any revamp or process change.

Appendix A

Condition Monitoring, Failure Modes

This appendix is not part of the standard, but is included to inform the user of relationships between failure modes, causes, and indicators related to condition monitoring.

Table A.1 — Condition monitoring failure modes

Failure Mode	Causes	Indicators
Bearing Failure (rolling element)		
Pitting and spalling of races	Overload	Bearing temperature
	Insufficient lubrication	Vibration (high frequency)
Cage breakage	Insufficient lubrication	Vibration (high frequency)
Cage wear	Insufficient lubrication	Vibration (high frequency)
	Contaminated oil	Vibration Oil analysis
Seizure	Overload	Bearing temperature
	Insufficient lubrication	Vibration (high frequency)
Inner/outer race rotation	Incorrect bearing fit	Vibration
Seal Leakage		
Seal face heat checking	Insufficient vapor pressure margin	Face temperature Seal pot pressure/level
	Lack of lubricant	Face temperature Seal reservoir pressure/level
Face blistering	Lack of lubricant	Face temperature Seal reservoir pressure/level
	Wrong lubricant	Face temperature
Face wear	Lack of lubricant	Face temperature Seal reservoir pressure/level
	Contaminated lubricant	Lubricant analysis

Table A.1 — Condition monitoring failure modes (*continued*)

Failure Mode	Causes	Indicators
Spring failure	Excessive deflection	Vibration Shaft position
	Improper installation	Sniffing Leakage observation
Bellows failure	Excessive deflection	Vibration Shaft position
	Improper installation	Sniffing Leakage observation
	Chemical attack	Sniffing Leakage observation
	Overheating due to dry running	Sniffing Leakage observation
Corrosion of springs, Bellows	Wrong material	Sniffing Leakage observation
	Excessive temperature	Seal chamber temperature
Dynamic secondary seal hang up	Solids in pumpage	Sniffing Leakage observation
	Chemical attack	Sniffing Leakage observation
Static seal corrosion	Wrong material	Sniffing Leakage observation
	Excessive temperature	Seal chamber temperature
Static seal breach	Cut O-ring	Preinstallation hydrostatic test
	Improper surface finish	Inspection
Coupling Failure		
Hub loose (set screws)	Improper installation	Vibration
	Worn shaft/hub	Vibration

Table A.1 — Condition monitoring failure modes (*continued*)

Failure Mode	Causes	Indicators
Key shearing	Overloaded key	Inspection
	Wrong material	Inspection
	Worn key/keyway	Inspection
Flexible element failure	Excessive misalignment	Vibration
	Overload	Power measurement
	Corrosion	Inspection
	Runout	Vibration
	Incorrect selection	Inspection
Shaft Breakage		
Bending fatigue	Excessive load	Power measurement
	Incorrect manufacture	Vibration
	Corrosion	Inspection Vibration
Torsional fatigue	Natural frequency	Vibration
	Vane pass excitation	Vibration
	Corrosion	Inspection Vibration
Torsional overload	Excessive load	Power measurement
	Material defect	Inspection
Corrosion		
Casing, impeller	Incorrect material	Corrosion monitor
	Excessive temperature	Corrosion monitor Temperature measurement
	Fluid variation	Corrosion monitor

Table A.1 — Condition monitoring failure modes (*continued*)

Failure Mode	Causes	Indicators
Cover, seal components	Incorrect material	Corrosion monitor
	Excessive temperature	Corrosion monitor Temperature measurement
	Fluid variation	Corrosion monitor
	Electrolytic cell	Corrosion monitor
Erosion		
Casing, cover, bowl wear rings	Incorrect material	Inspection
	Fluidborne abrasives	Inspection
Impeller	Incorrect material	Inspection
	Fluidborne abrasives	Inspection
	Low flow operation	Inspection Power measurement
	Cavitation	High vibration
	Recirculation	High vibration
Hydraulic		
Insufficient rate of flow	Plugging	Rate-of-flow measurement Power measurement
	Excessive solids	Rate-of-flow measurement
	Incorrect pump	Design review
	Air binding	Power measurement
	Low flow operation	Power measurement
	Suction piping	Design review
	Insufficient NPSHA	Power measurement Vibration
	Excessive fluid temperature	Vibration Temperature measurement

Table A.1 — Condition monitoring failure modes (*continued*)

Failure Mode	Causes	Indicators
Insufficient rate of flow (*continued*)	Manufacturing error	Vibration
	Low flow operation	Power measurement
Loss of head/flow	Increased clearances	Rate-of-flow measurement Inspection
High power	Changes in system	Pressure measurement Flow measurement
	Change in speed	Speed measurement Power measurement
	Impeller diameter change	Power measurement Inspection
	Excessive rate of flow	Rate-of-flow measurement
	Binding - Mechanical	Power measurement
	Internal rubbing	Power measurement
Pressure Boundry Leakage		
Gasket	Cut gasket	Preinstallation hydrostatic test
O-ring	Incorrect surface finish	Preinstallation hydrostatic test
	Insufficient gasket load	Leak detector
	Gasket corrosion	Leak detector
	Cut O-ring	Preinstallation hydrostatic test
Casing cover	Machining defects	Preinstallation hydrostatic test
	O-ring corrosion	Leak detector
	Corrosion	Leak detector
	Casting defects	Preinstallation hydrostatic test
	Fabrication defects	Preinstallation hydrostatic test
	Excessive pressure	Pressure measurement

Table A.2 — Additional failure modes for sealless pumps and pumps with journal bearings

Failure Mode	Causes	Indicators
Bearing Failure, Journal Type		
Worn-out bearing	Insufficient lubrication	Containment shell temperature Containment shell liquid temperature Bearing wear detector Power monitor Temperature monitor
	Cavitation	Vibration Bearing wear detector Power monitor
	Abrasives in lubricant	Bearing wear detector
Broken bearing	Insufficient lubrication	Containment shell temperature Pumped liquid temperature Bearing wear detector Power monitor
	Overload	Power monitor
	Cavitation	Vibration Bearing wear detector Power monitor
	Thermal shock	Power monitor Vibration
Seized bearing	Overload	Power monitor
	Trapped solids	Containment shell liquid temperature Containment shell temperature
	Failed antirotation device	Vibration Power monitor

Appendix B

Condition Monitoring Indicators

This appendix is not part of the standard, but is included to inform the user of relationships between failure modes, causes, and indicators related to condition monitoring.

Table B.1 — Condition monitoring indicators

Indicators	Cause	Failure Mode
Power		
High power	Overload	Coupling Shaft breakage
	Impeller rubbing	Low flow or head
	Impeller binding	Pump seized
	Oversize impeller	Excessive flow or head
	Increased speed	Excessive flow or head
	Excessive flow	Impeller cavitation
Low power	Low flow operation	Impeller erosion Shaft breakage Impeller cavitation
	Excessive air/gas	Low flow or head Zero flow
	Reduced impeller diameter	Low flow or head
	Insufficient NPSHA	Low flow or head Impeller cavitation
	Reduced speed	Low flow or head
	Impeller clogged	Low flow or head
Vibration		
High-frequency vibration rolling element bearings	Insufficient lubrication	Pitting/spalling of bearing races Cage breakage Cage wear Seizure

Table B.1 — Condition monitoring indicators (*continued*)

Indicators	Cause	Failure Mode
High vibration level	Contaminated oil	Bearing cage wear
	Incorrect bearing fit	Bearing race rotation
	Shaft movement (runout)	Mechanical seal face wear Flexible coupling failure
	Excessive shaft deflection	Mechanical seal spring failure Mechanical seal bellows failure
	Improper installation of coupling	Flexible coupling failure
	Loose coupling hub	Flexible coupling failure
	Shaft runout	Flexible coupling failure
	Incorrect shaft manufacturing	Shaft bending fatigue
	Corrosion	Shaft bending fatigue Shaft torsional fatigue
	Resonant frequency	Shaft torsional fatigue
	Vane pass excitation	Shaft torsional fatigue
	Excessive flow	Impeller cavitation
	Excessive fluid temperature	Impeller cavitation
	Impeller manufacturing error	Impeller cavitation
Temperature		
Excessive process fluid temperature	Process upset	Casing/impeller corrosion Seal component corrosion
Excessive seal chamber temperature	Loss of cooling	Corrosion of seal springs/bellows Mating ring corrosion Mating ring wear/heat checking
Seal face temperature	Excessive face loading	Seal face wear/grooving
	Lack of lubricant	Seal face checking
	Wrong lubricant	Seal face wear/grooving

Table B.1 — Condition monitoring indicators (*continued*)

Indicators	Cause	Failure Mode
Bearing temperature	Excessive static or dynamic loads	Pitting/spalling of bearing races Bearing seizure
Corrosion		
Corrosion monitor	Incorrect materials of construction	Corrosion of casing, impeller, and/or seal
	Excessive temperature	Corrosion of casing, impeller, and/or seal
	Fluid variation	Corrosion of casing, impeller, and/or seal
	Electrolytic cell	Corrosion of casing, impeller, and/or seal
Leak Detection		
Leak observation at seal	Improper installation	Seal spring or bellows failure
	Wrong material	Corrosion of springs and bellows Secondary seal corrosion/attack
Leak observation gasket joint	Insufficient gasket load	Gasket failure
	Gasket corrosion	Gasket failure
	O-ring corrosion	O-ring failure
Pressure		
Casing liquid pressure	Change in system	Loss of head/flow
	Excessive pressure	Casing/cover leakage
Seal reservoir pressure/level	Insufficient vapor pressure margin	Seal face heat checking
	Lack of lubricant	High seal face wear Seal face spalling
Lubricant		
Lubricant analysis	Contaminated lubricant	Seal face wear Bearing failure

Table B.1 — Condition monitoring indicators (*continued*)

Indicators	Cause	Failure Mode
Shaft position	Shaft runout	Drive mechanism wear Secondary seal wear
	Excessive deflection	Seal spring/bellows failure
Flow Measurement		
Process flow	Insufficient flow	Plugged impeller
	Excessive solids	Plugged impeller
	Increased clearances	Loss in head/flow
	Changes in system	Loss in head/flow
	Excessive flow	High power
Maintenance Inspection		
Inspection of coupling	Overloaded key	Coupling key sheared
	Wrong key material	Coupling key sheared
	Worn key/keyway	Coupling key sheared
	Corrosion of coupling	Coupling flex element failure
	Incorrect coupling selection	Coupling flex element failure
Inspection of shaft	Corrosion of shaft	Shaft bending fatigue
	Shaft material defect	Torsional overload
Inspection of liquid end parts	Incorrect material	Casing, cover, impeller, and ring wear
	Fluidborne abrasives	Casing, cover, impeller, and ring wear
	Low flow operation	Impeller wear
	Increased clearances	Low head/flow
	Impeller diameter change	Low head/flow

Table B.1 — Condition monitoring indicators (*continued*)

Indicators	Cause	Failure Mode
Speed (rpm)		
Speed measurement	Low speed	Low head/flow
Bearing Wear Detector		
Bearing wear detector	Insufficient lubricant	Worn bearing
	Cavitation	Worn bearing
	Abrasives in lubricant	Worn bearing
Preinstallation Hydrostatic Test		
Assembled liquid end	Cut gasket	Gasket leak
	Incorrect surface finish	Gasket/O-ring leak
	Cut O-ring	O-ring leak
	Casing/cover defect	Casing/cover leak
Design Review		
Design review	Incorrect pump	Plugged impeller
	Suction piping	Air-bound impeller Impeller cavitation

Appendix C

Definitions

This appendix is not part of the standard, but is included to help the user with factors referenced in the standard.

accuracy Accuracy is a measure of how closely the measured value agrees with the true value or how closely the controlled (actual) value agrees with the target (set point) value.

baseline The baseline is the beginning. In condition monitoring, baseline measurements are the values measured at the beginning of the monitoring process. Baseline condition is the condition at the beginning of the monitoring process. Baseline condition may be compared with current condition to detect changes and to predict and prevent failure.

cause A cause is a reason for a condition such as a failure condition.

condition The condition of a rotodynamic pump is its status, and is indicated by measurable parameters. For example, vibration amplitude is a measurable parameter; high vibration amplitude may indicate a condition of imbalance.

condition monitoring Condition monitoring is a process of monitoring measurable parameters, i.e., indicators, to determine the condition of a rotodynamic pump. The measured values are the process inputs. Condition of the pump is the process output.

control limits Control limits are upper and lower bounds allowed by the condition monitoring process.

failure Failure of a rotodynamic pump is a condition in which the pump does not satisfy specified operating limits. For example, if the pump must operate with bearing temperature below 150 °F and actual bearing temperature is 200 °F, the bearing has overheated and the pump is a failure.

failure mode A failure mode is a general description of the manifestation of the failure.

indicator Indicators are parameters identified by this standard as especially important to monitor because their measured values may be used to anticipate, predict, and/or prevent pump failure conditions.

informative The informative portion of a standard is reference information not mandatory for compliance.

monitoring Monitoring is a process of measuring or observing over a period of time. The monitoring process has a beginning and an end.

normative The normative portion of a standard is prescriptive in nature and thereby mandatory for compliance.

parameter Parameters are measurable or observable physical properties that may be used to describe the condition of a rotodynamic pump.

process A process that converts inputs into outputs. For example, a condition monitoring process may convert a mV thermocouple signal, as an input, into an output. The output will vary depending on the logic of the process. If the input value exceeds limits allowed by the process, then the process output may be an alarm or automatic equipment shutdown.

repeatability Repeatability is a measure of variation among a set of measurements.

stability Stability is a measure of changeability over time. A process is said to be stable when all of the response parameters used to measure the process have both constant means and constant variances over time, and also have a constant distribution.[1]

tolerance Tolerances are limits allowed for variation in measured values. Measured values falling out of tolerance indicate nonconformance with specified requirements.

trending Trending is baselining combined with monitoring. Trending shows trends, i.e., change and rate of change over the period of time monitored. Trends enable prediction of future performance, prevention of future problems, and help with troubleshooting of problems.

[1] *NIST/SEMATECH e-Handbook of Statistical Methods*, http://www.itl.nist.gov/div898/handbook/, 7/8/09.

Appendix D

Index

This appendix is not part of this standard, but is presented to help the user with factors referenced in the standard.

Note: an f. indicates a figure, and a t. indicates a table.

"БУРГАСНЕФТЕПРОЕКТ" ЕООД
Регистрационен индекс и дата
0333-ГБ 09.07.14

Подписващ :
Р. Пенев
Директор Дирекция
Капитално строителство

Подписващ :
L. Buonanno
Project Manager
SICES

Дата на срещата:
03.07.2014

Място на срещата:
„ЛУКОЙЛ Нефтохим Бургас" АД
ПТ Росенец в сградата на пожарната

Присъстващи:
Председател:
Ст. Буланов

ЛНБ
С. Буланов
П. Пулев
И. Иванов

SICES
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Maria Bakardzhieva

ПТР
К. Стоянов
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Р. Димов
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БНП
К. Иванов

G.P. GROUP
Т. Бояджиев
А. Тодоров

ЕК-5
Х. Стефанов

Протокол № 2

Съвещанието е открито от г-н С. Буланов с преглед изпълнението на задачите по Протокол №1 и приемане на нови решения.

1. SICES до 09.07.2014 г. да подготви и предаде списък на упълномощените лица за подписване на актове по Наредба №3./By 09.07.2014 Sices should prepare and submit a list of authorized persons to sign Acts in compliance with Ordinance No: 3.

2. SICES до 09.07.2014 г. да подготви и предаде списък на подизпълнителите извършващи СМР./ By 09.07.2014 Sices should prepare and submit a list of the subcontractors executing construction and assembly works.

3. SICES до 09.07.2014 г. да представи план за управление на отпадъците./ By 09.07.2014 Sices should submit Waste Management Plan.

4. За извършване на инструктаж SICES до 11.07.2014 г. да представи списък на служителите и работния персонал с приложени документи /удостоверения за

правоспособност, категории за Ел. защита и др/. / By 11.07.2014 Sices should submit a list of the employees and workers for training together with the necessary documents/certificates, electrical protection categories etc.

5. БНП до 21.07.2014 г. да представи метод и показатели за извършване на пробни статични натоварвания на пилотите./ By 21.07.2014 BNP should submit method and parameters for execution of test static loading of the piles.

6. Производство НТ Росенец да осигури непрекъснато подаване на ток към временното селище./ Port Terminal Rosenets should provide constant power supply to the temporary facilities.

7. Производство НТ Росенец, ДКС и SICES до 15.07.2014 г. да уточнят трасетата на кабелите за временно Ел. захранване на Площадка III./By 15.07.2014 Port Terminal Rosenets, DKS (State Construction Control) and Sices should specify the routes of the cables for temporary power supply of Site III.

8. Следващите оперативно съвещание по изключение ще се проведе на 11.07.2014 г. от 11.00 часа на ПТ Росенец в сградата на пожарната./ As an exception next weekly meeting shall be held at 11:00 on Friday - 11.07.2014 in the building of the Fire Department.

Протоколчик:
/Ив. Иванов/
Тел. 23-19