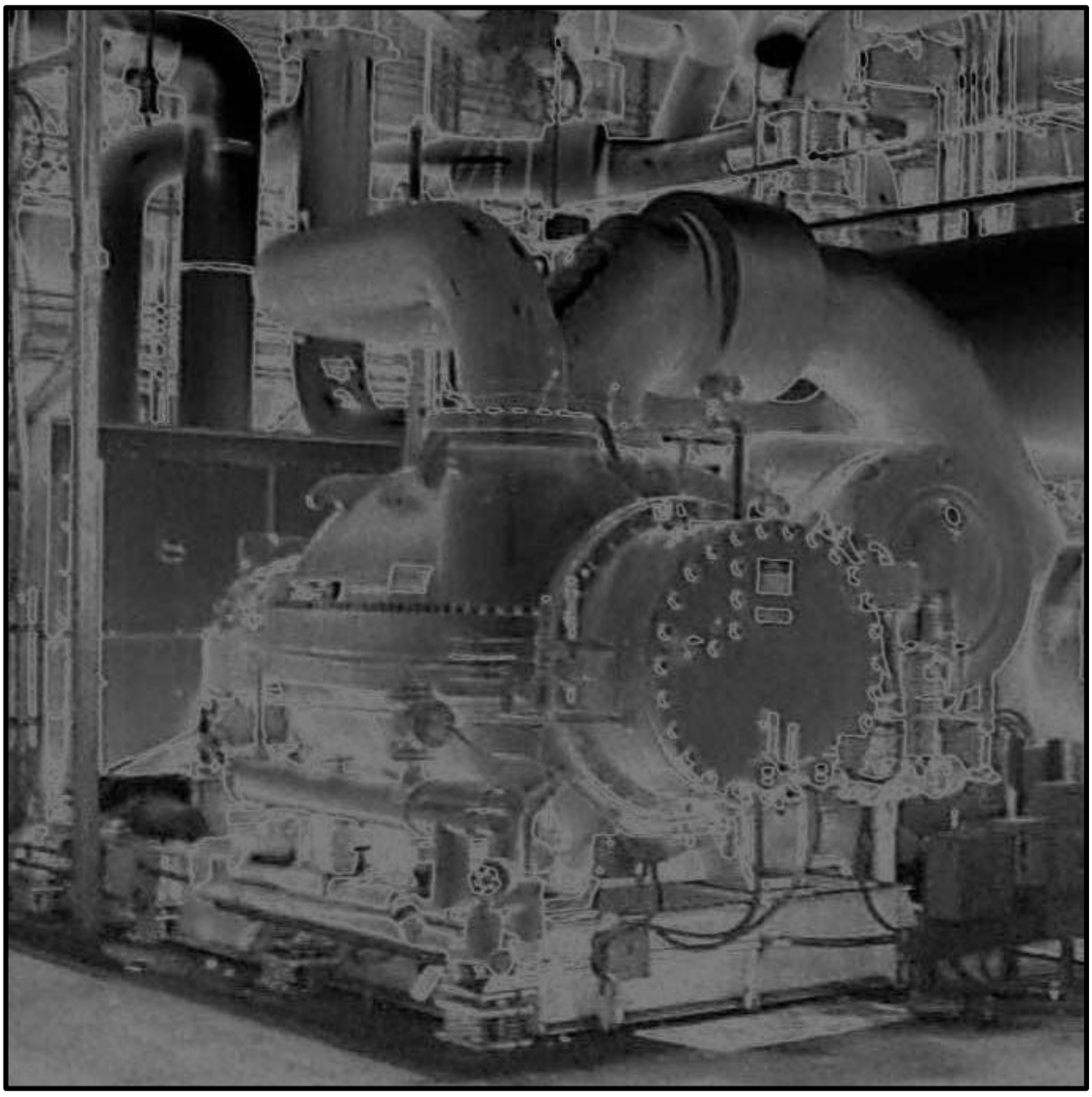
National Aeronautics and Space Administration

Standardized Facilities Preventive Maintenance Work Task Guide

(with initial performance frequencies and PT&I alarm values)



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Foreword

NASA sites have been converting to Performance Based Contracting for facilities maintenance during the same time that they have been moving to Reliability Centered Maintenance (RCM). Because of these parallel efforts at multiple sites, NASA had lost the initial opportunity to incorporate Standardized Preventive Maintenance (PM) work tasks that incorporated sensible and cost-effective RCM philosophy and Predictive Testing & Inspection (PT&I) technologies where applicable. This Guide provides samples tasks for the most common types of equipment found at NASA Centers (including Component Facilities). These tasks may be useful to the Centers in characterizing minimum maintenance requirements for maintenance contracts and for the future development of site and equipment specific tasks.

The work tasks in this Guide follow the approach developed in the NASA Reliability-Centered Maintenance Guide[1], Appendix J. Alert and alarm values, when applicable, have been included within the procedures. The alert and alarm values, along with the procedure steps, provide information applicable to a large population of machines, but not specific to any one machine. In order to be useful, the procedure may need to be changed to completely address the differences found both between Centers, and between different sites within the same Center. Within the same Center or site, differences will often be encountered due to different systems configurations, especially parallel configurations of the same machine that results in reduced system criticality and the related reduced consequences of failure. Between Centers, differences are often related to operating environments. This Guide is intended to be a tool that the Centers can use, along with Reliability-Centered Maintenance analysis, to develop effective facilities maintenance.

Comments or suggestions related to the content of this guide should be sent to:

National Aeronautics and Space Administration
NASA Headquarters, Attention: Code JX
Washington, DC 20546

[1] The latest version of the Reliability-Centered Maintenance Guide can be found on the NASA Internet web page (www.hq.nasa.gov/office/codej/codejx/)

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Standard Work Task

The objective of the Standard Work Task is to provide instructions without becoming overly detailed. Simple steps, that provide little value for the typical work force, have not been included. In some high-risk industry, like nuclear power, work tasks are extremely detailed and often do not allow even minor deviation when accomplishing. That is not the basis for the NASA Standard Work Task.

Reliability-Centered Maintenance Issues

This Guide is developed to help NASA Centers provide a convenient standardized starting point for how to perform preventive maintenance tasks for facilities systems and sets initial PT&I alarm limits. Reliability-Centered Maintenance (RCM) is discussed in detail in NASA's Reliability-Centered Maintenance Guide[2]. The focus of RCM is the selection of the most effective maintenance approach and requires an understanding of the selected machine's failure modes and the consequences of that failure. The consequences of failure will vary both from Center to Center and within any single Center, depending on the operating context of the machine or machine system.

A detailed RCM analysis of the common NASA facilities equipment is beyond the scope of this Guide and is a function to be performed by the NASA Center. However, the application of RCM principles has been used to identify and develop the sample procedures found in this Guide. For each equipment category in this Guide, there is a discussion of the most common (the dominant) failure modes. Failure modes are equipment and component-specific failures that result in functional failure of the facility system or subsystem. For example, a machinery system composed of a motor and pump can fail catastrophically due to failure of the motor windings, pump and motor bearings, shaft, impeller, controller, or seals. In addition, a functional failure also occurs if the pump performance degrades such that insufficient discharge pressure or flow exists to meet operating requirements.

Dominant failure modes are those failure modes responsible for a significant proportion of all the failures of the item. They are the most common modes of failure; the modes with the highest probability of occurring. They are the failure modes we try to control through maintenance. Other failure modes may not warrant maintenance because the likelihood of their occurring is remote or their effects are inconsequential.

Equipment Selection

The equipment selected for inclusion in this Guide is based upon an analysis of maintenance data provided by the Centers. This data included systems listings, maintenance procedures, and labor hours. The labor hours provided were either estimated hours used by the Center maintenance scheduling and management systems or actual hours expended. After a detailed review of the data, a Pareto analysis of the actual hours expended was used to identify the approximately 20% of the items that account for approximately 80% of the Center's

[2] The latest version of the Reliability-Centered Maintenance Guide can be found on the NASA Internet web page (www.hq.nasa.gov/office/codej/codejx/).

maintenance cost. There are 105 line items (equipment types) represented in the data including a Miscellaneous category of items that did not clearly fit one of the common equipment types.

The outcome of the analysis was a classic Pareto. The top 20% of the equipment types, as regards hours expended, was 21 of the 105 equipment categories. And the actual labor expended for those 21 equipment categories was approximately 80% of the total labor hours expended. That is, out of approximately 1,426,104 hours reported expended, approximately 1,136,603 hours is attributable to 21 equipment categories. Appendix B provides more details on the data analysis that was performed.

Maintenance Approach

The maintenance approach is based upon identifying, mitigating, and/or preventing failure. In addition to the failure mode, the consequence of failure must also be considered. For each equipment category in this Guide, there is a table that identifies the maintenance approach for the Equipment Items within the category. The table includes the Equipment Item, the applicable procedures, and three Periodicity Codes. The Periodicity Codes are provided to assist the NASA Centers in determining how often to perform the maintenance task based upon the consequences of failure. The periodicity can range from never performing (that is, let the equipment item run to failure), to performing often, sometimes on an hourly basis. Table 1 provides the method used to rank system criticality based upon the consequences of failure. This method is based upon a recommended approach for ranking potential industrial fire hazards[3] and is adapted from the military's safety program[4]. The word "facility" usually means the system, building, or area.

The periodicity is a recommended strategy based upon the three mid-rankings, as these are the areas where maintenance is most likely. For the lowest ranked systems (identified as Rank Number 1 on Table 1), a run-to-failure approach is often used. And in the highest ranked systems (Ranking Number 5), a redesign effort is usually undertaken to shift the consequence of failure to a lower rank. Facility systems rarely have a Catastrophic consequence of failure because such a system design would be intolerable.

An RCM analysis of the system, performed by the NASA Center, is necessary to assess the operating conditions/environment and the consequence of failure (factoring equipment redundancy) to then selecting the optimal maintenance approach.

[3] Industrial Fire Hazards Handbook, Third Edition, Arthur Cote, Editor-in-Chief, National Fire Protection Association, 1990, page 23.
[4] US Department of Defense, MIL-STD-882A, Military Standard: System Safety Program Requirements, 1977.

The recommended strategy identified in the table can, and should, be adjusted based upon more (or less) stressful operating conditions. System redundancies should be factored into the consequence of failure before selecting a specific strategy.

Table 1: Criticality Ranking

Ranking	Effect	Consequence
1	Negligible	The loss of function will be so minor that it would have no discernible effect on the facility or its operations.
2	Minimal	The loss will cause minimal curtailment of operations or may require minimal monetary investment to restore full operations. Normal contingency planning would cover the loss.
3	Marginal	The loss will have noticeable impact on the facility. It may have to suspend some operations briefly. Some monetary investments may be necessary to restore full operations. May cause minor personal injury.
4	Critical	Will cause personal injury or substantial economic damage. Loss would not be disastrous, but the facility would have to suspend at least part of its operations immediately and temporarily. Reopening the facility would require significant monetary investments.
5	Catastrophic	Will produce death or multiple death or injuries, or the impact on operations will be disastrous, resulting in long-term or permanent closing of the facility. The facility would cease to operate immediately after the event occurred.

Predictive Testing and Inspection

Predictive Testing and Inspection (PT&I), including sample procedures, is discussed in detail in the NASA Reliability-Centered Maintenance Guide[5] (sample procedures are in Appendix J). When it is applicable, the use of PT&I is included in the Maintenance Approach developed in this Guide. The PT&I procedures in this Guide (see the Procedures section) have, in some cases, been changed from the version found in the NASA Reliability-Centered Maintenance Guide. Changes were made to correct minor technical or typing errors and to add to, or expand, the information in the procedure.

Age Exploration

Age exploration is the process of determining the most effective intervals for maintenance tasks in order to reduce the cost of unnecessary and/or ineffective maintenance. Its called age exploration because it is often associated with identifying age related maintenance actions such as overhaul and discard tasks and then extending the interval between tasks.

[5] The latest version of the Reliability-Centered Maintenance Guide can be found on the NASA Internet web page (www.hq.nasa.gov/office/codej/codejx/)

The concept of age exploration was introduced as an RCM process in Nowlan and Heap's seminal publication, Reliability-Centered Maintenance[6]. When introduced, most maintenance actions were based on elapsed time or cycles and there was limited cost effective condition monitoring technologies (PT&I) available. Throughout this Guide overhaul and discard tasks are always based on monitored conditions, when cost effective PT&I is available. However the recommended task periodicity is just that, a recommendation, even when applicable PT&I technologies are not available. The use of Age Exploration should be evaluated to determine effective maintenance intervals. Age Exploration of safety-related components is possible, but only if they are de-coupled from their safety function. For example, the overhaul interval of safety relief valves could be examined using Age Exploration if a sample population of the valves could be operated and examined in a controlled condition, under the same in-service conditions, but not tied to the safety relief function.

Related to Age Exploration is the setting of inspection and PT&I monitoring intervals. Inspection is performed to uncover hidden failure. PT&I monitoring intervals are set in order to determine the onset of failure and to take an action before the failure occurs. Like all time/cycle tasks, if the interval is too short, there will be wasted effort (labor and material). And if the interval is too long, failures will occur. All of the intervals identified in this Guide are recommendations that must be examined by the Center and adjusted based upon specific machine conditions. For example, all of the PT&I intervals should be adjusted by the data analysts as they see conditions change. A quarterly vibration collection may shift to monthly or even weekly as a degrading condition develops. Likewise, following overhaul, the vibration data collection could start with a monthly interval and then move to a quarterly or semi-annual basis as the machine moves away from the infant mortality failure region.

Maintenance Approach Tables

The Maintenance Approach table is the mechanism for documenting the maintenance approach. There is a table for each Equipment Category developed in this Guide. Table 2 (below) provides a sample Maintenance Approach Table. In the table the periodicity's are labeled 2 through 4 and correspond to the three middle ranking numbers in Table 1 (Criticality Ranking Number 2, 3, and 4). The remainder of the table provides the equipment name and procedure information.

Table 2: Sample Maintenance Approach Table

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4

[6] F. Stanley Nowlan and Howard F. Heap, Reliability Centered Maintenance, United Airlines and Dolby Press, sponsored and published by the Office of Assistant Secretary of Defense, 1978

Periodicity Codes

The Periodicity Codes describe how often the procedure is to be performed. NASA Centers will want to modify the periodicity code to fit the site. Codes used in this Guide are:

D = Daily
W = Weekly
M = Monthly
Q = Quarterly
S = Semi-Annually
A = Annually
OC = On Condition: usually based upon results of a Predictive Testing & Inspection test.

Multiples of the above are sometimes used and are identified by a number followed by a letter. For example, 5A indicates a procedure is scheduled every 5 years.

Procedure Layout

The Standard Work Task is presented in a column format. The first column provides a heading or procedure number. The second column has text. There are no special characters or text highlighting (such as bolding) in order to enable a smooth transition into the CMMS.

The procedure layout is such that all actions are taken in sequence. A person performing the procedure should arrive at the work site with all of the necessary tools and materials (including reference material).

Standard Work Task headings are as follows:

Procedure Number - The number is assigned for use in referring to the procedure in this Guide.

System Description - This section is text that describes the machine/equipment application.

Procedure Description - Text to describe what the procedure does. The body of the procedure is often divided into sub-sections. Each sub-section has a heading and that heading is duplicated in the Procedure Description. This ensures that the entire scope of work is well understood.

Related Tasks - Identifies other tasks that should be performed. Usually tasks with a shorter periodicity. For example, an annual procedure will identify any semi-annual, quarterly, or monthly procedures to ensure that all work is done during a single visit to the work site.

Labor (Hrs) - This area is reserved for the NASA Center use. No estimates are provided in this Guide.

Special Tools - Identifies tools and test equipment that the technician will need at the job site. Common tools are not usually identified.

Materials - All materials that will be needed at the job site are listed in this section.

Reference Data - Identifies information, such as a test procedure, that the technician will need in order to perform the task. This section does not identify reference data that may have

been used to develop the procedure. Only that reference data needed to perform the task is listed in this section.

Warning Summary - A warning is identified in the procedure anytime there is the potential for injury (including toxic release to the environment). This section lists every warning that is part of the procedure. If a warning is used many times in the procedure, it is only listed once in this section.

Caution Summary - Similar to warning summary. A caution is identified in the procedure anytime there is the potential for damage to the equipment or damage to collateral equipment. Although not listed in a summary block, the procedure may also contain a Note. A note provides relevant information to the person performing the procedure.

Preliminary - The first part of the procedure is identified as the preliminary section. This section includes all steps taken before going to the job site, or if at the job site, before starting work on the specified machine. Although there is not a maximum number of preliminary steps, this section is usually less than 10 steps.

Procedure - The start of the procedure is clearly identified by the title "Procedure." The first step in the procedure is labeled "A" and is a phrase that identifies the work to be accomplished. The next step is labeled "A1" and is an action item. Each subsequent action step is numbered in ascending order, "A2, A3, ..." If the procedure can be broken into discrete sections, there maybe a "B" , "C", etc.

Inspection Data - If data is to be collected, there will usually be an Inspection Data section. The procedure will identify the data and direct where it is to recorded in the Inspection Data section or other location. The Inspection Data section is always located at the end of the Procedure section.

A section at the end of the Standard Work Task is identified as Engineers Notes. The Engineers Notes provides background information that may be useful when developing site-specific procedures. It is not part of the procedure in that it is not designed to be provided (printed out) for use in the field or entered into the site CMMS. The Engineers Notes are a tool for use in developing site-specific procedures.

Equipment Maintenance Approach

Transformers

Equipment types: Facility Transformer (Dry Type and Oil Filled), Distribution Transformer (Dry Type, Silicone and Mineral Oil Filled), Power Transformer (Oil Filled).

Reliability-Centered Maintenance Issues

Transformers have either dry insulation or liquid (mineral oil or silicone) insulation. Liquid insulated units consist of a steel tank, core and windings, high and low voltage bushings, temperature, liquid level, and pressure gauges, a dry nitrogen system or conservator, internal tap changer, concrete base, and connection to the local ground equipoise. Dry type units include the core and windings, high and low voltage bushings, temperature gauges, a vented

covering or enclosure, and the same internal tap changer, concrete base, and ground connection as liquid insulated units. On-load tap changers are not included in this section.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Facility Transformer, dry type, less than 300kVA, 120/208 volt secondary.	Tran-01	Inspect and Clean Dry Type Transformer	RTF	5A	3A
Facility Transformer, oil filled, less than 300kVA, 120/208 volt secondary.	Tran-02	Inspect and Clean Liquid Filled Transformer	RTF	3A	1A
	PT&I-04	Test Insulation	RTF	3A	1A
	PT&I-06	Sample and Test Transformer Oil	RTF	3A	1A
Distribution Transformer, silicone oil filled, from 4160 to 24,000 volts, 300kVA to 2MVA.	Tran-02	Inspect and Clean Liquid Filled Transformer	3A	3A	1A
	PT&I-04	Test Insulation	3A	3A	1A
	PT&I-06	Sample and Test Transformer Oil	1A	1A	1A
	PT&I-07	Power Factor Test	3A	3A	1A
Distribution Transformer, mineral oil filled, from 4160 to 24,000 volts, 300kVA to 2MVA.	Tran-02	Inspect and Clean Liquid Filled Transformer	3A	3A	1A
	PT&I-04	Test Insulation	3A	3A	1A
	PT&I-06	Sample and Test Transformer Oil	1A	1A	1A
	PT&I-07	Power Factor Test	3A	3A	1A
Distribution Transformer, dry type, from 4160 to 24,000 volts, 300kVA to 2MVA.	Tran-01	Inspect and Clean Dry Type Transformer	3A	3A	1A
	PT&I-04	Test Insulation	3A	3A	1A
	PT&I-07	Power Factor Test	3A	3A	1A
Power Transformer, oil filled, above 24,000 volts, over 2MVA.	Tran-02	Inspect and Clean Liquid Filled Transformer	1A	1A	1A
	PT&I-04	Test Insulation	1A	1A	1A
	PT&I-06	Sample and Test Transformer Oil	1A	1A	SA
	PT&I-07	Power Factor Test	1A	1A	1A
	PT&I-09	Power Factor Test	1A	1A	1A

Transformer dominant failure modes are deterioration of the electrical insulation, deterioration of the electrical connections, and exterior corrosion. Over time, heat generated internally slowly breaks down the paper insulation in all types of transformers. For oil filled transformers, the oil insulation system also deteriorates, also due to heat. In dry type units, moisture contamination contributes to the insulation deterioration. Repeated heating and

cooling cycling can loosen connections, both internal (tap connections, winding termination points) and external (bushing connections). Harsh ambient conditions can corrode transformer tanks, cooling fins, and attached accessories such as control panels and conservator tanks.

Most of the above failure modes progress slowly over time. Consequently go/no-go tests such as turns-ratio testing are ineffective at finding failure patterns. Trending test data is necessary to identify these failure patterns. The maintenance approach for transformers therefore focuses on using applicable PT&I technologies such as infrared thermography, oil testing and insulation power factor testing.

The Institute of Electrical and Electronic Engineers reports that the average downtime following a failure was 342 hours when there was no spare replacement transformer (601 to 15,000 volt) available[7]. This was the amount of time necessary to repair the unit and return it to service. However, a significant number of transformer failures are catastrophic in nature, can not be repaired and must be replaced. Costs of new units vary depending on size and type, and can range from $1,500 for a pole mount 25kVA unit to $250,000 for a 50MVA substation/switchyard unit. Additionally, lead-time for receiving a new unit ranges from 6-8 weeks for a small pole mount unit to 16-24 weeks for a larger, substation unit.

Circuit Breakers and Switchgear

Equipment types:

Circuit Breakers: Low Voltage (600 Volts and below) – Air and Molded Case. Medium Voltage (601 to 69,000 Volts) –SF_6, Oil Filled, Air, and Vacuum. High Voltage (above 69,000 Volts) –SF_6 and Oil Filled. Switchgear: Low Voltage and Medium Voltage.

Reliability-Centered Maintenance Issues

Circuit breakers come in four basic configurations:

- Molded Case – a sealed breaker with self-contained tripping and overload mechanisms.
- Oil Filled – mineral oil is the primary insulating medium. Normally medium and high voltage range.
- Vacuum – a ceramic cylinder contains the operating contacts. The insulating medium is a lack of air in the bottle, which allows for close contacts. This type of breaker is normally only used for medium voltage systems.
- Sulfur Hexifloride (SF_6) – SF_6 is used as the insulating medium. Operating voltage can be as high as 500 kV rated.

Circuit breakers include the mounting frame, tanks (for oil breakers), breaker control panel, operating mechanism, and connection bushings. Relays associated with these circuit breakers are not included in this section.

[7] IEEE Committee Report, Report on Reliability Survey of Industrial Plants, IEEE Transactions on Industry Applications and contained in the current ANSI/IEEE std 244-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, Table 47A.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Low Voltage Circuit Breaker, molded case	Panel-01	Inspection of Low Voltage Panels	RTF	3A	A
Low Voltage Circuit Breaker, Air.	Brkr-01	Inspect and Test Air Circuit Breaker	5A	3A	A
	PT&I-05	Test Insulation	5A	3A	A
Medium Voltage Circuit Breaker, Air	Brkr-01	Inspect and Test Air Circuit Breaker	5A	3A	A
	PT&I-05	Test Insulation	5A	3A	A
	PT&I-08	Power Factor Test	5A	3A	A
Medium Voltage Circuit Breaker, Vacuum	Brkr-02	Inspect and Test Vacuum or Oil Filled Circuit Breaker	3A	3A	A
	PT&I-05	Test Insulation	3A	3A	A
	PT&I-08	Power Factor Test	3A	3A	A
Medium Voltage Circuit Breaker, Oil Filled	Brkr-02	Inspect and Clean Transformer	3A	3A	A
	PT&I-05	Test Insulation	3A	3A	A
	PT&I-08	Power Factor Test	3A	3A	A
	PT&I-09	Power Factor Test	3A	3A	A
Medium Voltage Circuit Breaker, SF_6	Brkr-03	Inspect and Test SF_6 Circuit Breaker	3A	3A	A
	PT&I-05	Test Insulation	3A	3A	A
	PT&I-08	Power Factor Test	3A	3A	A
High Voltage Circuit Breaker, Oil Filled	Brkr-02	Inspect and Test Vacuum or Oil Filled Circuit Breaker	3A	3A	A
	PT&I-05	Test Insulation	3A	3A	A
	PT&I-08	Power Factor Test	3A	3A	A
	PT&I-09	Power Factor Test	3A	3A	A
High Voltage Circuit Breaker, SF_6	Brkr-03	Inspect and Test SF_6 Circuit Breaker	3A	3A	A
	PT&I-05	Test Insulation	3A	3A	A
	PT&I-08	Power Factor Test	3A	3A	A
	PT&I-09	Power Factor Test	3A	3A	A

Dominant failure modes for circuit breakers are binding in the operating mechanism, control circuitry failure, development of high resistance in the power connections, exterior corrosion, and deterioration of the electrical insulation. Of these failure modes, binding operating

mechanism and control circuitry failure are the most common, resulting in a circuit breaker that will not open or close as required. For oil filled breakers the oil system also deteriorates due to repeated operations, and for SF_6 breakers (SF_6 gas is the insulating medium) leaks in the SF_6 containment is a dominant failure mode.

It should be noted in the periodicity section of the above table that some breakers have recommended maintenance frequencies of no longer than three years, and only low voltage molded case breakers should be run to failure. The limiting factors for these determinations is both cost and reliability. The cost of new breakers varies depending on the type and size. A small 20 amp molded case breaker can cost under $20. However, a 115kV, 1200 amp SF_6 breaker can often cost well over $60,000, thus requiring a maintenance frequency of no longer than three years. Medium and high voltage units (especially SF_6 and air breakers) also benefit from maintenance cycles of three years or less. Lead times for receiving new breakers will also vary. Most molded case breakers are stocked by electrical supply houses and can be delivered to the work site within two to three days. Medium and high voltage breakers are almost always special order items and can have lead times from eight weeks to six months, depending on the breaker size and type.

Switchgear is normally made up of individual compartments that contain the circuit breakers and control circuits. Those compartments are attached to an insulated bus enclosure. The circuit breakers rack onto/into the bus enclosure to energize. The switchgear includes the enclosures, control circuits, mounting frame, mounting base, and bus work.

Dominant failure modes for switchgear are high resistance at bolted connections, control relay failure, and corrosion for units installed outdoors or in harsh environments. Additional failure modes that cause operational difficulties include racking mechanism failure (not allowing a breaker to be racked in/out) and shutter assembly/insulation barrier failure (which would not allow a breaker to be racked in or leave energized bus connection uncovered).

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Low Voltage Switchgear	Swthgear-01	Clean and Inspect Switchgear	5A	3A	A
	PT&I-05	Test Insulation	5A	3A	A
Medium Voltage Switchgear	Swthgear-01	Clean and Inspect Switchgear	3A	3A	A
	PT&I-05	Test Insulation	3A	3A	A
	PT&I-08	Power Factor Test	3A	3A	A

Of the dominant failure modes the one with the most serious consequences is high resistance at bolted connections. Switchgear bus and breaker stabs are made from copper bar stock and are normally made on an as ordered basis. Typically the bar is bent into specific angles and various lengths to fit the configuration of the switchgear. A failure at one of the bolted connections normally results in a bus bar that becomes greatly distorted and not able to be reused. Replacement times depend on the manufacturer being able to obtain the proper

copper bar stock and then manufacturing it into the proper configuration. A minimum of two weeks is normally required. As a result the use of PT&I technologies, Infrared Thermography and Ultrasonic testing, become very important for long term reliability.

High Voltage Electric Power Distribution Switches

Equipment types:

High Voltage (above 69,000 Volts) - air knife switch

Medium Voltage (601 to 69,000 Volts) –air knife switch, disconnect air switch, load-break SF_6, load-break oil, load-brake vacuum

Reliability-Centered Maintenance Issues

High and medium voltage switches come in four basic configurations:

- Air -not designed to open or close under load.
- Oil - can be opened under load, uses mineral oil as an insulating and arc-quenching medium.
- Vacuum - can be opened under load, uses a ceramic bottle, void of air, for an insulating medium.
- Sulfur Hexafloride (SF_6) - can be opened under load, uses SF_6 as the insulating medium.

All switches include termination points (either bushings or pot-heads), rotating operating mechanisms, stationary and moving contact assemblies, and mounting frames anchored to a solid base. The load-break switches all have an insulating medium contained within a pressure boundary.

Air switches, normally found in switchyards, are called air knife switches and are operated with a “hot stick” which attaches to a pull-ring. The operator either pulls the switch open, or pushes it closed. Enclosed air switches, called air disconnect switches, are operated with a spring-loaded mechanism and a handle that is pulled or pushed. All of the other switches, the load-break switches, are operated with a spring-loaded rotating handle. In addition, all of the various types of switches can be equipped with remote electrical operators, but the cost is usually prohibitive.

The dominant failure mode of all air knife switches is high resistance at the contacts. In addition to high contact resistance air disconnect switches also can suffer from operating mechanism failure, normally not allowing the unit to open or close properly. This failure mode tends to be a hidden failure, not manifesting itself until the unit is called upon to operate. Because these switches are not operated under load, this hidden failure is usually just a time consuming nuisance and not safety related.

Dominant failure modes for the load-brake switches are high resistance at the bolted connection (where the load and line side cables or bus connect) and SF_6 gas or oil leaks. The probability of failure of the switch itself is low since the operating mechanism and contact assemblies are located in the insulating medium, however loss of the insulating medium can increase the probability of catastrophic failure.

For all types of switches harsh ambient conditions can corrode enclosures, contaminate insulation and insulators, and cause operating mechanisms to corrode or loosen.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Medium and High Voltage Air Knife Switch	Switch-01	Inspect and Test Air Switch	5A	3A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	A	6M	Q
	PT&I-05	Test Insulation	RTF	3A	A
Medium Voltage Disconnect Air Switch	Switch-01	Inspect and Test Air Switch	3A	2A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	6M
	PT&I-05	Test Insulation	3A	2A	A
Medium Voltage Oil Loadbreak Switch	Switch-02	Inspect and Test Loadbreak Switch	3A	2A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	A	6M	Q
Medium Voltage Vacuum and SF_6Loadbreak Switch	Switch-03	Inspect and Test Loadbreak Switch	3A	2A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	A	6M	Q

The maintenance approach for high and medium voltage air knife switches is a combination of infrared thermography to identify high resistance contacts and connections, and both visual inspection and testing to verify insulation integrity. These switches are usually exposed to the environment and often undergo large temperature swings. This can lead to contact assemblies becoming loose, contributing to high resistance connections. The maintenance approach for the remaining air and load-break switches is also infrared thermography and visual inspection and testing, with the testing emphasis being on the insulating medium. Most of these switches can expect to have a life expectancy of at least 30 years. Replacement costs of switches cover a wide range, depending on the application and switch rating. A 15kV knife switch can cost as little as $600 per phase, where as a six-position SF_6 load-break switch, rated 15kV, 1200 amps, can cost upwards of $50,000. All switches of these types tend to be manufactured on an as-ordered basis, with lead times on the order of eight weeks not uncommon.

Electric Power Distribution Relays/Meters

Equipment types: Solid-state; Protective Relays, Metering, and Event Recording. Electromechanical; Protective Relays. Analog; Metering and Event Recording.

Reliability-Centered Maintenance Issues

Protective relays protect the electrical system from serious damage during faults or weather events. They trip circuits that are undergoing a failure (such as a transformer being struck by lightning) to prevent that failure from traveling to additional equipment and to eliminate shock hazards in that equipment. A relay will include the relay, the relay housing, the isolation switches, and the housing terminations.

Periodicity*	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Metering, analog	Meter-01	Inspect and Calibrate Current, Voltage, and Event Recording Meters	3A	2A	A
Metering, solid-state	Meter-01	Inspect and Calibrate Current, Voltage, and Event Recording Meters	5A	3A	3A
Metering, Event Recording, analog and solid-state	Meter-01	Inspect and Calibrate Current, Voltage, and Event Recording Meters	A	A	SA
Protective Relays, electromechanical	Relay-01	Clean, Test and Calibrate Protective Relays	3A	2A	A
Protective Relays, solid-state	Relay-01	Clean, Test and Calibrate Protective Relays	5A	3A	3A

Dominant failure modes for electromechanical relays are failure of the mechanical trip mechanism due to contamination (dirt, moisture, and foreign matter), burnt contacts (due to repeated operations) and loose connections (due to repeated openings and closings of switchgear panel doors). The dominant failure mode for solid-state relays is loose connections. Protective relays are passive devices during normal system operation, that is, they sit idle and only have to work when there is a failure elsewhere in the electric distribution system. The dominant failure modes are normally hidden. Consequently time-based inspection tasks are necessary to find these hidden failures. Note that maintenance frequencies are shorter on electromechanical relays because of the contamination issue and lack of self-diagnostics.

Meters inform operations and maintenance personnel of current and past operating parameters.

The dominant failure mode for meters is loose connections, with additional failure modes of operating mechanism failure, loss of paper, and failure of the inking system for event recording meters. Hidden failures are not as problematic for meters as they are for relays.

Low Voltage Distribution

Equipment types: 240/120 Volt Electrical Panel, 600 Volt Electrical Panel, 240/120 Volt Disconnect Switch, 600 Volt Disconnect Switch, 600 Volt Motor Control Center.

Reliability-Centered Maintenance Issues

Dominant failure modes of low voltage electrical panels are high resistance connections and molded case circuit breakers not operating properly, either tripping erroneously or not opening when required. Because of their relatively low cost, molded case breakers are generally replaced and not repaired. Most low voltage panels and their associated breakers are standard stock items. Procurement time is normally not an issue. Dominant failure modes of disconnect switches are high resistance connections and operating mechanism failure due to binding. As with panels, disconnect switches are also low in cost and readily available.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
240/120 volt Electrical Panel – Interior	Panel-01	Inspect and Clean Electrical Panels	RTF	3A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	5A	3A	A
240/120 volt Electrical Panel – Exterior	Panel-01	Inspect and Clean Electrical Panels	3A	2A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	3A	2A	A
600 volt Electrical Panel	Panel-01	Inspect and Clean Electrical Panels	5A	3A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	5A	3A	A
240/120 volt Disconnect Switch – Interior	Panel-01	Inspect and Clean Electrical Panels	5A	3A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	5A	3A	A
240/120 volt Disconnect Switch – Exterior	Panel-01	Inspect and Clean Electrical Panels	3A	2A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	3A	2A	A
600 volt Disconnect Switch	Panel-01	Inspect and Clean Electrical Panels	5A	3A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	5A	3A	A
600 volt Motor Control Centers (with and without Motor Starter Contactors)	MCC-01	Inspect and Clean Motor Control Centers and Motor Starter Contactors	3A	2A	A
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	A
	PT&I-05	Test Insulation	3A	2A	A

An additional failure mode for both electrical panels and disconnect switches in outdoor locations is corrosion. Consequently maintenance frequencies for exterior mounted units are slightly different as referenced in the maintenance approach table.

The maintenance approach for electrical panels and disconnect switches focuses on the non-intrusive technologies infrared thermography, ultrasonic noise, and visual inspection. Historically, the maintenance on these items included tightening each electrical connection. Not only is this time consuming, but also it adds little value as most connections are not in need of tightening and the approach increases the chance for causing damage by over-tightening or breaking connectors.

Motor control centers (MCC) are more complex than electrical panels and disconnects. An MCC includes the enclosure, installed circuit breakers, main connection cubicle, installation pad and ground connection, and all installed control circuits. Protective relays and metering, however, are not included in this section. MCC'c can handle large amounts of current, and in some cases include motor contactors for remote operation. Dominant failure modes are high resistance connections (both cable and phase bus), molded case circuit breakers not operating properly, either tripping erroneously or not opening when required, burnt motor contacts (due to continued opening and closing), and failure of control relays. The maintenance approach for MCC's includes a combination of non-intrusive technologies for monitoring the electrical connections, and visual inspection, measurement, and restoration for contactors and control circuits.

Unlike electrical panels and disconnect switches, motor control centers are normally made to order, with delivery times ranging from four weeks to six months. Additionally, cost of a new unit depends on the amount of cubicles, with eight (two columns of four) normally being the smallest size available. Minimum cost of an eight-cubicle unit would be approximately $10,000.

Interior Emergency Area Lighting

Equipment types: Self-contained wall/ceiling mount units (incandescent and florescent) and 32 Volt Centralized System.

Reliability-Centered Maintenance Issues

Most interior emergency lighting systems are self-contained incandescent or florescent units, which have one or two lights, a battery, and a loss of normal power sensing circuit to turn the lamp on. These types of systems are normally inexpensive, easily repaired or replaced, and require minimal attention.

A centralized emergency lighting system uses individual low voltage (normally 32 volts) light fixtures located throughout a facility. The fixtures are powered from a single set of batteries. Like self-contained units, there is a loss of normal power sensing circuit to turn on all of the lamps. Unlike self-contained units, a centralized system has the capability to be expanded with additional fixtures, and larger batteries can be added giving a longer illumination time.

Dominant failure modes are the loss of normal power sensing circuit and battery weakness or failure. Both of these are hidden failures, that is, the failure is not evident to occupants of the facility. Interior emergency area lighting is designed to illuminate on loss of electrical power to the facility and to operate for at least 90 minutes[8]. Consequently, the maintenance approach is based on periodic testing to confirm proper operation, with the inspection periodicity being determined buy national and local building and fire protection codes.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Self-Contained Wall/Ceiling Mount Units	EmLights-01	Inspect/Repair Self-Contained Wall/Ceiling Units	A	A	A
	EmLights-03	Annual 90 Minute Operational Test	A	A	A
32 Volt Centralized System	EmLights-02	Inspect/Repair 32 Volt System	SA	SA	Q
	EmLights-03	Annual 90 Minute Operational Test	A	A	A
	PT&I-11	Battery Impedance Test	A	6M	Q

Electrical Distribution Support Structures

Equipment types: Wooden Power Poles and Cable Vaults

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Wooden Power Pole	Pole-01	Inspect Wooden Power Pole	5A	3A	A
Cable Vaults	Vault-01	Inspect Cable Vaults	5A	3A	A

Reliability-Centered Maintenance Issues

Wooden power poles are used throughout most of the NASA centers as the primary support for overhead electrical power distribution. They are normally spruce poles treated with creosote, and are buried at least 10 feet below grade. At most NASA centers the individual poles are not part of the maintenance database and are included with power cable maintenance. Consequently the total number of power poles is not known.

Dominant failure modes for wooden power poles are wood rot and animal/insect damage. Wood rot and insect damage normally occurs near the base of the pole at the earth/pole

[8] National Fire Protection Association, NFPA Standard 101, Life Safety Code, 1999

intersection. This is due to the poles being direct buried in the soil with no supporting concrete at the base. This is a hidden failure and can not be discovered without an inspection and/or test. Animal damage is normally concentrated in the upper regions of the pole.

Failure of a pole (falling down or breaking during a storm) will normally cause an entire electrical power feeder to be lost. There is also a potential safety hazard if the overhead line remains energized and in close proximity to people.

Cable distribution vaults are used throughout the NASA Centers for underground distribution. They are concrete with round steel access covers, are usually 10 to 20 feet deep, and are located 300 to 400 yards apart. They are used for access to underground power cables, control cables, and communication (data and telephone) cables. They are also used as cable pulling points during installations. As with wooden power poles they are not always a standalone part of the maintenance database.

Dominant failure modes for cable vaults are cracking or deterioration of the concrete (due to settling, excessive water, or damage) and failure of the cable racks (due to corrosion). The maintenance approach for cable vaults is periodic visual inspections to identify degraded conditions.

Motors

Equipment types: Induction and Synchronous Motors

Reliability-Centered Maintenance Issues

Motors throughout the NASA centers range from fractional horsepower (hp) units to 60,000 hp units. A motor includes the foundation and mounting, electrical connection box, motor frame, and all of the components within the motor frame. Not included in this section is the motor controller and other components of the power supply.

Dominant failure modes for electric motors are; bearing failure (bearing failure modes include seizing, fracture, and race & ball/roll surface degradation), insulation system failure (resulting in short and open circuits), mechanical failure of rotor components, and mechanical failure of the housing including the bearing seating surfaces, the frame, and the motor feet. An additional failure mode on synchronous motors is loss of field or failure of the field to flash (both caused by diode failures, brush/slip ring failure or control circuit failure). Failure of the field to flash would be a hidden failure, as it only becomes apparent when trying to start-up the motor.

Maintenance approach for motors is based on using non-invasive technologies such as vibration analysis and infrared thermography to identify beginning mechanical failures (such as bearing and rotor/frame failures) before they cause loss of function, and electrical testing to trend insulation condition.

It should be noted that routine periodic lubrication of motor bearings is not a recommended maintenance approach. This is because bearing failure is often induced by over greasing. Several NASA Centers no longer routinely lubricate motor bearings and are replacing failed

bearing with pre-lubricated sealed bearings.[9] Lubricating of bearings should only be performed when indicated by the vibration analysis program.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Induction motors 600 Volts and less, 15 hp and less	Motor-01	Inspect and Test Motor	RFT	2A	A
Induction motors 600 Volts and less, more than 15 hp	Motor-01	Inspect and Test Motor	2A	2A	A
	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	A
	PT&I-03	Test Insulation	3A	2A	A
Induction motors above 600 Volts	Motor-01	Inspect and Test Motor	2A	2A	A
	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	SA
	PT&I-03	Test Insulation	2A	2A	A
	PT&I-10	Sample and Test Lubrication Oil	A	SA	Q
Synchronous motors	Motor-01	Inspect and Test Motor	2A	2A	A
	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	SA
	PT&I-03	Test Insulation	2A	2A	A
	PT&I-10	Sample and Test Lubrication Oil	A	SA	Q

Replacement costs of motors vary over a wide range. Small 120-volt fractional hp motors will normally cost less than $200 and are a stock item for most electrical suppliers. On the other hand, a 4160-volt 1000 hp motor will probably cost in excess of $20,000 and have a lead-time of up to six months.

Pumps

Equipment types: Pumps

A pump system consists of a driver (usually an electric motor), a coupling and the pump. Pumps most commonly fall into two general categories; Centrifugal (single and multi-stage) or Positive Displacement (sliding vane, reciprocating piston, rotating screw, peristaltic,

[9] A recent case study indicated that 86 percent of motor failures in their study plant was attributed to over-greasing. Using Vibration Analysis to Grease Motors?, John C. Robertson, maintenance reliability specialist, Strategic Work Systems, November 1998

diaphragm, etc.). Pump design is selected based on application. The purpose of a pump is to add energy (head pressure) to a fluid system in order to do some form of work.

Reliability-Centered Maintenance Issues

Pumps are susceptible to failure by motor failure, coupling failure, leaking fluid past sealing valves, bearing failure, impeller wear, impeller corrosion, and housing corrosion or wear, pump base corrosion or looseness, pipe strain, and clogging.

The maintenance approach to pumps is to perform non-invasive condition monitoring, predominately vibration analysis and lubrication on a time/cycle basis and to overhaul the pump when performance conditions indicate overhaul is needed. When the pump is overhauled, all bearings and seals are replaced, and the impeller either rebuild or replaced and then balanced.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Pumps	Pumps-01	Inspect, Lubricate and Clean	SA	Q	M
	PT&I-01	Vibration Analysis	SA	Q	M
	PT&I-02	Infrared Thermography	A	SA	Q
	PT&I-10	Lubricant Analysis	A	SA	Q

Hidden failure modes include damage to impeller due to cavitation and leaking past internal sealing surfaces due to erosion, causing lower head pressures. Impeller wear can often be detected with vibration analysis, showing up as a change in vane-rate frequencies and imbalance. Internal leaking is only detected by noting poor pump performance and comparison of flow rates and pressures with design pump curves.

Periodicity of lubrication and vibration analysis should be examined to find opportunities for extending periods between maintenance visits.

Valves

Equipment types: Fire Control Valves, Isolation Valves, and Control Valves.

Reliability-Centered Maintenance Issues

Valves are used to modulate or stop the flow of fluids in a piping system. They consist of a valve body with a bonnet and seats, a gating mechanism, a stem attached to the gating mechanism, and a control device. Control devices for manual valves are merely handles or hand wheels. Control devices for automatic valves are actuators; hydraulic, pneumatic or electric.

Dominant failure modes for valves are leaking around stem and bonnet, debris and erosion on sealing surfaces, corrosion, insufficient energy for actuation (voltage or pressure), broken

return spring, improper calibration (automatic valves) and over-pressure discharge (pressure relief valves). Valves in continuous service are rarely operated and are the most susceptible to failure when needed during shutdown. A simple and effective maintenance activity is to simply operate the valve to help prevent failure. Other preventive maintenance techniques are focused on providing adequate lubrication, leak prevention and corrosion inhibition.

New valves must be stored properly to avoid corrosion on machined surfaces and bent valve stems. Valves can easily be damaged in storage and transport by mishandling the stems, handles or gland adjustment pieces. Valves should be cleaned and flushed out before placing in service.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Fire Control Valves	Valve-01	Inspect, Test and Clean	A	A	A
Isolation Valves	Valve-02	Inspect, Test and Clean	A	A	S
Control Valves	Valve-03	Inspect, Test and Clean	A	A	S

Procedures for pressure relief valves are not developed in this guide. See ASME PTC 25-1994 (and 1998 Special Addenda), Pressure Relief Devices[10] for standards for conducting and reporting tests on reclosing and non-reclosing pressure relief devices. The PTC covers the methods and procedures to determine relieving capacity and additional operating characteristics that may be required for certification or other purposes by other codes.

Backflow Preventer

Equipment type: Backflow Preventer

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Backflow Preventer	BFP-01	Inspect and Clean	3A	2A	A

Backflow preventer is a mechanical device designed to protect the potable water supply system from contamination. It is a single device containing a double set of check valves separated by an open air space. It is used as a physical connection to non-potable water systems. In order to ensure the device is working as designed, it must be tested periodically.

Many backflow preventers are certified and registered with water supply authorities. Tampering with, or unauthorized work on, backflow preventers may violate local statutes.

[10] American Society of Mechanical Engineers (ASME) Performance Test Code (PTC) 25-1994 (and 1998 Special Addenda), Pressure Relief Devices.

Reliability-Centered Maintenance Issues

Dominant failure modes for backflow preventers are check seal failure caused by debris or erosion of sealing surfaces or pressure relief valve failure in reduced pressure (RP) backflow preventers. Maintenance methods typically involve removing the back flow preventer from the piping system, disassembling the unit, inspecting the sealing surfaces, checking for corrosion, lubricating and reassembling the device then placing it back into service.

Periodicity of testing, inspections and cleaning may be governed by local statue or regulating authorities.

Heating, Ventilation and Air Conditioning (HVAC) Units

Equipment types: Direct Exchange Air Conditioning (A/C) Units (Room A/C Units, Heat Pump Units, Split-System Condenser Units), Package A/C Units, Air Handling Units and Fan Coil Units, Fans, Variable Air Volume (VAV) Terminals, Heaters, Chillers (Centrifugal, Reciprocating, Rotary Screw, and Absorption)

HVAC nomenclature:

- Direct Exchange (DX) - systems designed with one heat transfer step, typically refrigerant-to-air. This differs from water-coil systems that have multiple heat transfer steps typically air-to-water-to-refrigerant.
- Room A/C units (also known as Window A/C units) are direct exchange, generally .75 to 3 tons in cooling capacity and seldom ducted.
- Heat Pumps are DX A/C units with reversing capability i.e. the condenser becomes the evaporator and vice-versa. They are commonly found in sizes ranging from 1.5 to 5 tons.
- Split System, Sidewall A/C units and Package A/C units are the primary configurations for DX A/C systems. The split system has two parts, an evaporator coil and condenser unit. The evaporator is installed indoors, in a supply air stream, and the condenser is installed outdoors. Heat is transferred between the two via insulated copper tubing containing refrigerant. Sidewall units and package units are combined (evaporator and condenser), the difference being that sidewall units are mounted to vertical surfaces, package units horizontally. They commonly range from 5 to 50 tons, with package units found as large as 150 tons. All three configurations are typically ducted. Large package units, that have motors 25 hp and greater, should be included in the vibration analysis program.
- Air Handler is a catchall phrase, however it typically refers to ducted air-moving equipment large enough for a person to enter. Air handlers can be supply or exhaust, fresh-air (makeup) or re-circulating. Supply air handlers are often configured with chilled/hot water coils. Smaller water-coil units are frequently called “fan coil units”. Large package units may also be referred to as “air handlers.”
- The term “Fan” applies to air moving equipment consisting of a prime mover, typically a motor, a coupling system, often pulley/belt, a fan and an airflow control device called a damper. Types of fans include variable and fixed-pitch propeller, vaneaxial, squirrel

cage centrifugal, airfoil centrifugal and plug centrifugal. The choice of fan type depends on the application.

- A Variable Air Volume (VAV) terminal is a duct-mounted, thermostat-controlled device used to modulate air flow to control heating and cooling of a local space. It typically consists of a variable damper, a damper actuator, hot/cold water coils and may also be equipped with a small fan.
- Chiller refers to equipment used to continuously chill water. A chiller consists of an evaporator heat exchanger, a condenser heat exchanger and a compressor. Other significant elements include a purge system, control system and valves. Various mechanical means are employed to compress the refrigerant gas - centrifugal, piston (reciprocating) and rotary screws. A fourth type of chiller uses a chemical process and is called “absorption chiller” or “absorption unit.”

Reliability-Centered Maintenance Issues

Air Conditioning Equipment

See the section on Motors for a detailed discussion on the maintenance approach for this common component. Follow the guidelines in that section for smaller units discussed in this section.

Common failure modes for direct exchange air conditioning units are refrigerant leaks, compressor failure, fan motor failure, filter failure and clogging, damper control failure, coil fin damage and condensate drain blockage. For units with belt driven fans and compressors, belt and sheave failure are also dominant failure modes. Outdoor condenser units require thorough filter inspections and cleaning to reduce the risk of clogged coil fins.

DX units providing less than 10 tons of cooling are excluded from vibration data collection routes because the cost of motor/fan replacement does not justify the cost of data collection and analysis. Often compressors are sealed units that are run to failure, typically lasting several decades.

Dominant failure modes for chilled water coil air handlers are fan shaft bearing failure, fan imbalance, damper failure, coil blockage, coil corrosion, condenser drain pan overflow, and excessive biological growth. For belt driven units, sheaves and belt failure are also dominant failure modes.

The periodicity of maintenance for air handlers is largely affected by the operating environment and the purpose for which the air handler is used. Filter changes for pre-filter stages are relatively low cost and can be replaced on a calendar basis. Final filters featuring 95% or higher filtration rates (ULPA, HEPA) are more expensive by comparison to pre-filters and should be changed on a performance basis. Filter manufacturers provide guidance regarding the maximum pressure differential across the filter. Once this maximum pressure differential is reached, the filter must be changed. The lead-time for ordering high filtration media is often long and should be accounted for when scheduling filter changes.

Fans

Dominant failure modes for fans are dirt buildup on blades causing imbalance and excessive vibration, belt and sheave failure, bearing failure, damper failure and fan blade damage, fan motor failure, filter failure and clogging. Routine scheduled fan cleaning reduces imbalance and has a significant effect on service life of bearings. Maintenance methods and scheduling are designed to address each of these failure modes.

Variable pitch fan blade linkage is prone to failure due to the significant number of moveable parts excited by fan vibration. Annual inspections and lubrication of pitch adjustment linkage are necessary to avoid failure. Where possible, pitch adjustment linkage may be replaced with variable speed motors.

Fan units with air-drying refrigerant coils should additionally be treated as Fan Coil Units.

VAV Terminals

Dominant failure modes for VAV terminals are damper failure, coil clogging and loss of calibration causing inconsistent airflow. Occasional checks for proper damper functionality, proper cleaning of coil strainers as well as cleaning moving parts is sufficient for long VAV life. Occasionally a power outage will cause a reset condition in VAV terminals requiring re-calibration to restore proper operation. Proper water treatment is a key factor in reducing the amount of maintenance required by VAV terminals.

Chillers

Compressor-type chillers (centrifugal, reciprocating and screw type) draw significant amounts of power for operation. Heat transfer efficiency changes due to contamination buildup can change rapidly and has a large effect on the cost of operation. Chiller data is examined closely to catch trends indicating changes in efficiency and loss of refrigerant.

Chiller efficiency is directly affected by cleanliness of heat exhangers, (condenser and evaporator), and leaks. Many chillers operate at low pressures and leaks draw outside air (non-condensable gas) into the refrigeration cycle. Purge units are designed to eject non-condensable gas from the chiller. Improperly functioning purge units will release excessive refrigerant during the purge cycles. Excessive release of refrigerants is both expensive and a potential environmental issue.

The condenser tube water is prone to contamination and treatment depletion because of exposure to atmosphere in the cooling tower. For this reason, condenser components, i.e. tubes, strainers and piping, should be cleaned and inspected at least annually.

Evaporator operation is more stable than condenser operation because the chilled water typically loops in a closed system. For this reason, evaporator tube cleaning may be spaced from three to five years, depending on findings during cleanings.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Room A/C Unit, Heat Pump Unit, Split-System Condenser Unit	HVAC-01	Inspect and Clean (DX Coil)	A	A	S
Air Handler, Package A/C Unit, Fan Coil unit	HVAC-01	Inspect and Clean (DX Coil)	A	A	S
	HVAC-02	Inspect and Clean (Water Coil)	A	A	S
	HVAC-03	Belt Check, Filter Change & Lubrication	A	S	Q
	PT&I-01	Vibration Analysis	A	Q	M
VAV Terminal, Heater	HVAC-04	Inspect and Clean	A	A	A
	Motor-01	Inspect and Test Motor	2A	2A	A
	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	A
	PT&I-03	Test Insulation	3A	2A	A
Fans	Fan-01	Inspect and Clean	A	S	Q
	HVAC-03	Belt Check, Filter Change & Lubrication	A	A	A
	Motor-01	Inspect and Test Motor	2A	2A	A
	Panel-01	Inspect and Clean Electrical Panels	5A	3A	A
	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	A
	PT&I-03	Test Insulation	3A	2A	A
Chiller	Chiller-01	Readiness Inspection and Cleaning, Clean Condenser/Absorber Tubes	A	A	A
	Chiller-02	Evaporator Tube Inspection and Cleaning	5A	4A	3A
	Motor-01	Inspect and Test Motor	2A	2A	A
	Panel-01	Inspect and Clean Electrical Panels	5A	3A	A
	PT&I-01	Vibration Analysis	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	SA	Q
	PT&I-10	Extract Lubricant Sample	A	A	SA

In addition to the efficiency concerns and purge unit failures listed above, dominant modes of failure for centrifugal compressors are linkage failure, motor coupling failure, motor failure and tube failure. For reciprocating compressors, failure modes include drive failure, coupling or belt failure, internal bearing wear, lubrication failure and tube failure. Failure modes for screw compressors include drive failure, coupling failure, internal mechanical wear, gear wear, lubrication failure and tube failure.

Preventive maintenance for chillers is staged in at least two intervals, routine maintenance required throughout the year, and an annual readiness inspection. The frequency of time-consuming maintenance activities such as condenser and evaporator tube cleaning can be strongly affected by water treatment programs. Better water treatment lowers the cost of chiller maintenance. Examination of heat exchanger efficiency over time is the best indicator of required maintenance interval. Trending data such as refrigerant pH and replenishment amounts can be used to discover slowly developing problems. Refrigerant pH is an indicator of air leaking into the refrigerant through leaking joints under vacuum.

The most common cause of unscheduled shutdown for absorption chillers is crystallization caused by: failure of system controls, malfunction of a pressure-reducing valve, or introduction of air into the machine. Also, interruption of electric power, which will cause the machine to shut down without the normal dilution cycle, may result in crystallization. Other significant failure modes are solvent pump failure, seal failure, steam valve failure and internal corrosion. Careful maintenance practices will ensure low occurrence of leaks and allow longer periods between scheduled maintenance activities.

Filters

Equipment types: Water Cooler, Process Water Filter, and Air-Cooled Equipment/Air Compressors

Reliability-Centered Maintenance Issues

Filters consist of the filter media, the media cartridge and the filter housing.

Common failure modes for filters are clogging, rupturing or seal failure. Care should be taken to only install manufacturer recommended filters. Improper filter selection may result in poor air flow causing overheating, excessive energy usage, poor exhaust and safety hazards. Manufacturers recommended maximum static pressure drop across filter media should be observed to avoid failure.

Low-cost filters are typically changed on a calendar-based period. High-cost filters are monitored for condition based on static pressure drop across filter media. Each filter should have a log showing when it was last serviced or changed. Filters used for potable water should be clearly labeled at the filter housing showing when filters were last changed and what the filtration level is.

Filters, like any part of a water system, are strongly affected by water quality and treatment. Investment in proper water treatment has a long-standing proven track record of lowering overall costs associated with water circulation. Shocking the system with spikes of chemical treatments have a predictable negative effect on the life of filters.

For those filters that do not have a condition monitoring capability, the filter change periodicity should be evaluated by the Centers using an Age Exploration process (see the section on Age Exploration) to determine the optimal change time.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Drinking Water Cooler	Filter-01	Change Filter	A	A	S
Process Water Filter	Filter-02	Change Filters	A	SA	SA
Air-Cooled Equipment/Air Compressors	Filter-03	Change Intake Air Filters	A	SA	Q

Steam Traps

Equipment types: Steam Traps

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Steam Traps	Strap-01	Test and Purge	A	SA	Q

Steam traps allow condensate and non-condensable gasses to escape from a steam system while retaining the steam. In order to ensure the device is working as designed, it must be tested periodically.

Reliability-Centered Maintenance Issues

Dominant failure modes for steam traps are failure to properly open or close, clogged strainer, or blocked discharge. Improperly functioning steam traps waste money by discharging valuable steam to the atmosphere and creating excessive pressure in low-pressure condensate systems. Signs of trap failure include; high room temperatures where steam traps are installed, condensate receiver venting steam, difficulty maintaining boiler pressure, water hammer, repeated condensate pump seal failure, high fuel utilization, and steam in condensate lines.

Maintenance for steam traps consists of cleaning the strainer, verifying the discharge remains free of blockage and checking the opening and closing to ensure proper operation.

Additionally, improperly insulated steam pipes are susceptible to corrosion. This is a hidden failure in that condensate can creep underneath insulation and cause weak spots in steam piping. Infrared thermography along steam pipes is capable of locating areas where the insulation is affected by water buildup.

Air Compressors

Equipment types: Centrifugal, Rotary Screw, and Reciprocating Piston Air Compressors

Reliability-Centered Maintenance Issues

A compressor consists of a motor, coupling, compressor, a cooling system, receiver tank and control valve. Air compressors fall into three categories; Rotary Screw, Centrifugal and Reciprocating Piston. Air compression is an exothermic process and compressors require proper cooling for long service life. Air-cooled compressors have either integrally mounted or separate oil and air coolers. Water-cooled compressors require coolant systems free of blockage, crimped hoses and tubes and adequate coolant for long service life.

Dominant failure modes include motor failure, coupling/belt failure, bearing failure, relief valve failure, lubrication breakdown or depletion, seal failure, corrosion, moisture trap overfilling, clogged filters, equipment support failure, tubing rupture and pressure switch failure.

Hot air has the ability to absorb much moisture. This moisture is carried into the compressor, then as the air cools, the moisture condenses inside the compressor receiving tank. Condensate must be reliably drained to prevent hidden corrosion, leading to premature failure of the pressure vessel.

Maintenance procedures focus on providing optimum operating conditions for properly sized compressors including filter changes, oil changes, belt changes, moisture trap drainage, tank drainage. High performance filters are recommended. Wear particle analysis of the lubricant is recommended over vibration analysis for reciprocating compressors due to the inability of vibration analysis to detect subtle changes in the midst of high level vibration caused by stroking pistons and valves. Vibration analysis is effective for centrifugal and rotary screw type compressors.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Air Compressors	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-10	Rotating Machinery – Extract Lubricant Sample	SA	Q	M
	AComp-01	Operation Inspection	SA	Q	M
	AComp-02	Belt Inspection and Replacement	A	SA	Q

Efficiency is critical. Belt drives are easier to maintain and provide the most flexibility in pressure selection. Automatic belt-tensioning devices ensure transmission efficiency and protect bearings from excess stress.

The ratio of runtime to load time should be as low as possible to eliminate unnecessary idling. Data should be recorded and logged to allow proper tuning of the control system.

Sites with multiple compressors should rotate the load through all compressors for maximum life cycle.

Cranes, Elevators and Lifts

Equipment types: Cranes and Hoists, Lift Platforms, Elevators, Slings

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Cranes and Hoists	Hoist-01	Inspect, Lubricate, Test and Clean	A	Q	M
Lift Platforms	Hoist-02	Inspect Lubricate, Test and Clean	A	Q	M
Elevators	Elevator-01	Inspect, Lubricate, Test and Clean	A	SA	Q
Cranes and Hoists, Lift Platforms, and Elevators	Motor-01	Inspect and Test Motor	2A	2A	A
	Panel-01	Inspect and Clean Electrical Panels	3A	2A	A
	PT&I-01	Vibration Data Collection	SA	Q	M
	PT&I-02	Qualitative Infrared Thermography Inspection	A	A	A
	PT&I-03	Test Insulation	3A	2A	A
Slings	Sling-01	Inspect	D	D	D

Reliability-Centered Maintenance Issues

Cranes and hoists consist of a control system, supporting boom (moveable or fixed), a winch motor, clutch mechanism, a take-up drum, a wire rope, pulley blocks, hooks, straps and spreader devices with accompanying attachment devices. Dominant modes of hoist failure include wire rope failure, chain failure, hook failure, strap failure, motor drive clutch failure, wheel surface failure, wheel bearing failure, electrical failure due to overheating or loose connections, wear due to misaligned travel ways, boom failure, corrosion, hydraulic fluid loss, limit switch failure causing over-travel and indicator light failure.

Lift platforms consist of a hydraulic lifting mechanism, hydraulic pump, fluid reservoir, hydraulic actuators, mobile platform, batteries, drive motor, steering mechanism, wheels, extension boom or scissors boom. Dominant modes of failure are battery failure, corrosion, tire flattening, bearing failure, hydraulic pump failure, hydraulic hose failure and motor failure.

Elevators consist of a passenger car, guide ways, pulleys, lifting winch with wire rope, motor, clutch and winding drum and brakes. Additionally, there are level indicators, control system, alarm system and door opening mechanisms. Dominant modes of failure include wire rope wear, motor failure, travel way degradation, door opening mechanism failure, user interface failure and control calibration.

Maintenance methods include proper and frequent lubrication of all moving parts, travel ways and wire ropes, as well as frequent inspection of hooks, straps, wire ropes, beams and

supports for signs of overloading and excess stress. Periodicity of maintenance is strongly affected by application and amount of use. Frequently used cranes may be inspected and lubricated daily, and others used for stand-by purposes my only require annual inspection and maintenance.

Because of the dangers inherent to cranes, hoists, elevators and lift platforms, the federal Occupational Safety and Heath Administration (OSHA) has developed strict inspection guidelines. These guidelines call for inspections of lifting equipment, not only on a mandatory periodic basis, but on a per-use basis as well[11]. It is the intent and design of these rigid inspection requirements to avoid failures of any kind. In addition, NASA has developed a safety standard[12].

Most cranes require some level of monthly inspection and all in-service cranes, hoists and lifts require annual inspection surveys. Personnel elevators are federally regulated and require certified inspections by licensed inspectors.

There are currently no officially recognized substitution inspection methods available to offset the cost of maintenance with cranes, hoists, elevators or lifting straps.

The maintenance approach for electric motors and electric systems control panels is discussed in the Motors and in the Low Voltage Distribution sections of this Guide. When possible, the use of PT&I should be included in the maintenance approach for cranes, hoists, elevators and lift platforms. However, vibration readings are difficult at best. For motor-driven cable systems the relatively slow and varying speed and acceleration, combined with short cycles (due to cable wind-up or trolley length) make vibration readings difficult.

Fire Detection/Protection

Equipment types:

Fire Detection Systems (control panels, smoke and heat detectors)

Fire Protection – Water Systems, Wet and Dry Chemical

Reliability-Centered Maintenance Issues

A fire detection system is a passive system that senses when a fire has started. The system will then alarm or it can alarm and also initiate a fire protection system action. A fire detection system consists of heat and/or smoke sensors, pull stations, alarm bells or buzzers, and control panels.

Dominant failure modes for fire detection systems are failure of a detector, failure of system power (battery), and loose electrical connections, both at the detector and the control panel. Some newer digital systems have self-diagnostics. Even so failures are, for the most part, hidden.

[11] OSHA Standards - 29 CFR, Part 1910 Subpart N - Materials Handling and Storage, Section 1910.179
[12] NSS/GO-1740.9B, NASA Safety Standard For Lifting Devices and Equipment (and its proposed revision NSS 8719.9)

A fire protection system is an active system that is designed to control or extinguish a fire. A water based fire protection system consists of piping, sprinkler heads, valves, relays, pumps and motors, and control panels. A chemical based fire protection system consists of piping, spray heads, pressurized cylinders, valves, and control panels. Pumps and motors are discussed in separate sections.

Dominant failure modes for fire protection systems are corrosion at sprinkler heads (which won't allow full water flow or the device to actuate), loss of system pressure due to leaks, and no signal from the fire detection system (not signaling the system to operate). Sprinkler head corrosion and loss of signal from the detection system are hidden failures.

There are many types and manufacturers of these types of systems. As a result manufactures recommendations are often basic in nature, with many references to The National Fire Protection Association (NFPA) and local fire codes regarding the required maintenance frequencies.

Equipment Item	Procedure		Periodicity By Criticality Rank		
	Number	Description	2	3	4
Fire Detection Systems	Fire-01	Inspect Fire Detection Systems	A	A	A
Fire Protection Systems – Water Systems	Fire-02	Inspect Water Fire Protection Systems	A	A	A
Fire Protection Systems – Wet and Dry Chemical	Fire-03	Inspect Chemical Fire Protection Systems	A	A	A

Appendix A - Procedures

Summary Listing of Procedures

NASA Standard Facilities Work Tasks - Index Procedures accompany the NASA Standardized Facilities Preventive Maintenance Work Guide		
Procedure Number	Machine/System	Procedure Summary
PT&I-01	Rotating Machinery	Vibration Data Collection
PT&I-02	Various	Qualitative Infrared Thermography Inspection
PT&I-03	Motor	Test Insulation
PT&I-04	Transformer	Test Insulation
PT&I-05	Electrical Distribution	Test Insulation
PT&I-06	Oil Filled Transformer	Sample and Test Transformer Oil
PT&I-07	Transformer	Power Factor Test
PT&I-08	Electrical Distribution	Power Factor Test
PT&I-09	Bushing	Power Factor Test
PT&I-10	Rotating machinery	Extract Lubricant Sample
PT&I-11	Battery Bank	Battery Impedance Test
Tran-01	Dry Type Transformer	Inspect and Clean Dry Type Transformer
Tran-02	Liquid Filled Transformer	Inspect and Clean Liquid Filled Transformer
Brkr-01	Medium/Low Voltage Air Circuit Breaker	Inspect and Test Air Circuit Breaker
Brkr-02	High/Medium Voltage Vacuum or Oil Circuit Breaker	Inspect and Test Vacuum or Oil filled Circuit Breaker
Brkr-03	High/Medium Voltage SF_6 Circuit Breaker	Inspect and Test SF_6 Circuit Breaker
Swthgear-01	Electrical Distribution	Clean and Inspect Switchgear
Switch-01	High/Medium Voltage Air Switch	Inspect and Test Air Switch
Switch-02	Medium Voltage Oil Loadbreak Switch	Inspect and Test Loadbreak Switch
Switch-03	Medium Voltage SF_6 or Vacuum Loadbreak Switch	Inspect and Test Loadbreak Switch
Relay-01	Protective Relays	Clean, Test, and Calibrate Protective Relays
Meter-01	Electrical Meters	Inspect and Calibrate Current, Voltage, and Event Recording Meters
Panel-01	Electrical Distribution	Inspect and Clean Electrical Panels
MCC-01	Electrical Distribution	Inspect and Clean Motor Control Centers and Motor Starter Contactors

Pole-01	Overhead Distribution	Inspect Wood Power Pole
Vault-01	Underground Distribution	Inspect Cable Vaults
Motor-01	Motors	Clean and Inspect Motors
Pumps-01	Pumps	Inspect, Lubricate and Clean
Valve-01	Fire Control Valves	Inspect and Clean
Valve-02	Isolation Valves	Inspect and Clean
Valve-03	Automatic Control Valves	Inspect and Clean
BFP-01	Backflow Preventer	Inspect and Clean
HVAC-01	DX Air Conditioning Unit	Inspect and Clean (DX Coil)
HVAC-02	Air Handler/Package A/C Unit	Inspect and Clean (Water Coil)
HVAC-03	Air Handler	Change Filter, Inspect Belts
HVAC-04	VAV Unit, Heating Unit	Inspect and Clean
Fan-01	Fans	Inspect and Clean
Chiller-01	Chillers	Inspect and Clean, Clean Condenser/Absorber Tubes
Chiller-02	Chillers	Evaporator Tube Inspection and Cleaning
Filter-01	Drinking Water Cooler	Change Filter
Filter-02	Process Water Filter	Change Filters
Filter-03	Air Cooled Equipment/Air Compressors	Change Intake Air Filters
Strap-01	Steam Trap	Test and Purge
AirComp-01	Air Compressor	Operation Inspection
AirComp-02	Air Compressor	Belt Inspection and Replacement.
Hoist-01	Cranes and Hoists	Inspect, Lubricate, Test and Clean
Hoist-02	Lift Platforms	Inspect, Lubricate, Test and Clean
Elevator-01	Elevators	Inspect, Lubricate, Test and Clean
Sling-01	Slings	Inspect
Fire-01	Fire Detection/Protection Systems	Inspect Fire Detection Systems
Fire-02	Fire Detection/Protection Systems	Inspect Water Fire Protection Systems and Fire Hydrants
Fire-03	Fire Detection/Protection Systems	Inspect Chemical Fire Protection Systems

Predictive Testing and Inspection

Procedure Number	Machine/System	Procedure Summary
PT&I-01	Rotating Machinery	Vibration Data Collection
PT&I-02	Various	Qualitative Infrared Thermography Inspection
PT&I-03	Motor	Test Insulation
PT&I-04	Transformer	Test Insulation
PT&I-05	Electrical Distribution	Test Insulation
PT&I-06	Oil Filled Transformer	Sample and Test Transformer Oil
PT&I-07	Transformer	Power Factor Test
PT&I-08	Electrical Distribution	Power Factor Test
PT&I-09	Bushing	Power Factor Test
PT&I-10	Rotating machinery	Extract Lubricant Sample
PT&I-11	Battery Bank	Battery Impedance Test

PT&I-01: Rotating Machinery - Vibration Data Collection

Block Title	Text
Procedure Number	PT&I-01
System Description	
Procedure Description	Vibration Data Collection
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Vibration Data Collector (with Magnet Mounted Accelerometer)
Materials	
Reference Data	
Warning Summary	Exercise caution when working around rotating machinery.
Caution Summary	
Reserved	
Preliminary	
1	Charge batteries and backup batteries.
2	Download vibration collection route data from host computer.
3	Test operation of vibration data collector and accelerometer.

4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Vibration Data Collection
WARNING	Exercise caution when working around rotating machinery.
A1	Notify operators or other local occupant before collecting vibration data.
A2	Record machine operating condition (usually directly into the data collector).
A3	Place magnet mounted accelerometer on installed machine sound disk. Ensure sound disk is clean and dry. Roll magnet onto the sound disk to avoid damage and overload to the accelerometer.
Note	If sound disk is missing, take data directly on machine surface. Ensure surface is clean and dry. Scrape any paint or glue off surface. Replace sound disk at next opportunity.
A4	Collect vibration data. If needed, adjust data collector and take additional data.
A5	Note any unsatisfactory conditions (machine or area) and report them to supervisor.
A6	Repeat procedure for remaining positions on machine.
A7	Repeat procedure for remaining machines on schedule (route).
A8	Upload vibration data to host computer.
Engineer's Notes	
EN1	For time estimating purposes, allow one minute per data point. Approximately 10 to 12 minutes for a typical 4 bearing machine. Triaxial accelerometers will require less time to collect data.
EN2	Periodicity can be adjusted after a baseline is established.
EN3	The setting of vibration alert and alarm values is determined by many machine related factors. See the NASA Reliability-Centered Maintenance Guide for guidelines on alert and alarm values.
EN3a	The latest version of the Reliability-Centered Maintenance Guide can be found on the NASA Internet web page (www.hq.nasa.gov/office/codej/codejx/).

PT&I-02: Various - Qualitative Infrared Thermography Inspection

Block Title	Text
Procedure Number	PT&I-02
System Description	
Procedure Description	Qualitative Infrared Thermography Inspection

Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Infrared Camera, Spare Batteries, Notepad
Materials	
Reference Data	
Warning Summary	1. Exercise caution when working around rotating machinery.
	2. Maintain minimum safe distance from energized electrical circuits.
	3. Observe standard safety precautions when working on elevated structures or roofs.
Caution Summary	
Reserved	
Preliminary	
1	Charge batteries and backup batteries for infrared camera.
2	Prepare image storage devices such as computer disks or PCMICA cards.
3	Inspect imaging system cables and test camera operation. Verify correct date/time (if available) has been set in camera.
4	Notify operators or other local occupant before starting inspection.
5	Ensure electrical circuits to be inspected are opened and energized to minimum 40% of full load current.
6	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Qualitative Infrared Thermography Inspection
WARNING	Exercise caution when working around rotating machinery.
WARNING	Maintain minimum safe distance from energized electrical circuits.
WARNING	Observe standard safety precautions when working on elevated structures or roofs.
A1	Adjust camera settings such as distance to object and emissivity.
A2	Perform thermographic inspection looking for hot and cold spots, relative differences in temperature, and temperature deviations from the normal or expected range.
A3	Save image of items of interest. Ensure camera is adjusted to show entire temperature range (no "white" or "black" areas in the image).
A4	Note machine, location, and operating or environmental conditions for each image saved and (if any) immediate actions taken to correct fault.
A5	Repeat procedure for remaining machines/areas on schedule.
A6	Notify operators or other local occupant when inspection is complete.

Note	Immediately notify supervisor of any temperature difference (delta-T) greater than 40C (72F).
A7	Upload infrared images to host computer for analysis and reporting (if required). Provide notes for analyst use.
Engineer's Notes	
EN1	Detailed information regarding safety guidelines is contained in OSHA Regulations Part 1910.
EN1a	See standard 1910.333 for electrical safety including closest approach distances for energized circuits.
EN2	In-service condition for electrical and mechanical systems can be assessed and work prioritized based upon the following temperature difference criteria (T) guideline.
EN2a	Greater than 40C (72F), failure probable. Emergency work, safety issue or loss of utility possible.
EN2b	15C (27F) to 40C (72F), deficiency, repair immediately. Urgent work, complete to ensure continuous operation.
EN2c	3C (6F) to 15C (27F), deficiency, needs to be repaired. Priority work, complete before routine work.
EN2d	1C (2F) to 3C (6F), possible deficiency, investigate. Routine work, complete in order of receipt.
EN2e	Less than 1C (2F), normal condition, no action.

PT&I-03: Motor - Test Insulation

Block Title	Text
Procedure Number	PT&I-03
System Description	Motor
Procedure Description	Test Insulation
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Direct Current Insulation Resistance Tester (Megohmmeter, Megger), Thermometer
Materials	
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Circuit may have dangerous voltage potential following testing.
Caution Summary	Protect semi-conductor control devices from potential high voltage.

Reserved	
Preliminary	
1	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
2	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Test Insulation
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Open motor control panels or doors to gain access to circuit to be tested.
WARNING	Test to ensure all circuits are de-energized.
A3	Place thermometer in close proximity to circuit to be tested.
CAUTION	Protect semi-conductor control devices from potential high voltage.
A4	Inspect all ground connections. Ensure connections are clean and tight. Treat with corrosion inhibitor as required.
A5	Perform a continuity test on motor ground.
Note 1	There should be zero ohms between the motor and the grounding network. If there is not continuity do not proceed until repair has been made.
A6	Attach ground cable (black cable) from tester to ground.
A7	Test to ensure a ground established.
A8	Attach test cable (usually red cable) to circuit to be tested.
A9	Energize tester.
A10	Record test results at one minute intervals for 10 minutes.
A11	De-energize tester.
WARNING	Circuit may have dangerous voltage potential following testing.
A12	Discharge circuit.
A13	Remove test cables.
A14	Remove thermometer, record temperature.
A15	Close access doors and panels.
A16	Return motor to service.
Inspection Data	
ID-1	Insulation Resistance at 1 min (Megohm)
ID-2	Insulation Resistance at 2 min (Megohm)
ID-3	Insulation Resistance at 3 min (Megohm)
ID-4	Insulation Resistance at 4 min (Megohm)

ID-5	Insulation Resistance at 5 min (Megohm)
ID-6	Insulation Resistance at 6 min (Megohm)
ID-7	Insulation Resistance at 7 min (Megohm)
ID-8	Insulation Resistance at 8 min (Megohm)
ID-9	Insulation Resistance at 9 min (Megohm)
ID-10	Insulation Resistance at 10 min (Megohm)
ID-11	Temperature (degree C or F)
Engineer's Notes	
EN1	Specify the Insulation Resistance test voltage as follows:
EN1a	Circuit 480V or less, test voltage 500V
EN1b	Circuit 600V, test voltage 1000V
EN1c	Circuit 2400V, test voltage 2500V
EN1d	Circuit 4160V and above, test voltage 5000v
EN2	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN3	For most motors found at NASA Centers, a Motor Circuit Evaluation test set can be used in place of the Direct Current Insulation Resistance Tester (Megohmmeter, Megger). Check with the test manufacturer for MCE effectiveness on large motors.
EN4	For motors above 600 volts Insulation Power Factor testing has been successfully used to trend the condition of the windings; however no industry standards have yet been identified.
EN5	See IEEE Standard 43-1974, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery, for guidance on insulation condition and interpretation of polarization index test results.
EN5a	Minimum insulation resistance for a new winding is 100 megohm and polarization index of 3 or greater.
EN5b	Minimum insulation resistance for an in-service winding is 10 megohm and polarization index of 1.5 or greater.
EN5c	An in-service winding with a polarization index less than 1.5 should be cleaned.

PT&I-04: Transformer - Test Insulation

Block Title	Text
Procedure Number	PT&I-04
System Description	Transformer

Procedure Description	Test Insulation
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Three Terminal Ground Resistance Tester, Direct Current Insulation Resistance Tester (Megohmmeter, Megger), Thermometer, 2-Shorting Cables (copper wire or braid)
Materials	
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. If results of the 3 point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
	3. Circuit may have dangerous voltage potential following testing.
Caution Summary	
Preliminary	
1	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
2	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Test Insulation
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Open transformer panels or doors to gain access to primary and secondary winding bushings.
WARNING	Test to ensure all circuits are de-energized.
A3	Place thermometer in close proximity to transformer bushings.
A4	Perform three point ground test. Record test results.
WARNING	If results of the 3 point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
A5	Disconnect all lighting arresters, current transformers, and bus or cable connections. Disconnect primary switch.
A6	Attach ground cable (black cable) from tester to ground.
A7	Test to ensure a ground established.
A8	Tie (short circuit) the primary bushings together using copper wire or braid.
A9	Tie (short circuit) the secondary bushings together using copper wire or braid.

A10	Attach test cable (usually red cable) to primary bushing.
A11	Energize tester.
A12	Record test results at one minute intervals for 10 minutes.
A13	De-energize tester.
WARNING	Circuit may have dangerous voltage potential following testing.
A14	Discharge circuit.
A15	Move test cable to secondary bushing.
A16	Repeat steps A11 through A14.
WARNING	Circuit may have dangerous voltage potential following testing.
A17	Move test cable back to primary bushing.
A18	Move ground cable to secondary bushing.
A19	Repeat steps A11 through A14.
WARNING	Circuit may have dangerous voltage potential following testing.
A20	Attach ground cable (black cable) from tester to primary switch ground.
A21	Test to ensure a ground established.
A22	Move test cable to primary switch, load side, A-phase.
A23	Energize tester.
A24	Record test results at one minute.
A25	De-energize tester.
WARNING	Circuit may have dangerous voltage potential following testing.
A26	Discharge circuit.
A27	Repeat steps A21 through A25 for B- and C-phase.
A28	Remove test and shorting cables.
A29	Remove thermometer, record temperature.
A30	Perform related tasks, if any.
A31	Reconnect all lighting arresters, current transformers, and bus or cable connections. Reconnect primary switch.
A32	Close access doors and panels.
A33	Return transformer to service.
Inspection Data	
ID-1	Ground Test (ohms)
ID-2	Primary to Ground Insulation Resistance at 1 min (Megohm)
ID-3	Primary to Ground Insulation Resistance at 2 min (Megohm)
ID-4	Primary to Ground Insulation Resistance at 3 min (Megohm)

ID-5	Primary to Ground Insulation Resistance at 4 min (Megohm)
ID-6	Primary to Ground Insulation Resistance at 5 min (Megohm)
ID-7	Primary to Ground Insulation Resistance at 6 min (Megohm)
ID-8	Primary to Ground Insulation Resistance at 7 min (Megohm)
ID-9	Primary to Ground Insulation Resistance at 8 min (Megohm)
ID-10	Primary to Ground Insulation Resistance at 9 min (Megohm)
ID-11	Primary to Ground Insulation Resistance at 10 min (Megohm)
ID-12	Secondary to Ground Insulation Resistance at 1 min (Megohm)
ID-13	Secondary to Ground Insulation Resistance at 2 min (Megohm)
ID-14	Secondary to Ground Insulation Resistance at 3 min (Megohm)
ID-15	Secondary to Ground Insulation Resistance at 4 min (Megohm)
ID-16	Secondary to Ground Insulation Resistance at 5 min (Megohm)
ID-17	Secondary to Ground Insulation Resistance at 6 min (Megohm)
ID-18	Secondary to Ground Insulation Resistance at 7 min (Megohm)
ID-19	Secondary to Ground Insulation Resistance at 8 min (Megohm)
ID-20	Secondary to Ground Insulation Resistance at 9 min (Megohm)
ID-21	Secondary to Ground Insulation Resistance at 10 min (Megohm)
ID-22	Primary to Secondary Insulation Resistance at 1 min (Megohm)
ID-23	Primary to Secondary Insulation Resistance at 2 min (Megohm)
ID-24	Primary to Secondary Insulation Resistance at 3 min (Megohm)
ID-25	Primary to Secondary Insulation Resistance at 4 min (Megohm)
ID-26	Primary to Secondary Insulation Resistance at 5 min (Megohm)
ID-27	Primary to Secondary Insulation Resistance at 6 min (Megohm)
ID-28	Primary to Secondary Insulation Resistance at 7 min (Megohm)
ID-29	Primary to Secondary Insulation Resistance at 8 min (Megohm)
ID-30	Primary to Secondary Insulation Resistance at 9 min (Megohm)
ID-31	Primary to Secondary Insulation Resistance at 10 min (Megohm)
ID-32	Primary Switch, Phase-A to Ground Insulation Resistance at 1 min (Megohm)
ID-33	Primary Switch, Phase-B to Ground Insulation Resistance at 1 min (Megohm)
ID-34	Primary Switch, Phase-C to Ground Insulation Resistance at 1 min (Megohm)
ID-35	Temperature (degree C or F)
Engineer's Notes	

EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ANSI/IEEE Standard C57.12.90-1993; IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.
EN1b	ANSI/IEEE Standard C57.12.91-1979 (updated 1995); IEEE Test Code for Dry-Type Distribution and Power Transformers .
EN2	Specify the Insulation Resistance test voltage as follows:
EN2a	Circuit 480V or less, test voltage 500V
EN2b	Circuit 600V, test voltage 1000V
EN2c	Circuit 2400V, test voltage 2500V
EN2d	Circuit 4160V and above, test voltage 5000v
EN3	The Polarization Index (PI) is the 10 minute insulation resistance reading divided by the 1 minute insulation resistance reading. This value should be monitored and trended to help determine the condition of the windings. Guidelines are from S.D.Myers.
EN3a	For liquid filled transformers: PI greater than 2.0 is good, 1.25 to 2.0 is fair, 1.1 to 1.25 is poor, and less than 1.1 is bad.
EN3b	For dry transformers the PI will normally be between 1.0 and 1.25. Insulation resistance value should be greater than 10,000 megohms.
EN4	Procedure is written for a step-down transformer and assumes the high voltage side is the line side. For step-up transformer, reverse the test procedure to test the load side first.
EN4a	If the line side of the primary switch is also de-energized, you can modify this procedure to test the line and load sides of the primary switch. Prior to step A22 close the primary switch and then take insulation data. Add Warning to test the circuit.
EN5	Time estimate should include 2 to 3 hours to de-energize and tag out.

PT&I-05: Electrical Distribution - Test Insulation

Block Title	Text
Procedure Number	PT&I-05
System Description	Electrical Distribution
Procedure Description	1. Circuit Breaker/Air Switch Insulation Test
	2. Switchgear and Phase Bus Insulation Test
	3. Loadbreak Switch Insulation Test
Related Tasks	
Periodicity	
Labor (Hrs)	

Special Tools	Direct Current Insulation Resistance Tester (Megohmmeter, Megger), Thermometer, Shorting Cable (copper wire or braid)
Materials	
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Circuit may have dangerous voltage potential following testing.
Caution Summary	
Reserved	
Preliminary	
1	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
2	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Circuit Breaker/Air Switch Insulation Test
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Open circuit breaker/air switch panels or doors to gain access to line side and load side bushings.
WARNING	Test to ensure all circuits are de-energized.
A3	Place thermometer in close proximity to circuit breaker/air switch mechanism.
A4	Attach ground cable (black cable) from tester to ground.
A5	Test to ensure a ground established.
A6	Tie (short circuit) the A-phase line and load bushings together using copper wire or braid.
A7	Attach test cable (usually red cable) to A-phase bushing.
A8	Energize tester.
A9	Record test results at one minute.
A10	De-energize tester.
A11	Discharge circuit.
WARNING	Circuit may have dangerous voltage potential following testing.
A12	Repeat steps A6 through A11 for the B-phase.
WARNING	Circuit may have dangerous voltage potential following testing.
A13	Repeat steps A6 through A11 for the C-phase.
WARNING	Circuit may have dangerous voltage potential following testing.
A14	Remove test and shorting cables.
A15	Remove thermometer, record temperature.

A16	Close access doors and panels.
A17	Return circuit breaker/air switch to service.
B	Switchgear and Phase Bus Insulation Test
B1	De-energize equipment and tag out in accordance with site safety practices.
B2	Open switchgear panels or doors.
WARNING	Test to ensure all circuits are de-energized.
B3	Disconnect all lighting arresters, current transformers, and bus or cable connections.
B4	Place thermometer in close proximity to switchgear or phase bus.
B5	Rack out all circuit breakers and open all switches.
B6	Remove or disconnect all potential transformers.
B7	Connect test set ground to switchgear or phase bus ground.
B8	Connect test set high voltage lead to A-phase bus.
WARNING	Energized electrical circuits. Observe test device safety precautions.
B9	Perform A-phase test and record results.
WARNING	Circuit may have dangerous voltage potential following testing.
B10	Discharge circuit.
B11	Repeat steps B7 through B10 for B-phase.
B12	Repeat steps B7 through B10 for C-phase.
B13	Remove thermometer, record temperature.
B14	Remove all test cables.
B15	Rack in all circuit breakers and close switches.
B16	Reconnect all lightning arresters, current transformers, bus and cable connections, and potential transformers.
B17	Close switchgear panels or doors.
B18	Return Switchgear/Phase Bus to service.
C	Loadbreak Switch Insulation Test
C1	De-energize equipment and tag out in accordance with site safety practices.
C2	Open loadswitch panels or doors if applicable.
WARNING	Test to ensure all circuits are de-energized.
C3	Disconnect all lighting arresters, current transformers, and bus or cable connections.
C4	Place thermometer in close proximity to switchgear or phase bus.
C5	Attach ground cable (black cable) from tester to loadbreak switch ground.
C6	Test to ensure a ground established.

C7	Tie (short circuit) position 1 load side bushings together with copper wire or braid.
C8	Tie (short circuit) position 1 line side bushings together with copper wire or braid.
C9	Close loadbreak switch position 1
C10	Attach test cable (usually red cable) to A-phase bushing.
C11	Energize tester.
C12	Record test results at one minute.
C13	De-energize tester.
C14	Discharge circuit.
WARNING	Circuit may have dangerous voltage potential following testing.
C15	Repeat steps C7 through C14 for each loadbreak switch position.
WARNING	Circuit may have dangerous voltage potential following testing.
C16	Remove test and shorting cables.
C17	Remove thermometer, record temperature.
C18	Close access doors and panels.
C19	Return loadbreak switch to service.
Inspection Data	
ID-1	Phase-A to Ground Insulation Resistance at 1 min (Megohm)
ID-2	Phase-B to Ground Insulation Resistance at 1 min (Megohm)
ID-3	Phase-C to Ground Insulation Resistance at 1 min (Megohm)
ID-4	Temperature (degree C or F)
ID-5	Loadbreak Switch Position 1 Insulation Resistance at 1 min (Megohm)
ID-6	Loadbreak Switch Position 2 Insulation Resistance at 1 min (Megohm)
ID-7	Loadbreak Switch Position 3 Insulation Resistance at 1 min (Megohm)
ID-8	Loadbreak Switch Position 4 Insulation Resistance at 1 min (Megohm)
ID-9	Loadbreak Switch Position 5 Insulation Resistance at 1 min (Megohm)
Engineer's Notes	
EN1	Specify the Insulation Resistance test voltage as follows:
EN1a	Circuit 480V or less, test voltage 500V
EN1b	Circuit 600V, test voltage 1000V
EN1c	Circuit 2400V, test voltage 2500V
EN1d	Circuit 4160V and above, test voltage 5000v

EN2	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN2a	ANSI/IEEE Standard C37.50-1989; American National Standard for Switchgear-Low Voltage AC Power Circuit Breakers Used in Enclosures - Test Procedures.
EN2b	ANSI/IEEE Standard C37.09-1979; IEEE Standard Test Procedures for AC High-Voltage Breakers Rated on a Symmetrical Current Basis.
EN2c	IEEE C37.35-1995, IEEE Guide for the Application, Installation, Operation, and Maintenance of High Voltage Air Disconnecting and Interrupter Switches.
EN2d	IEEE C37.20.2-1993, IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear.
EN2e	IEEE C37.20.1-1993, IEEE Standard for Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear.

PT&I-06: Oil Filled Transformer - Sample and Test Transformer Oil

Block Title	Text
Procedure Number	PT&I-06
System Description	Oil Filled Transformer
Procedure Description	1. Sample Transformer Oil
	2. Perform Field Oil Tests
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	50cc Glass Syringe, Two 16 Ounce Glass Oil Sample Bottles, Power Factor Test Set, Acidity Test Kit, Oil Dielectric Test Set, Oil Color Chart
Materials	
Reference Data	ASTM Standard Test Methods (STM)
	D-3613-92 - Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content
	D-877-87 - Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes (Dielectric Withstand Test)
	D-1534-90 - Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration
	D-1524-84 - Visual Examination of Used Electrical Insulating Oil of Petroleum Origin In the Field
	Power Factor Test Set Operating Instructions

Warning Summary	Prior to obtaining oil sample verify transformer is not PCB filled or PCB contaminated. PCB oil goes by many trade names including Inerteen, Pyranol, and Askarel. Contact maintenance engineer if oil type is not known.
Caution Summary	
Preliminary	
1	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
2	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Sample Transformer Oil
WARNING	Prior to obtaining oil sample verify transformer is not PCB filled or PCB contaminated. PCB oil goes by many trade names including Inerteen, Pyranol, and Askarel. Contact maintenance engineer if oil type is not known.
A1	Collect dissolved gas oil sample from transformer. Use 50cc glass syringe and follow procedure in ASTM standard D-3613-92.
A2	Collect two additional oil samples in sample bottles. Record equipment number, date, and oil temperature on one bottle.
B	Perform Field Oil Tests
B1	Use oil in un-labeled bottle for steps B2 through B5.
B2	Perform Dielectric Withstand Test (ASTM D-877-87).
B3	Perform Field Acidity Test (ASTM D-1534-90).
B4	Perform Visual Examination (ASTM D-1524-84).
Note	See Power Factor Test Set operating instructions for Oil Power Factor test procedure.
B5	Perform Oil Power Factor.
B6	Record test results in Inspection Data Section, item ID-1 to ID-4.
B7	Deliver oil sample in labeled bottle and 50cc glass syringe to supervisor or PT&I for analysis.
Inspection Data	
ID-1	Dielectric Withstand Test (kV)
ID-2	Field Acidity Test (mg KOH/ml)
ID-3	Visual Examination (color scale)
ID-4	Oil Power Factor (percent)
Engineer's Notes	

EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	ANSI/IEEE Standard C57.12.90-1993; IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.
EN1b	ANSI/IEEE Standard C57.111-1989; IEEE Guide for Acceptance of Silicone Insulating Fluid and It's Maintenance in Transformers.
EN1c	ANSI/IEEE Standard C57.104-1991; IEEE Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers.
EN2	Send oil sample in the labeled bottle to test lab for a Karl Fischer (ASTM D-1533-88), Acid Number (ASTM D-974-87), and Interfacial Tension (ASTM D- 971-82) test.
EN3	Send 50cc syringe to test lab for gas-in-oil analysis (ASTM D-3613-92).
EN4	Field oil test results shall be as follows:
EN4a	Dielectric Test: >30kV
EN4b	Acidity Test: <.05 mg KOH/ml
EN4c	Visual Examination: <4.0
EN4d	Power Factor: <2.0%
EN5	Generate work order if tests fall outside minimum parameters.

PT&I-07: Transformer - Power Factor Test

Block Title	Text
Procedure Number	PT&I-07
System Description	Transformer
Procedure Description	Power Factor Test
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Three Terminal Ground Resistance Tester, Power Factor Test Set, Psychrometer (or temperature/humidity meter), 2-Shorting Cables (copper wire or braid)
Materials	
Reference Data	Power Factor Test Set Operating Instructions
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. If results of the 3 point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.

	3. Energized electrical circuits. Observe test device safety precautions.
	4. Circuit may have dangerous voltage potential following testing.
Caution Summary	Ensure shorting cables are removed from primary and secondary bushings.
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-10.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Power Factor Test
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Open transformer panels or doors to gain access to primary and secondary winding bushings.
WARNING	Test to ensure all circuits are de-energized.
A3	Perform three point ground test. Record test results.
WARNING	If results of the 3 point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
A4	Disconnect all lighting arresters, current transformers, and bus or cable connections.
A5	Tie (short circuit) the primary bushings together using copper wire or braid.
A6	Tie (short circuit) the secondary bushings, including neutral, together using copper wire or braid.
Note 1	If transformer has on-load tap changer, mark the as found position. Test can not be performed with the on-load tap changer in the neutral position. Leave no-load tap changer, if installed, in normal operating position.
A7	Move on-load tap changer (if installed) to minus 1 from neutral position.
A8	Connect test set high voltage lead to primary bushing.
A9	Connect test set return lead to secondary bushing.
A10	Connect test ground to transformer ground.
Note 2	For each test performed, record results in Inspection Data section.
WARNING	Energized electrical circuits. Observe test device safety precautions.
A11	Perform primary-to-secondary test with ground circuit guarded.
A12	Perform primary-to-secondary test with secondary circuit guarded.

A13	Perform primary-to-secondary test with secondary and ground circuit included.
WARNING	Circuit may have dangerous voltage potential following testing.
A14	Discharge circuit.
A15	Connect test set high voltage lead to secondary bushing.
A16	Connect test set return lead to primary bushing.
WARNING	Energized electrical circuits. Observe test device safety precautions.
A17	Perform secondary-to-primary test with ground circuit guarded.
A18	Perform secondary-to-primary test with ground circuit included.
WARNING	Circuit may have dangerous voltage potential following testing.
A19	Discharge circuit.
A20	Remove shorting cables from primary and secondary bushings.
A21	Move on-load tap changer (if installed) to neutral.
Note 3	If transformer has no-load tap changer, leave in normal operating position.
A22	Connect test set high voltage lead to primary bushing 1 (usually identified as H1).
A23	Connect test set return lead to primary bushing 2 (usually identified as H2).
WARNING	Energized electrical circuits. Observe test device safety precautions.
A24	Perform excitation test H1 to H2.
WARNING	Circuit may have dangerous voltage potential following testing.
A25	Discharge circuit.
A26	Connect test set high voltage lead to primary bushing 2 (usually identified as H2).
A27	Connect test set return lead to primary bushing 3 (usually identified as H3).
WARNING	Energized electrical circuits. Observe test device safety precautions.
A28	Perform excitation test H2 to H3.
WARNING	Circuit may have dangerous voltage potential following testing.
A29	Discharge circuit.
A30	Connect test set high voltage lead to primary bushing 3 (usually identified as H3).
A31	Connect test set return lead to primary bushing 1 (usually identified as H1).
WARNING	Energized electrical circuits. Observe test device safety precautions.
A32	Perform excitation test H3 to H1.
WARNING	Circuit may have dangerous voltage potential following testing.
A33	Discharge circuit.

A34	Remove all test cables.
A35	Reconnect all lighting arresters, current transformers, and bus or cable connections.
A36	Return tap changer to original position.
CAUTION	Ensure shorting cables are removed from primary and secondary bushings.
A37	Perform related tasks, if any.
A38	Close access doors and panels.
A39	Return transformer to service.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)
ID-4	Weather Conditions (Cloudy, etc.)
ID-5	Oil Level
ID-6	Oil Temperature (C)
ID-7	Maximum Oil Temperature (C)
ID-8	Winding Temperature (C)
ID-9	Maximum Winding Temperature (C)
ID-10	Tank Pressure (psi)
ID-11	Ground Test (ohms)
ID-12	Power Factor, primary-to-secondary, ground circuit guarded.
ID-13	Power Factor, primary-to-secondary, secondary circuit guarded.
ID-14	Power Factor, primary-to-secondary, secondary and ground circuit included.
ID-15	Power Factor, secondary-to-primary, ground circuit guarded.
ID-16	Power Factor, secondary-to-primary, ground circuit included.
ID-17	Power Factor Excitation, H1-H2
ID-18	Power Factor Excitation, H2-H3
ID-19	Power Factor Excitation, H3-H1
Engineer's Notes	
EN1	Specify the Power Factor test voltage as follows:
EN1a	Circuit less than 2400V, test voltage 500V
EN1b	Circuit 2400V to 4160V, test voltage 2500V
EN1c	Circuit 4160V to 10,000V, test voltage 5000V

EN1d	Circuit 10,000V and above, test voltage 10,000V
EN2	The time estimate to perform this task should include 2 to 3 hours to de-energize and tag out the unit.
EN3	A Power Factor test measures the watts loss and the phase angle between the current and voltage in the equipment under test. From this information a determination can be made as to the integrity of the insulation.
EN3a	Power Factor results are listed in percent, because the final reading is multiplied by 100, as one would do when converting a number into a percentage. In this case, though, the number is not a percentage comparison but a stand alone number that should be trended over time.
EN3b	The Power Factor test is NOT a go-no/go test. Comparisons of past readings are necessary to determine the insulation condition
EN3c	All test values must be temperature corrected to 20C.
EN3d	Liquid filled (Oil, Silicone): less than 2% indicates good condition; 2% to 4% investigate; over 4% bad condition.
EN3e	Dry windings: less than 5% indicates good condition; 5% to 8% investigate; over 8% dry out transformer and retest.
EN4	The excitation test is the amount of current required to magnetize the iron and produce a voltage on the secondary.
EN4a	This current value is different for every transformer, dependent on the amount of iron in the winding core, purity of the iron/silicone laminations, and amount of copper/aluminum in the windings.
EN4b	Consequently there is not an absolute value/limit that is applicable; the % change from the transformer baseline is the monitored condition.
EN4c	Excitation: Any two phases approximately the same, third phase 20% less than the other two. A change of 10% from previous test needs to be investigated.

PT&I-08: Electrical Distribution - Power Factor Test

Block Title	Text
Procedure Number	PT&I-08
System Description	Electrical Distribution
Procedure Description	1. Switchgear and Phase Bus Power Factor Test
	2. Circuit Breaker Power Factor Test
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Power Factor Test Set, Psychrometer (or temperature/humidity meter), Shorting Cable (copper wire or braid), Thermometer

Materials	
Reference Data	Power Factor Test Set Operating Instructions
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Energized electrical circuits. Observe test device safety precautions.
	3. Circuit may have dangerous voltage potential following testing.
	4. Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
Caution Summary	Ensure shorting cables are removed from circuit breaker bushings.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-4.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Switchgear and Phase Bus Power Factor Test
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Open switchgear panels or doors.
WARNING	Test to ensure all circuits are de-energized.
A3	Disconnect all lighting arresters, current transformers, and bus or cable connections.
A4	Place thermometer in close proximity to switchgear or phase bus.
A5	Rack out all circuit breakers and open all switches.
A6	Remove or disconnect all potential transformers.
A7	Connect test set ground to switchgear or phase bus ground.
A8	Connect test set high voltage lead to A-phase bus.
WARNING	Energized electrical circuits. Observe test device safety precautions.
A9	Perform A-phase test and record results.
WARNING	Circuit may have dangerous voltage potential following testing.
A10	Discharge circuit.
A11	Repeat steps A7 through A9 for B-phase.
A12	Repeat steps A7 through A9 for C-phase.
A13	Remove thermometer, record temperature.

A14	Remove all test cables.
A15	Reconnect all lighting arresters, current transformers, and bus or cable connections.
A16	Perform related tasks, if any.
A17	Rack in and close circuit breakers and switches as required.
CAUTION	Ensure shorting cables are removed from circuit breaker bushings.
A18	Return distribution system to service.
B	Circuit Breaker Power Factor Test
B1	Open circuit breaker.
WARNING	Test to ensure all circuits are de-energized.
B2	Rack out circuit breakers, open all switches, or otherwise disconnect from phase leads or phase bus.
B3	Place thermometer in close proximity to circuit breaker mechanism.
B4	Connect test set ground to circuit breaker ground.
Note	Circuit breaker bushings number 1 through 3 are line side A-phase through C-phase respectively. Bushings 4 through 6 are load side A-phase through C-phase respectively.
B5	Connect test set high voltage lead to circuit breaker bushing 1.
WARNING	Energized electrical circuits. Observe test device safety precautions.
B6	Perform circuit breaker power factor test and record results.
WARNING	Circuit may have dangerous voltage potential following testing.
B7	Discharge circuit.
B8	Repeat steps B4 through B6 for circuit breaker bushing 2.
B9	Repeat steps B4 through B6 for circuit breaker bushing 3.
B10	Repeat steps B4 through B6 for circuit breaker bushing 4.
B11	Repeat steps B4 through B6 for circuit breaker bushing 5.
B12	Repeat steps B4 through B6 for circuit breaker bushing 6.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
B13	Close circuit breaker.
B14	Tie (short circuit) the A-phase line and load bushings together using copper wire or braid.
B15	Connect test set high voltage lead to circuit breaker bushing 1.
WARNING	Energized electrical circuits. Observe test device safety precautions.
B16	Perform circuit breaker power factor test and record results.
WARNING	Circuit may have dangerous voltage potential following testing.
B17	Discharge circuit.

B18	Remove shorting cable from A-phase bushings.
B19	Repeat steps B13 through B17 for B-phase bushings.
B20	Repeat steps B13 through B17 for C-phase bushings.
B21	Remove thermometer, record temperature.
B22	Open the circuit breaker.
B23	Rack in circuit breaker or reconnect phase leads or phase bus.
B24	Repeat procedure for remaining circuit breakers.
B25	Remove all test cables.
B26	Perform related tasks, if any.
CAUTION	Ensure shorting cables are removed from circuit breaker bushings.
B27	Rack in and close circuit breakers and switches as required.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)
ID-4	Weather Conditions (Cloudy, etc.)
ID-5	Power Factor Switchgear or Phase Bus, A-phase, ground specimen test.
ID-6	Power Factor Switchgear or Phase Bus, B-phase, ground specimen test.
ID-7	Power Factor Switchgear or Phase Bus, C-phase, ground specimen test.
ID-8	Temperature (degree C or F)
ID-9	Power Factor Circuit Breaker, Bushing 1, ground specimen test.
ID-10	Power Factor Circuit Breaker, Bushing 2, ground specimen test.
ID-11	Power Factor Circuit Breaker, Bushing 3, ground specimen test.
ID-12	Power Factor Circuit Breaker, Bushing 4, ground specimen test.
ID-13	Power Factor Circuit Breaker, Bushing 5, ground specimen test.
ID-14	Power Factor Circuit Breaker, Bushing 4, ground specimen test.
ID-15	Power Factor Circuit Breaker, A-phase, ground specimen test.
ID-16	Power Factor Circuit Breaker, B-phase, ground specimen test.
ID-17	Power Factor Circuit Breaker, C-phase, ground specimen test.
ID-18	Temperature (degree C or F)
Engineer's Notes	
EN1	Specify the Power Factor test voltage as follows:
EN1a	Circuit less than 2400V, test voltage 500V

EN1b	Circuit 2400V to 4160V, test voltage 2500V
EN1c	Circuit 4160V to 10,000V, test voltage 5000V
EN1d	Circuit 10,000V and above, test voltage 10,000V
EN2	A Power Factor test measures the watts loss and the phase angle between the current and voltage in the equipment under test. From this information a determination can be made as to the integrity of the insulation.
EN2a	Power Factor results are listed in percent, because the final reading is multiplied by 100, as one would do when converting a number into a percentage. In this case, though, the number is not a percentage comparison but a stand alone number that should be trended over time.
EN2b	The Power Factor test is NOT a go-no/go test. Comparisons of past readings are necessary to determine the insulation condition
EN2c	Note that all test values must be temperature corrected to 20C.
EN2d	For the switchgear and phase bus, power factor should be less than 2%. High readings indicate excess moisture or loose connections. Loose connections can be verified using infrared thermography on an energized circuit.
EN2e	For the circuit breakers, bushings test is for the individual bushing while the phase test is for the bushing and the lift rods and contacts. Each phase and bushing should be within 5% of each other.
EN2f	Individual bushings should be less than 5% after cleaning. Large 115kV and 230kV breakers with oil filled bushings will have the Power Factor baselines etched on the bushing base.

PT&I-09: Bushing - Power Factor Test

Block Title	Text
Procedure Number	PT&I-09
System Description	Bushing
Procedure Description	1. Power Factor Oil Filled Bushing - Hot Collar Method
	2. Power Factor Oil filled Bushing - Capacitance Tap Method
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Power Factor Test Set, Psychrometer (or temperature/humidity meter), Thermometer, Culenite Bushing Cleaner
Materials	
Reference Data	Power Factor Test Set Operating Instructions
Warning Summary	1. Test to ensure all circuits are de-energized.

	2. Energized electrical circuits. Observe test device safety precautions.
	3. Circuit may have dangerous voltage potential following testing.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-4.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Power Factor Test Hot Collar Method
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Gain access to bushing.
WARNING	Test to ensure all circuits are de-energized.
A3	Disconnect all lighting arresters, current transformers, and bus or cable connections.
A4	Clean bushing.
Note	Do not use any alcohol based cleaning product.
A5	Place thermometer on bushing.
A6	Place power factor test hot collar strap under uppermost bushing petticoat or rain shield.
A7	Connect test set high voltage lead to hot collar strap.
A8	Ground bushing terminal.
WARNING	Energized electrical circuits. Observe test device safety precautions.
A9	Perform grounded specimen power factor test and record results.
WARNING	Circuit may have dangerous voltage potential following testing.
A10	Discharge circuit.
A11	Remove thermometer, record temperature.
A12	Remove all test cables.
A13	Repeat steps A2 through A12 for other bushings.
A14	Reconnect all lighting arresters, current transformers, and bus or cable connections.
A15	Perform related tasks, if any.
A16	Return system to service.

B	Power Factor Test Capacitance Tap Method
B1	De-energize equipment and tag out in accordance with site safety practices.
B2	Gain access to bushing.
WARNING	Test to ensure all circuits are de-energized.
B3	Disconnect all lighting arresters, current transformers, and bus or cable connections.
B4	Clean bushing.
Note	Do not use any alcohol based cleaning product.
B5	Place thermometer on bushing.
B6	Remove capacitance tap cover (at base of bushing).
B7	Connect test set return lead to capacitance tap.
B8	Connect test set high voltage lead to bushing terminal.
WARNING	Energized electrical circuits. Observe test device safety precautions.
B9	Perform grounded specimen power factor test and record results.
WARNING	Circuit may have dangerous voltage potential following testing.
B10	Discharge circuit.
B11	Remove thermometer, record temperature.
B12	Remove all test cables.
B13	Repeat steps B2 through B12 for other bushings.
B14	Reconnect all lighting arresters, current transformers, and bus or cable connections.
B15	Perform related tasks, if any.
B16	Return system to service.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)
ID-4	Weather Conditions (Cloudy, etc.)
ID-5	Power Factor Bushing, ground circuit guarded.
ID-6	Bushing Capacitance
ID-7	Temperature (degree C or F)
Engineer's Notes	
EN1	Specify the Power Factor test voltage as follows:

EN1a	Circuit less than 2400V, test voltage 500V
EN1b	Circuit 2400V to 4160V, test voltage 2500V
EN1c	Circuit 4160V to 10,000V, test voltage 5000V
EN1d	Circuit 10,000V and above, test voltage 10,000V
EN2	A Power Factor test measures the watts loss and the phase angle between the current and voltage in the equipment under test. From this information a determination can be made as to the integrity of the insulation.
EN2a	Power Factor results are listed in percent, because the final reading is multiplied by 100, as one would do when converting a number into a percentage. In this case, though, the number is not a percentage comparison but a stand alone number that should be trended over time.
EN2b	The Power Factor test is NOT a go-no/go test. Comparisons of past readings are necessary to determine the insulation condition
EN2c	All test values must be temperature corrected to 20C.
EN2d	Individual bushings should be less than 5% after cleaning. Large 115kV and 230kV oil filled bushings will have the Power Factor baselines etched on the bushing base.

PT&I-10: Rotating machinery - Extract Lubricant Sample

Block Title	Text
Procedure Number	PT&I-10
System Description	
Procedure Description	Extract Lubricant Sample
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Lubricant Extraction Pump, Tubing
Materials	Sample Bottles, Labels
Reference Data	
Warning Summary	Exercise caution when working around rotating machinery.
Caution Summary	
Reserved	
Preliminary	
1	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
2	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.

3	Observe site safety precautions when opening machinery lubricant systems.
Procedure	
A	Extract Lubricant Sample
A1	Label bottle with equipment number, oil type, building number and collection date.
A2	Flush oil sample port before taking sample.
Note	Lubricant must be extracted from the middle of the reservoir. Do not extract oil from the bottom or top of reservoir.
A3	Remove bottle cap and fill bottle to shoulder with lubricant sample.
A4	Replace bottle cap immediately after sample is taken.
Note	Use lubricant extraction pump (if applicable). Use a dip-stick to pre-measure the extraction tube depth. Replace sample tubing after each sample. Keep bottle closed until sample is taken. Be careful not to contaminate the sample with dirt from the sample port.
A5	Check oil level, add if system is low.
A6	Record unsatisfactory conditions on work order and report them to supervisor.
A7	Remove debris from work-site.
Engineer's Notes	
EN1	For time estimating purposes, allow 10 minutes per sample.
EN2	Periodicity can be adjusted after a baseline is established.
EN3	Alert and alarm values are set based upon changes from new lubricant baseline. Typical minimum conditions to monitor include:
EN3a	Fluid cleanliness by ISO 4406 standard. Vickers Corporation provides a guideline for common industrial equipment.
EN3b	Viscosity as specified by the lubricant manufacturer.
EN3c	Water, usually none present. Greater than 0.1% water is usually indicated by hazy appearance (water is either suspended or emulsified).
EN3d	Total Acid or Total Base Number

PT&I-11: Battery Bank -Battery Impedance Test

Block Title	Text
Procedure Number	PT&I-11
System Description	Battery Bank
Procedure Description	Battery Impedance Test
Related Tasks	

Periodicity	
Labor (Hrs)	
Special Tools	Battery Impedance Test Set
Materials	Scotchbrite or Very Fine Emery Cloth.
Reference Data	Manufacture's/equipment output specification.
Warning Summary	1. Observe standard safety precautions when working on energized electrical circuits.
	2. Wear proper protective clothing; batteries contain acid.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Observe site safety precautions for working on acid filled batteries.
Procedure	
A	Battery Impedance Test
WARNING	Observe standard safety precautions when working on energized electrical circuits.
WARNING	Wear proper protective clothing; batteries contain acid.
A1	Connect battery impedance test set AC signal leads to positive (+) and negative (-) terminals of battery bank.
A2	Clamp impedance receiver unit around positive AC signal lead.
A3	Measure impedance of first cell. Record impedance reading on note paper or in battery book.
A4	Measure impedance of first strap. Record impedance reading on note paper or in battery book.
A5	Repeat steps A3 and A4 for each cell/strap combination in battery bank.
A6	Inspect batteries and battery connections for leaks, overheating, or corrosion.
A7	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
A8	Perform cleaning and touchup painting as required.
A9	Record battery voltage and trickle charge rate.
A10	Remove debris from work-site.

Inspection Data	Fill in all applicable.
ID-1	Battery impedance test results (use separate sheet or record in battery book).
ID-2	Record battery voltage and trickle charge in standby mode.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	IEEE Standard 446-1995, "IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications", IEEE Orange Book.
EN2	Battery impedance tests.
EN2a	Battery cell impedance shall be within 10% of each other and within 10% from last test.
EN2b	Battery strap impedance shall be less than 0.1 ohm. Readings above 0.1 ohm require cleaning and retorque.
EN3	Battery voltage and trickle charge in standby to be within 5% of manufacturer's specifications.

Transformers

Procedure Number	Machine/System	Procedure Summary
Tran-01	Dry Type Transformer	Inspect and Clean Dry Type Transformer
Tran-02	Liquid Filled Transformer	Inspect and Clean Liquid Filled Transformer

Tran-01: Dry Type Transformer - Inspect and Clean Dry Type Transformer

Block Title	Text
Procedure Number	Tran-01
System Description	Dry Type Transformer
Procedure Description	Inspect and Clean Dry Type Transformer.
Related Tasks	PT&I-04, PT&I-07
Periodicity	
Labor (Hrs)	
Special Tools	Vacuum Cleaner, Psychrometer (or temperature/humidity meter)

Materials	Corrosion Inhibitor, Culenite Bushing Cleaner
References	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. If results of the three point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Repair Transformer
A1	De-energize equipment and tag out in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
A2	Open transformer panels or doors as necessary to gain access to components and install safety grounds.
Note1	This procedure is for dry type transformers. Components identified for inspection in this procedure are not necessarily on all transformers.
A3	Inspect all exposed ground connections. Ensure connections are clean and tight. Treat with Corrosion Inhibitor.
A4	Perform three point ground test. Record test results in Inspection Data section, Item ID-1.
WARNING	If results of the three point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Note 2	Perform electrical insulation tests on dry type transformers immediately after the unit has been de-energized and safety isolated.
A5	Perform related tasks PT&I-04 and PT&I-07 if required.
A6	Inspect transformer and disconnect device (where applicable) for signs of excessive heating and/or insulation damage.
A7	Inspect all exposed conduit and potheads/connection boots for secure mounting, corrosion, damaged fittings, and signs of moisture contamination.
A8	Inspect enclosure, gauges, fuses, and other external parts and accessories for corrosion, looseness, and damage.

A9	Clean transformer windings and enclosure with vacuum cleaner and/or compressed air.
A10	Clean transformer high and low voltage bushings (if accessible). Clean disconnect switch bushings and insulators (where applicable). Examine bushings for cracks, chips, or corona flashover.
A11	Ensure heaters are working properly.
A12	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
A13	Perform spot cleaning and touchup painting as required.
A14	Remove safety grounds.
A15	Close access doors.
A16	Re-energize transformer and return to service.
A17	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Three Point Ground Test Results
Engineer's Notes	
EN1	In order make effective use of time, this procedure for cleaning and inspecting a transformer should be used in conjunction with other procedures (identified in Related Task section) for testing transformers.
EN2	Dry type transformer windings are very hydroscopic in nature, thus as a unit is taken off-line and begins to cool the windings begin to accumulate moisture. Consequently, it is important to perform the electrical insulation tests immediately after the unit is de-energized to minimize the moisture effect on the test results.
EN3	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN3a	ANSI/IEEE Standard C57.12.91-1979; IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.

Tran-02: Liquid Filled Transformer - Inspect and Clean Liquid Filled Transformer

Block Title	Text
Procedure Number	Tran-02
System Description	Liquid Filled Transformer
Procedure Description	Inspect and Clean Liquid Filled Transformer
Related Tasks	PT&I-04, PT&I-06, PT&I-07

Periodicity	
Labor (Hrs)	
Special Tools	
Materials	Corrosion Inhibitor, Culenite Bushing Cleaner
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. If PCB or PCB contaminated oil has leaked from the transformer, stop work, and notify maintenance engineer.
	3. If results of the three point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Perform related task PT&I-06, Sample and Test Transformer Oil, if required, prior to de-energizing the unit.
Procedure	
A	Inspect and Clean Transformer
A1	De-energize equipment and tag out in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
A2	Open transformer panels or doors as necessary to gain access to components and install safety grounds.
Note1	This procedure is for silicone and oil filled transformers. Components identified for inspection in this procedure are not necessarily on all transformers.
Note 2	Some older liquid filled transformers may be PCB filled or PCB contaminated. PCB oil goes by many trade names including Inerteen, Pyranol, and Askarel. Contact maintenance engineer if oil type is not known.
WARNING	If PCB or PCB contaminated oil has leaked from the transformer, stop work, and notify maintenance engineer.
A3	Inspect transformer and disconnect device (where applicable) for signs of excessive heating and/or insulation damage.
A4	Inspect all exposed conduit and potheads for secure mounting, corrosion, damaged fittings, and signs of moisture contamination.

A5	Inspect tank, cooling accessories, seals, valves, gauges, fittings, fans, fuses, and other external parts and accessories for corrosion, leaks, looseness, and damage.
A6	Inspect desiccant and desiccant lines (on conservator units) for looseness and corrosion. Replace desiccant if more than 50% has changed color from blue to clear.
A7	Inspect nitrogen system (on blanketed units) for corrosion, looseness, and leaks.
A8	Inspect all exposed ground connections. Ensure connections are clean and tight. Treat with corrosion inhibitor.
A9	Perform three point ground test. Record test results in Inspection Data section, Item ID-1.
WARNING	If results of the three point ground test are greater than .5 ohm do not continue with this procedure until the ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
A10	Clean transformer primary and secondary bushings (if accessible). Clean disconnect switch bushings and insulators (where applicable). Examine bushings for cracks, chips, or corona flashover.
A11	Clean transformer enclosure and/or panels.
A12	Ensure heaters (if installed) are working correctly.
A13	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
A14	Perform spot cleaning and touchup painting as required.
A15	Perform related tasks PT&I-04 and PT&I-07 if required.
A16	Remove safety grounds.
A17	Close access doors.
A18	Re-energize transformer and return to service.
A19	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Three Point Ground Test Results
Engineer's Notes	
EN1	In order make effective use of time, this procedure for cleaning and inspecting a transformer should be used in conjunction with other procedures (identified in Related Task section) for testing transformers.
EN2	All oil sampling for testing should be accomplished prior to the unit being de-energized. As the windings cool dissolved gases and moisture tend to migrate back into the windings. If the sample is taken after the unit has started to cool, the test results will not be accurate and will indicate lower concentrations of these items than are actually present in the operating unit.

EN2	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN2a	ANSI/IEEE Standard C57.12.90-1993; IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

Circuit Breakers and Switchgear

Procedure Number	Machine/System	Procedure Summary
Brkr-01	Medium/Low Voltage Air Circuit Breaker	Inspect and Test Air Circuit Breaker
Brkr-02	High/Medium Voltage Vacuum or Oil Circuit Breaker	Inspect and Test Vacuum or Oil Filled Circuit Breaker
Brkr-03	High/Medium Voltage SF_6 Circuit Breaker	Inspect and Test SF_6 Circuit Breaker
Swthgear-01	Electrical Distribution	Clean and Inspect Switchgear

Brkr-01: Medium/Low Voltage Air Circuit Breaker - Inspect and Test Air Circuit Breaker

Block Title	Text
Procedure Number	Brkr-01
System Description	Medium/Low Voltage Air Circuit Breaker
Procedure Description	Inspect and Test Circuit Breaker
Related Tasks	PT&I-05, PT&I-08
Periodicity	
Labor (Hrs)	
Special Tools	Contact Resistance Test Set, Psychrometer (or temperature/humidity meter), Thermometer, Vacuum Cleaner
Materials	
Reference Data	Contact Resistance Test Set Operating Instructions
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
Caution Summary	Do not over tighten nuts, bolts, or screws.
Reserved	

Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-4.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Circuit Breaker
A1	Open breaker, de-energize and tag out in accordance with site safety practices.
A2	Open electrical panels or cubicle doors.
WARNING	Test to ensure all circuits are de-energized.
A3	Install safety grounds if applicable.
A4	Disconnect line and load cables/bus from circuit breaker bushings or rack breaker out and remove from cubicle.
A5	Remove phase barriers and arc chutes.
A6	Vacuum circuit breaker and arc chutes.
A7	Inspect breaker stabs for cracks, looseness, flaking, burning, and arcing/tracking.
CAUTION	Do not over tighten nuts, bolts, or screws.
A8	Inspect operating mechanism for loose nuts, bolts, and pins, and broken springs and keepers. Tighten or repair as necessary.
A9	Inspect control wiring for burnt or frayed insulation.
A10	Inspect moving and stationary contacts for pitting and burning/arcing.
A11	Clean contacts with scotch brite. Contacts that can not be cleaned sufficiently shall be replaced.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
A12	Inspect mechanism for sudden movement or binding by "slow closing" the breaker.
A13	Verify all three moving contacts meet stationary contacts simultaneously and they are properly aligned.
A14	Open circuit breaker.
A15	Operate circuit breaker manually once, then electrically, leaving breaker in closed position.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.

A16	Perform Breaker Contact Resistance test and record results in Inspection Data section; Item ID5 to ID7. It may be necessary to remove breaker stabs to get an accurate reading.
A17	Adjust operating mechanism as necessary. Refer to manufacturer's instructions.
A18	Lubricate all working mechanical parts and pivot points. Lubricate mechanical sliding edge parts. Consult manufacturers instructions for proper lubricant.
A19	Cycle circuit breaker electrically.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
A20	Perform second Breaker Contact Resistance test and record results in Inspection Data section; Item ID8 to ID10.
A21	Perform related tasks PT&I-05 on all breakers and PT&I-08 on medium voltage breakers.
A22	Install arc chutes.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
A23	Check for proper operation of contact puffers by opening breaker and observing air coming from arc chute exhaust opening. Repair as required.
A24	Perform cleaning and touchup painting as required.
A25	Reassemble circuit breaker and return to cubicle.
A26	Return breaker to service.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)
ID-4	Weather Conditions (Cloudy, etc.)
ID-5	Contact Resistance Test 1, Phase A
ID-6	Contact Resistance Test 1, Phase B
ID-7	Contact Resistance Test 1, Phase C
ID-8	Contact Resistance Test 2, Phase A
ID-9	Contact Resistance Test 2, Phase B
ID-10	Contact Resistance Test 2, Phase C
Engineer's Notes	

EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	IEEE C37.11-1997 IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
EN1b	ANSI/IEEE C37.09-1979, Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
EN1c	IEEE C37.13-1990, IEEE Standard for Low-Voltage AC Power Circuit Breakers used in Enclosures.
EN2	Contact resistance measurements normally range from 50 microhms to 1200 microhms. Consult manufacturers specifications for specific values. Contact resistance of each phase should be within 10% of the other phases. Deviations indicate burnt or misaligned contacts, or misadjusted operating mechanism.
EN3	Connector torque value, see specification SAE AIR1471. All values are + or - 12.5%.
EN3a	5/32-32: 25 in-lb.
EN3b	5/32-36: 26 in-lb.
EN3c	3/16-32: 42 in-lb.
EN3d	1/4-28: 95 in-lb.
EN3e	5/16-24: 185 in-lb.
EN3f	1/2-20: 800 in-lb.

Brkr-02: High/Medium Voltage Vacuum or Oil Circuit Breaker - Inspect and Test Vacuum or Oil Filled Circuit Breaker

Block Title	Text
Procedure Number	Brkr-02
System Description	High/Medium Voltage Vacuum or Oil Circuit Breaker
Procedure Description	Inspect and Test Circuit Breaker
Related Tasks	PT&I-05, PT&I-08, PT&I-09
Periodicity	
Labor (Hrs)	
Special Tools	Breaker Timing Test Set, Contact Resistance Test Set, Psychrometer (or temperature/humidity meter), Thermometer
Materials	
Reference Data	ASTM Standard Test Methods (STM)
	D-877-87 - Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes (Dielectric Withstand Test).

	D-1534-90 - Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration.
	Breaker Timing Test Set Operating Instructions
	Contact Resistance Test Set Operating Instructions
	Vacuum Bottle Tester or DC HiPot Test Set Instructions
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
	3. If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	Do not over tighten connectors.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-6.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Circuit Breaker
A1	Open breaker, de-energize and tag out in accordance with site safety practices.
A2	Open electrical panels or cubicle doors.
WARNING	Test to ensure all circuits are de-energized.
A3	Install safety grounds if applicable.
A4	Disconnect line and load cables/bus from circuit breaker bushings or rack breaker out and remove from cubicle.
A5	Inspect breaker bushings and connectors for cracks, chips, looseness, burning, and arcing/tracking.
A6	Inspect operating mechanism, for loose nuts, bolts, and pins.
A7	Inspect control wiring for burnt or frayed insulation.
Note 1	Loose connections are identified through infrared thermography inspection. Torque connectors to specified value or, if unknown, maximum 25 in-lb.
CAUTION	Do not over tighten connectors.
A8	Tighten loose connectors.

A9	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
A10	Inspect Ground Connections. Treat with corrosion inhibitor as required.
A11	Perform three point ground test. Record test results in Inspection Data section, item ID-7.
WARNING	If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
A12	Perform breaker timing test. Record test results in Inspection Data section, item ID-8.
Note 2	See Breaker Timing Test Set Operating Instructions for procedure.
A13	Perform related task PT&I-05, PT&I-08, and PT&I-09.
A14	Perform contact resistance test. Record test results in Inspection Data section, item ID-9 to ID-11.
Note 3	See Contact Resistance Test Set Operating Instructions for procedure.
Note 4	Perform step A15 for vacuum type breakers. Perform step A16 through A18 for oil filled type breakers.
A15	Perform vacuum bottle integrity test and/or DC high-potential test at 2.5 times rated AC voltage level. Record results in Inspection Data section, item ID-12 to ID-14.
Note 5	There is currently no standard for bottle integrity test. See manufacturer instructions for guidance.
A16	Perform Dielectric Withstand Test (ASTM D-877-87). Record results in Inspection Data section, item ID-15.
A17	Perform Field Acidity Test (ASTM D-1534-90). Record results in Inspection Data section, item ID-16.
A18	Filter oil if needed.
Note 6	Oil will need to be filtered if dielectric breakdown is less than 24kV or acidity is more than .3 gram KOH/ml.
A19	Perform cleaning and touchup painting as required.
A20	Remove safety grounds.
A21	Reassemble circuit breaker and return to service.
A22	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)

ID-4	Weather Conditions (Cloudy, etc.)
ID-5	Oil Filled Breaker Oil Level
ID-6	Oil Filled Breaker Oil Temperature (C)
ID-7	Three Point Ground, ohms
ID-8	Breaker Timing Test data
ID-9	Contact Resistance, Phase A
ID-10	Contact Resistance, Phase B
ID-11	Contact Resistance, Phase C
ID-12	Vacuum Bottle, Phase A
ID-13	Vacuum Bottle, Phase B
ID-14	Vacuum Bottle, Phase C
ID-15	Oil dielectric, kV
ID-16	Acidity, gram KOH/ml
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	IEEE C37.11-1997 IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
EN1b	ANSI/IEEE C37.09-1979, Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
EN2	Breaker timing test results should verify the integrity of the operating mechanism. Compare current test with last test to confirm velocity, travel, time, and contact wipe. Deviations from the manufacturers specs indicate adjustment is required.
EN3	Contact resistance measurements normally range from 50 microhms to 1200 microhms. Consult manufacturers specifications for specific values. Contact resistance of each phase should be within 10% of the other phases. Deviations indicate burnt or misaligned contacts, or misadjusted operating mechanism.
EN4	A Vacuum Bottle Integrity Test and/or a DC High-Pot at 2.5 the rated AC voltage level are go/no-go tests that verify the bottle is still in a vacuum condition.
EN5	Oil tests for Oil Circuit Breakers can reveal the operating history and condition of the contact assemblies. High acidity and low dielectric are indicative of burning or arcing contacts, and/or high numbers of full load operations. Levels outside the values identified in the procedure, Note 6, require the oil to be filtered and the contact assemblies to be inspected.
EN6	Connector torque value, see specification SAE AIR1471. All values are + or - 12.5%.

EN6a	5/32-32: 25 in-lb.
EN6b	5/32-36: 26 in-lb.
EN6c	3/16-32: 42 in-lb.
EN6d	1/4-28: 95 in-lb.
EN6e	5/16-24: 185 in-lb.
EN6f	1/2-20: 800 in-lb.

Brkr-03: High/Medium Voltage SF_6 Circuit Breaker - Inspect and Test SF_6 Circuit Breaker

Block Title	Text
Procedure Number	Brkr-03
System Description	High/Medium Voltage SF_6 Circuit Breaker
Procedure Description	Inspect and Test Circuit Breaker
Related Tasks	PT&I-05, PT&I-08, PT&I-09
Periodicity	
Labor (Hrs)	
Special Tools	SF_6 Gas Collector, SF_6 Sniffer, Breaker Timing Test Set, Contact Resistance Test Set, Psychrometer (or temperature/humidity meter), Thermometer
Materials	
Reference Data	Breaker Timing Test Set Operating Instructions
	Contact Resistance Test Set Operating Instructions
	Circuit Breaker Operating Instructions
Warning Summary	1.Opening an SF_6 circuit breaker without a sufficient amount of SF_6 present could cause catastrophic failure of the breaker and serious personnel injury.
	2. Test to ensure all circuits are de-energized.
	3. Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
	4. If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	Do not over tighten connectors.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).

2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-4.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Circuit Breaker
WARNING	Opening an SF_6 circuit breaker without a sufficient amount of SF_6 present could cause catastrophic failure of the breaker and serious personnel injury.
A1	Verify SF_6 pressure is within normal operating limits. Record pressure in Inspection Data Section, item ID-5. If pressure is outside limits investigate and resolve prior to opening circuit breaker under load.
A2	Open breaker, de-energize and tag out in accordance with site safety practices.
A3	Open electrical panels or cubicle doors.
WARNING	Test to ensure all circuits are de-energized.
A4	Install safety grounds if applicable.
A5	Disconnect line and load cables/bus from circuit breaker bushings.
A6	Inspect breaker bushings and connectors for cracks, chips, looseness, burning, and arcing/tracking.
A7	Inspect operating mechanism, for loose nuts, bolts, and pins.
A8	Inspect control wiring for burnt or frayed insulation.
Note 1	Loose connections are identified through infrared thermography inspection. Torque connectors to specified value or, if unknown, maximum 25 in-lb.
CAUTION	Do not over tighten connectors.
A9	Tighten loose connectors.
A10	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
A11	Inspect Ground Connections. Treat with corrosion inhibitor as required.
A12	Perform three point ground test. Record test results in Inspection Data section, item ID-6.
WARNING	If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
WARNING	Closed circuit breaker has high spring pressure. Keep clear of all moving parts.
A13	Perform breaker timing test. Record test results in Inspection Data section, item ID-7.
Note 2	See Breaker Timing Test Set Operating Instructions for procedure.

A14	Perform related task PT&I-05, PT&I-08, and PT&I-09.
A15	Perform contact resistance test. Record test results in Inspection Data section, item ID-8 to ID-10.
Note 3	See Contact Resistance Test Set Operating Instructions for procedure.
A16	Perform cleaning and touchup painting as required.
A17	Remove safety grounds.
A18	Reassemble circuit breaker and return to service.
A19	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)
ID-4	Weather Conditions (Cloudy, etc.)
ID-5	SF_6 Pressure
ID-6	Three Point Ground, ohms
ID-7	Breaker Timing Test Results
ID-8	Contact Resistance, Phase A
ID-9	Contact Resistance, Phase B
ID-10	Contact Resistance, Phase C
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	IEEE C37.11-1997 IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
EN1b	ANSI/IEEE C37.09-1979, Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
EN2	Breaker timing test results should verify the integrity of the operating mechanism. Compare current test with last test to confirm velocity, travel, time, and contact wipe. Deviations from the manufacturers specs indicate adjustment is required.
EN3	Contact resistance measurements normally range from 50 microhms to 1200 microhms. Consult manufacturers specifications for specific values. Contact resistance of each phase should be within 10% of the other phases. Deviations indicate burnt or misaligned contacts, or misadjusted operating mechanism.

EN4	In-service SF_6 is a suspected carcinogen. If the circuit breaker fails any of the electrical tests and requires an internal inspection contact the manufactures instructions for the proper SF_6 purge procedure.
EN5	Connector torque value, see specification SAE AIR1471. All values are + or - 12.5%.
EN5a	5/32-32: 25 in-lb.
EN5b	5/32-36: 26 in-lb.
EN5c	3/16-32: 42 in-lb.
EN5d	1/4-28: 95 in-lb.
EN5e	5/16-24: 185 in-lb.
EN5f	1/2-20: 800 in-lb.

Swthgear-01: Electrical Distribution - Clean and Inspect Switchgear

Block Title	Text
Procedure Number	Swthgear-01
System Description	Electrical Distribution
Procedure Description	Clean and Inspect Switchgear
Related Tasks	Brkr-01, Brkr-02, PT&I-05, PT&I-08
Periodicity	
Labor (Hrs)	
Special Tools	Breaker Racking Handle, Breaker Racking Motor (for electrical racking mechanisms), Vacuum Cleaner, Soft Bristle Brush.
Materials	
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Ensure electrical equipment is properly grounded before applying test voltage.
Caution Summary	1. Do not use compressed air to clean electrical switchgear.
	2. Do not over tighten nuts, bolts, or screws.
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1 to ID-3.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.

Procedure	
A	Clean and Inspect Switchgear
Note 1	Make note of indicating lights, voltage and current meters, and breaker positions as these items can not always be verified once the switchgear is de-energized and safety tags are placed.
A1	Record operating parameters of switchgear making note of indicating lights and metering.
A2	Open all circuit breakers, de-energize switchgear and tag out in accordance with site safety practices.
A3	Open cubicle doors.
WARNING	Test to ensure all circuits are de-energized.
A4	Install safety grounds if applicable.
A5	Record circuit breaker information for each cubicle in Inspection Data section, Items ID-4 to ID-8
A6	Rack out and remove all circuit breakers.
A7	Verify isolation shutters operate properly. Shutters should close as breakers are racked out. If not repair or replace shutter and/or mechanism
A8	Inspect isolation barriers and shutters for burns, tracking, and damage. Clean, repair or replace as necessary.
A9	Ensure doors, door latches, and door locks are operating properly. Lubricate as required.
A10	Examine bus, cable, and breaker connections for burning, arcing, or overheating. Repair as required.
A11	Examine switchgear housing and structure for corrosion. Repair as necessary.
A12	Examine breaker racking mechanism for proper operation. Lubricate and realign as required.
CAUTION	Do not use compressed air to clean electrical switchgear.
A13	Clean cubicles using vacuum cleaner and soft bristle brush.
CAUTION	Do not over tighten nuts, bolts, or screws.
A14	Inspect control wiring for insulation damage and loose connections. Repair or tighten as required.
A15	Inspect cubicle heaters for proper operation. Repair or replace as required.
A16	Inspect ground connections. Treat with corrosion inhibitor as required.
A17	Perform a continuity test on switchgear ground.
Note 2	There should be zero ohms resistance between the switchgear enclosure and the grounding network. If there is not continuity do not proceed until repair has been made.
WARNING	Ensure electrical equipment is properly grounded before applying test voltage.

A18	Perform related task PT&I-05, then PT&I-08
A19	Perform related task Brkr-01 or Brkr-02.
A20	Perform cleaning and touchup painting as required.
A21	Reinstall breakers in proper cubicle.
A22	Remove safety grounds.
A23	Close all doors and install covers.
A24	Remove debris from work-site.
A25	Return system to service.
Inspection Data	Fill in all applicable.
ID-1	Wet Bulb Temperature (C)
ID-2	Dry Bulb Temperature (C)
ID-3	Relative Humidity (%)
ID-4	Breaker Manufacturer
ID-5	Model or Type
ID-6	Serial Number
ID-7	Cubicle or Feeder Number
ID-8	Current Rating
Engineer's Notes	
EN1	In order make effective use of time, this procedure for cleaning and inspecting switchgear should be used in conjunction with other procedures (identified in Related Task section).
EN2	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN2a	ANSI/IEEE Standard C37.20.2-1993; IEEE Standard for Metal-Clad and Station Type Cubicle Switchgear.
EN2b	ANSI/IEEE Standard C37.20.1-1993; IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.
EN3	All electrical equipment enclosures should be properly connected to the building grounding system. An improperly grounded enclosure can become energized during a fault condition because the fault current can not "drain off" through the ground. This results in a serious shock hazard for any personnel in contact with the enclosure or any metal object connected to the enclosure.
EN4	Connector torque value for cable in a connector, see specification IEEE 576-1989.
EN4a	#10 wire and less, less than 1/4 inch slot, 20 in-lb.

EN4b	#10 wire and less, greater than 1/4 inch slot, 35 in-lb.
EN4c	#8 wire and less, hex head, 80 in-lb.
EN4d	#8 wire, less than 1/4 inch slot, 25 in-lb.
EN4e	#8 wire, greater than 1/4 inch slot, 40 in-lb.
EN4f	#6 wire, less than 1/4 inch slot, 35 in-lb.
EN4g	#6 wire, greater than 1/4 inch slot, 45 in-lb.
EN4h	#6 and #4 wire, hex head, 165 in-lb.
EN4i	#4 wire and greater, over 1/4 inch slot, 50 in-lb.
EN4j	#3,#2,#1 wire, hex head, 275 in-lb.
EN5	For other fasteners if the manufacturers torque values are not available use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN5a	5/32-32: 25 in-lb.
EN5b	5/32-36: 26 in-lb.
EN5c	3/16-32: 42 in-lb.
EN5d	1/4-28: 95 in-lb.
EN5e	5/16-24: 185 in-lb.
EN5f	1/2-20: 800 in-lb.

High Voltage Electric Power Distribution Switches

Procedure Number	Machine/System	Procedure Summary
Switch-01	High/Medium Voltage Air Switch	Inspect and Test Air Switch
Switch-02	Medium Voltage Oil Loadbreak Switch	Inspect and Test Loadbreak Switch
Switch-03	Medium Voltage SF_6 or Vacuum Loadbreak Switch	Inspect and Test Loadbreak Switch

Switch-01: High/Medium Voltage Air Switch - Inspect and Test Air Switch

Block Title	Text
Procedure Number	Switch-01

System Description	High/Medium Voltage Air Switch
Procedure Description	Inspect and Test Air Switch
Related Tasks	PT&I-05
Periodicity	
Labor (Hrs)	
Special Tools	Contact Resistance Test Set, Psychrometer (or temperature/humidity meter), Thermometer, Insulation Resistance Test Set (Megger) or Ground Tester.
Materials	Culenite Bushing Cleaner
Reference Data	Contact Resistance Test Set Operating Instructions
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Spring-loaded operating mechanisms have high spring pressures when closed. Keep clear of all moving parts.
	3. If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	Do not over tighten connectors.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Air Switch
A1	Open air switch, de-energize and tag out in accordance with site safety practices.
A2	Open electrical panels or cubicle doors.
WARNING	Test to ensure all circuits are de-energized.
A3	Install safety grounds.
A4	Inspect insulators for cracks, burns, chips, and cement/potting deterioration. Clean insulators with culenite bushing cleaner or some other non-alcohol based solvent.
A5	Inspect contacts for burning, pitting, flaking, and corrosion. Clean with scotch brite. Replace any contacts that can not be cleaned sufficiently.
WARNING	Spring-loaded operating mechanisms have high spring pressures when closed. Keep clear of all moving parts.
A6	Manually close air switch.

A7	Inspect switch for proper alignment and contact pressure. Repair as necessary.
CAUTION	Do not over tighten connectors.
A8	Inspect operating mechanism for loose nuts, bolts, keepers, pins, and bent linkages. Tighten and repair as required. Refer to manufacturers instructions for proper torque requirements.
A9	Lubricate mechanism if required. Consult manufacturers instructions for proper lubricant.
A10	Inspect ground connections. Treat with corrosion inhibitor as required.
A11	Perform three point ground test. Record test results in Inspection Data section, Item ID-1.
WARNING	If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
A12	Perform related procedure PT&I-05.
A13	Perform a Contact Resistance Test on all three phases and record results in Inspection Data section, Item ID-2 to ID-4.
Note 1	See Contact Resistance Test Set Operating Instructions for procedure.
Note 2	Contact resistance outside manufacturers recommendations require investigation and repair or replacement.
WARNING	Spring-loaded operating mechanisms have high spring pressures when closed. Keep clear of all moving parts.
A14	Operate switch. Check arc-puffers (if applicable) for proper operation.
Note 3	If operating properly, air will come out of arc-puffer exhaust opening.
A15	Ensure air switch is fully assembled.
A16	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A17	Perform cleaning and touchup painting as required.
A18	Remove safety grounds (if applicable).
A19	Perform operational test of air switch
A20	Return air switch to service.
A21	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Three Point Ground Test Results
ID-2	Contact Resistance, Phase A
ID-3	Contact Resistance, Phase B
ID-4	Contact Resistance, Phase C

Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	IEEE C37.35-1995, IEEE Guide for the Application, Installation, Operation, and Maintenance of High Voltage Air Disconnecting and Interrupter Switches.
EN2	Insulation resistance is taken to ensure that stand-off insulators and stresscones are not dirty or wet. Readings (Megger) for each phase to ground should be at least 100 Megohms.
EN3	Contact resistance measurements normally range from 50 microhms to 1200 microhms. Consult manufacturers specifications for specific values. Contact resistance of each phase should be within 10% of the other phases. Deviations indicate burnt or misaligned contacts, or misadjusted operating mechanism.
EN4	If the manufacturers torque values are not available use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN4a	5/32-32: 25 in-lb.
EN4b	5/32-36: 26 in-lb.
EN4c	3/16-32: 42 in-lb.
EN4d	1/4-28: 95 in-lb.
EN4e	5/16-24: 185 in-lb.
EN4f	1/2-20: 800 in-lb.

Switch-02: Medium Voltage Oil Loadbreak Switch - Inspect and Test Loadbreak Switch

Block Title	Text
Procedure Number	Switch-02
System Description	Medium Voltage Oil Loadbreak Switch
Procedure Description	Inspect and Test Loadbreak Switch
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Oil Dielectric Test Set, Neutralization Number Test Set, Oil Filter Press, Insulation Resistance Test Set (Megger) or Ground Tester.
Materials	
Reference Data	ASTM Standard Test Methods (STM)

	D-877-87 - Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes (Dielectric Withstand Test).
	D-1534-90 - Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration.
	D-1524-84 - Visual Examination of Used Electrical Insulating Oil of Petroleum Origin In the Field.
Warning Summary	1. Do not operate an energized oil loadbreak switch without first verifying the oil level is within the manufacturers recommendations. Failure to do so can result in failure of the switch and serious personnel injury.
	2. Test to ensure all circuits are de-energized.
	3. If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	Do not over tighten bolts, nuts, and fasteners.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	Record as-found conditions in Inspection Data section; Item ID-1.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Loadbreak Switch
WARNING	Do not operate an energized oil loadbreak switch without first verifying the oil level is within the manufacturer's recommendations. Failure to do so can result in failure of the switch and serious personnel injury.
A1	De-energize and tag out loadbreak switch in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
Note 1	Installation of safety grounds can not normally be accomplished on loadbreak switches as connections and terminations are not accessible. In instances where access is not an issue installation of safety grounds is always desired.
A2	Clean tank exterior, bushings, and/or stresscones.
A3	Operate each loadbreak position to ensure proper movement and ease of operation. Operate loadbreak electrically if so equipped.
A4	Inspect cable terminations for signs of overheating, arcing, and damage.
A5	Verify operator locking device and ground stop pin works properly. Lubricate as necessary.

A6	Examine tank, supports, seals, valves, and gauges for leaks, corrosion, and broken glass. Repair as necessary.
A7	Ensure a positive pressure on tank. Add dry nitrogen if necessary.
A8	Obtain an oil sample from the sample valve and perform a dielectric test, color test, and acidity (neutralization number) test.
Note 2	The minimum acceptable test results are - Dielectric: 27kV or more; Color: 3.5 or less; Acidity: .30 or less. If the oil fails any test it must be filtered.
A9	Filter oil if needed and repeat step A8
Note 3	The minimum acceptable test results after filtering are - Dielectric: 33kV or more; Color: 3.5 or less; Acidity: .20 or less. If the oil can not be brought to at least these levels it must be replaced (exchanged).
A10	Replace oil if necessary.
CAUTION	Do not over tighten bolts, nuts, and fasteners.
A11	Tighten loose bolts, nuts and fasteners. Refer to manufacturers instructions for the proper torque requirements.
A12	Inspect ground connections. Treat with corrosion inhibitor as required.
A13	Perform three point ground test. Record test results in Inspection Data section, Item ID-2.
WARNING	If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
A14	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A15	Perform cleaning and touchup painting as required.
A16	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Oil Level
ID-2	Three Point Ground Test Results
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	D-877-87 - Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes (Dielectric Withstand Test).
EN1b	D-1534-90 - Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration.
EN1c	D-1524-84 - Visual Examination of Used Electrical Insulating Oil of

	Petroleum Origin In the Field.
EN2	Insulating oil in oil switches will degrade slowly based on how many openings and closings there are under load. As the oil quenches the arc carbon is developed, contaminating the oil and reducing it's insulating strength. Filtering the oil through a filter press or diatomaceous earth will normally restore the oil to usable condition. At some point (see note 3) the oil additives will become exhausted and the oil will have to be changed out.
EN3	If the manufacturers torque values are not available use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN3a	5/32-32: 25 in-lb.
EN3b	5/32-36: 26 in-lb.
EN3c	3/16-32: 42 in-lb.
EN3d	1/4-28: 95 in-lb.
EN3e	5/16-24: 185 in-lb.
EN3f	1/2-20: 800 in-lb.

Switch-03: Medium Voltage SF_6 or Vacuum Loadbreak Switch - Inspect and Test Loadbreak Switch

Block Title	Text
Procedure Number	Switch-03
System Description	Medium Voltage SF_6 or Vacuum Loadbreak Switch
Procedure Description	Inspect and Test Loadbreak Switch
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Insulation Resistance Test Set (Megger) or Ground Tester
Materials	
Reference Data	
Warning Summary	1. Do not operate an energized SF_6 loadbreak switch without first verifying the SF_6 pressure is within the manufacturers recommendations. Failure to do so can result in failure of the switch and serious personnel injury.
	2. Test to ensure all circuits are de-energized.
	3. If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Caution Summary	Do not over tighten connectors.

Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Loadbreak Switch
WARNING	Do not operate an energized SF_6 loadbreak switch without first verifying the SF_6 pressure is within the manufacturer's recommendations. Failure to do so can result in failure of the switch and serious personnel injury.
A1	Record SF_6 pressure in Inspection Data Section, Item ID-1, if applicable.
A2	De-energize and tag out Loadbreak Switch in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
Note 1	Installation of safety grounds can not normally be accomplished on loadbreak switches as connections and terminations are not accessible. In instances where access is not an issue installation of safety grounds is always desired.
A3	Clean tank exterior, bushings, and/or stresscones.
A4	Operate each loadbreak position to ensure proper movement and ease of operation. Operate loadbreak electrically if so equipped.
A5	Inspect cable terminations for signs of overheating, arcing, and damage.
A6	Verify operator locking device works properly.
CAUTION	Do not over tighten bolts, nuts, and fasteners.
A7	Tighten loose bolts, nuts and fasteners. Refer to manufacturers instructions for proper torque requirements.
A8	Inspect Ground Connections. Treat with corrosion inhibitor as required.
A9	Perform three point ground test. Record test results in Inspection Data section, Item ID-2.
WARNING	If results of three point ground test are greater than .5 ohm do not continue with this procedure until ground has been repaired. Testing equipment without a proper ground can cause serious personnel injury.
Note	Step A10 is for SF_6 switches only.
A10	Ensure filling valve cap is in place and secure.
A11	Perform touch-up painting, if required.
A12	Remove safety grounds, if applicable.
A13	Remove debris from work-site.

Inspection Data	Fill in all applicable.
ID-1	SF_6 Pressure
ID-2	Three Point Ground Test Results
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN2	The SF_6 is the insulating and arc quenching medium within the SF_6 switch. If there is not a sufficient amount of SF_6 then the arc could propagate, damaging the switch and possibly rupturing the tank. The SF_6 pressure should be checked prior to operating the switch to ensure the proper pressure, and to compare with previous reading as SF_6 can slowly escape over time.
EN3	If the manufacturers torque values are not available use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN3a	5/32-32: 25 in-lb.
EN3b	5/32-36: 26 in-lb.
EN3c	3/16-32: 42 in-lb.
EN3d	1/4-28: 95 in-lb.
EN3e	5/16-24: 185 in-lb.
EN3f	1/2-20: 800 in-lb.

Electric Power Distribution Relays/Meters

Procedure Number	Machine/System	Procedure Summary
Relay-01	Protective Relays	Clean, Test, and Calibrate Protective Relays
Meter-01	Electrical Meters	Inspect and Calibrate Current, Voltage, and Event Recording Meters

Relay-01: Protective Relays - Clean, Test, and Calibrate Protective Relays

Block Title	Text
Procedure Number	Relay-01

System Description	Protective Relays
Procedure Description	1. Clean, Test, and Calibrate Electromechanical Protective Relays
	2. Clean, Test, and Calibrate Solid-state Protective Relays
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Relay Test Set, Burnishing Tool, Soft Paint Brush, Vacuum Cleaner
Materials	
Reference Data	Relay Manufacturer's Instruction Booklet, Relay Calibration Settings
Warning Summary	
Caution Summary	1. Relay is part of a functional electrical system and can trip critical circuits if not properly isolated.
	2. Do not over tighten nuts, bolts, or screws.
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Contact power system dispatcher or supervisor prior to beginning this procedure.
5	Obtain a current copy of applicable relay calibration documents.
Procedure	
A	Clean, Test, and Calibrate Electromechanical Protective Relays
CAUTION	Relay is part of a functional electrical system and can trip critical circuits if not properly isolated.
A1	Note calibration seal and record condition of seal in Inspection Data section, Item ID-1.
A2	Remove relay from service by first isolating trip circuits.
A3	Remove relay from housing.
A4	Inspect relay and relay housing for dirt, dust, and the presence moisture or foreign contaminates. Clean with soft paintbrush or vacuum cleaner.
A5	Inspect relay induction disk. Ensure disk moves freely and does not touch magnets or other parts.
A6	Inspect magnets for metal particles. Clean as required.
CAUTION	Do not over tighten nuts, bolts, or screws.
A7	Inspect all relay terminal and relay housing connections for looseness. Tighten as necessary.

Note 1	Relay calibration settings are usually determined by engineering and documented on relay calibration documents and drawings. A copy of these documents should be obtained prior to performing a calibration.
A8	Test relay to determine as found settings. Record in Inspection Data section; Item ID-2 to ID-5.
A9	Verify relay targets operated properly during as-found tests.
A10	Calibrate relay to system specifications, if required.
A11	Record as left settings in Inspection Data section; Item ID-6 to ID-9.
A12	Reinstall relay into housing. Ensure cover gasket seals properly. Replace as required.
A13	Install new calibration seal on cover.
A14	Remove debris from work-site.
B	Clean, Test, and Calibrate Solid-state Protective Relays
CAUTION	Relay is part of a functional electrical system and can trip critical circuits if not properly isolated.
B1	Note calibration seal and record condition of seal in Inspection Data section, Item ID-1.
Note 2	Some solid-state relays have a monitoring circuit that records events and changes in settings. Refer to manufacturers manual for proper method of data retrieval.
B2	Retrieve any operation information from relay and record in Inspection Data section; Item ID-10.
B3	Remove relay from service by first isolating the trip circuits.
B4	Remove relay from housing.
B5	Inspect relay and relay housing for dirt, dust, and the presence moisture or foreign contaminates. Clean with soft paintbrush or vacuum cleaner.
CAUTION	Do not over tighten nuts, bolts, or screws.
B6	Inspect all relay terminal and relay housing connections for looseness. Tighten as necessary.
Note 3	Relay calibration settings are usually determined by engineering and documented on relay calibration documents and drawings. A copy of these documents should be obtained prior to performing a calibration.
B7	Test relay to determine as found settings. Record in Inspection Data section; Item ID-2 to ID-5.
B8	Verify relay targets operated properly during as-found tests.
B9	Calibrate relay to system specifications, if required.
B10	Record as left settings in Inspection Data section; Item ID-6 to ID-9.
B11	Reinstall relay into housing. Ensure cover gasket seals properly. Replace as required.
B12	Install new calibration seal on cover.
B13	Remove debris from work-site.

Inspection Data	Fill in all applicable.
ID-1	Condition of relay calibration seal
ID-2	As Found - Tap Setting
ID-3	As Found - Long Time
ID-4	As Found - Short Time
ID-5	As Found - Instantaneous
ID-6	As Left - Tap Setting
ID-7	As Left - Long Time
ID-8	As Left - Short Time
ID-9	As Left - Instantaneous
ID-10	Relay Information
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	IEEE Std 242-1986; IEEE Recommended Practice for Protection and Coordination of Industrial and commercial Power Systems (The IEEE Buff Book)
EN2	Some solid-state relays have a monitoring circuit that records events and changes in settings. Additionally some solid-state relays will send an alarm signal if their settings drift. Refer to manufacturers manual for options, descriptions, and proper methods of data retrieval.

Meter-01: Electrical Meters - Inspect and Calibrate Current, Voltage, and Event Recording Meters

Block Title	Text
Procedure Number	Meter-01
System Description	Electrical Meters
Procedure Description	Inspect and Calibrate Current, Voltage, and Event Recording Meters
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Soft Bristled Brush, Lint Free Cloth, Vacuum Cleaner

Materials	Ink Writing Supply (for Esterline Angus Meters), Paper Rolls (for Event recorders)
Reference Data	
Warning Summary	If shorting blocks are not located in meter circuit between transducer and meter notify supervisor and do not continue this procedure. Lethal voltages can be present if isolation is attempted without shorting blocks.
Caution Summary	Do not over tighten nuts, bolts, or screws.
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Contact power system dispatcher or supervisor prior to beginning this procedure.
Procedure	
A	Inspect and Calibrate Current, Voltage, and Event Recording Meters
Note 1	Some solid-state meters and all event recorders have a monitoring circuit that records events and changes in settings. Refer to manufacturers manual for proper method of data retrieval.
A1	Retrieve data from event recorder or meter and forward to engineering group.
A2	Note calibration seal and record condition of seal in Inspection Data section, Item ID-1.
Note 2	Step A3 is for analog event recording meters, A4 is for all event recording meters.
A3	Inspect paper roll and ink module for proper operation. Replace as required.
A4	Check clock times on all event recorders. Ensure time is set properly (normally to GMT).
Note 3	A meter is normally fed from a transducer which takes high level current (current transformer, or CT) and voltages (potential transformer, or PT) and transforms them into millamps and millivolts. The meter is isolated from the transducer by small knifeswitches called shorting blocks.
WARNING	If shorting blocks are not located in meter circuit between transducer and meter notify supervisor and do not continue this procedure. Lethal voltages can be present if isolation is attempted without shorting blocks.
A5	Isolate meter from transducer.
A6	Inspect meter for dirt, dust, and the presence moisture. Clean with soft bristle brush, lint free cloth, or vacuum cleaner.
CAUTION	Do not over tighten nuts, bolts, or screws.
A7	Inspect all meter connections for looseness. Tighten as necessary.

A8	Calibrate meter by supplying a known voltage and current into the meter's input. Refer to manufacturers specifications for the proper levels. Adjust meter display or printout as required to match input.
A9	Affix a dated calibration sticker to the meter.
A10	Reconnect transducers to meter.
A11	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Condition of meter calibration seal
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current version of the standard.
EN1a	IEEE Std C57.13-1978, IEEE Standard Requirements for Instrument Transformers.
EN1b	IEEE Std 242-1986; IEEE Recommended Practice for Protection and Coordination of Industrial and commercial Power Systems (The IEEE Buff Book)
EN2	A meter is normally fed from a transducer which takes high level current (current transformer, or CT) and voltages (potential transformer, or PT) and transforms them into millamps and millivolts. The meter reads these and displays the number that corresponds to the proper reading.
EN2a	Calibration of the system takes place at the meter as the transducer has a fixed ratio from input to output. Most meters will have a calibration screw or bolt that can be adjusted.

Low Voltage Distribution

Procedure Number	Machine/System	Procedure Summary
Panel-01	Electrical Distribution	Inspect and Clean Electrical Panels
MCC-01	Electrical Distribution	Inspect and Clean Motor Control Centers and Motor Starter Contactors

Panel-01: Electrical Distribution - Inspect and Clean Electrical Panels

Block Title	Text
Procedure Number	Panel-01
System Description	Electrical Distribution
Procedure Description	1. Inspect and Clean Electrical Panels
	2. Inspect and Clean Disconnect Switches
Related Tasks	PT&I-02
Periodicity	
Labor (Hrs)	
Special Tools	Vacuum Cleaner, Ohmmeter
Materials	
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Closed disconnect has high spring pressure. Keep clear of all moving parts.
Caution Summary	1. Do not over tighten connectors.
	2. Do not use compressed air to clean electrical switchgear.
Reserved	
Preliminary	
1	Perform related task PT&I-02.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Clean Electrical Panels
A1	De-energize equipment and tag out in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
A2	Remove cover and deadfront from panel.
Note 1	High resistance connections are identified through infrared thermography inspection.
CAUTION	Do not over tighten connectors.
A3	Repair high resistance connections.
Note 2	Repair of high resistance connections can include replacement of connectors, cleaning, and tightening. If connection is loose, torque connectors to specified value or, if unknown, maximum 25 in-lb.

A4	Verify anchor bolts supporting panel enclosure are tight.
A5	Verify that all conduit entering panel enclosure is properly connected to panel and attached to wall/mounting bracket.
A6	For exterior panels, inspect enclosure gaskets and spare conduit hubs for tightness. Repair as required.
A7	Inspect all ground connections. Ensure connections are clean and tight. Treat with corrosion inhibitor as required.
A8	Perform a continuity test on panel ground.
Note 3	There should be zero ohms between the panel enclosure and the grounding network. If there is not continuity do not proceed until repair has been made.
CAUTION	Do not use compressed air to clean electrical switchgear.
A9	Clean panel with vacuum cleaner.
A10	Ensure heaters (if installed) are working correctly.
Note 4	Main conductors on three phase systems are normally color coded as follows; Phase A - Black, Phase B - Red, Phase C - Blue, Neutral - White, Ground - Green.
A11	On three phase systems, verify main conductors are properly color coded.
A12	Inspect molded case circuit breakers for damage. Replace as required.
A13	Verify panel directory is attached to panel and each circuit is properly numbered. Correct panel directories that need updating.
A14	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
A15	Perform cleaning and touchup painting as required.
A16	Reinstall panel deadfront and cover.
A17	Return panel to service.
A18	Remove debris from work-site.
B	Inspect and Clean Disconnect Switches
B1	De-energize equipment and tag out in accordance with site safety practices.
B2	Open cover on disconnect.
WARNING	Test to ensure all circuits are de-energized.
Note 5	High resistance connections are identified through infrared thermography inspection.
CAUTION	Do not over tighten connectors.
B3	Repair high resistance connections.
B4	Verify anchor bolts supporting disconnect enclosure are tight.
B5	Verify that all conduit entering disconnect enclosure is properly connected to panel and attached to wall/mounting bracket.

B6	For exterior disconnects, inspect enclosure gaskets and spare conduit hubs for tightness. Repair as required.
B7	Inspect fuses and fuse holders for arcing, burning, and corrosion. Repair as required.
WARNING	Closed disconnect has high spring pressure. Keep clear of all moving parts.
B8	Inspect operating mechanism for loose or broken keepers, springs, and arc shields. Ensure operating mechanism works firmly.
B9	Inspect all ground connections. Ensure connections are clean and tight. Treat with corrosion inhibitor as required.
B10	Perform a continuity test on disconnect ground.
Note 6	There should be zero ohms between the disconnect enclosure and the grounding network. If there is not continuity do not proceed until repair has been made.
CAUTION	Do not use compressed air to clean electrical switchgear.
B11	Clean panel with vacuum cleaner.
Note 7	Main conductors on three phase systems are normally color coded as follows; Phase A - Black, Phase B - Red, Phase C - Blue, Neutral - White, Ground - Green.
B12	On three phase systems, verify main conductors are properly color coded.
B13	Make minor repair. Contact supervisor if repairs are not possible. Note on work order.
B14	Perform cleaning and touchup painting as required.
B15	Return disconnect to service.
B16	Remove debris from work-site.
Engineer's Notes	
EN1	Connector torque value for cable in a connector, see specification IEEE 576-1989.
EN1a	#10 wire and less, less than 1/4 inch slot, 20 in-lb.
EN1b	#10 wire and less, greater than 1/4 inch slot, 35 in-lb.
EN1c	#8 wire and less, hex head, 80 in-lb.
EN1d	#8 wire, less than 1/4 inch slot, 25 in-lb.
EN1e	#8 wire, greater than 1/4 inch slot, 40 in-lb.
EN1f	#6 wire, less than 1/4 inch slot, 35 in-lb.
EN1g	#6 wire, greater than 1/4 inch slot, 45 in-lb.
EN1h	#6 and #4 wire, hex head, 165 in-lb.
EN1i	#4 wire and greater, over 1/4 inch slot, 50 in-lb.
EN1j	#3,#2,#1 wire, hex head, 275 in-lb.

EN2	For other fasteners if the manufacturers torque values are not available use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	All electrical equipment enclosures should be properly connected to the building grounding system. An improperly grounded panel can become energized during a fault condition because the fault current can not "drain off" through the ground. This results in a serious shock hazard for any personnel in contact with the enclosure or any metal object connected to the enclosure.

MCC-01: Electrical Distribution - Inspect and Clean Motor Control Centers and Motor Starter Contactors

Block Title	Text
Procedure Number	MCC-01
System Description	Electrical Distribution
Procedure Description	Inspect and Clean Motor Control Centers and Motor Starter Contactors
Related Tasks	PT&I-02, PT&I-05
Periodicity	
Labor (Hrs)	
Special Tools	Vacuum Cleaner
Materials	
Reference Data	
Warning Summary	1. Test to ensure all circuits are de-energized.
	2. Do not apply test voltages to any electrical equipment unless the electrical equipment is properly grounded. Failure to do so could result in serious personnel injury.
Caution Summary	Do not use compressed air to clean electrical switchgear.
Reserved	
Preliminary	
1	Perform related task PT&I-02.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.

3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Clean Motor Control Centers and Motor Starter Contactors
A1	De-energize equipment and tag out in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
A2	Remove covers from rear of MCC.
A3	Open front cubicles of MCC.
CAUTION	Do not use compressed air to clean electrical switchgear.
A4	Clean MCC cubicles with vacuum cleaner.
A5	Inspect wiring for damaged insulation and loose connections.
A6	Inspect control relays for loose connections, broken cotter pins, and faulty holding coils.
A7	Inspect terminal blocks for cracks, deterioration, and loose connections.
A8	Inspect motor starter assembly connections, if applicable, for looseness and overheating.
A9	Inspect molded case circuit breaker connections for looseness and overheating.
Note 1	High resistance connections are identified through infrared thermography inspection.
CAUTION	Do not over tighten connectors.
A10	Repair high resistance connections.
Note 2	Repair of high resistance connections can include replacement of connectors, cleaning, and tightening. If connection is loose, torque connectors to specified value or, if unknown, maximum 25 in-lb.
A11	Verify molded case circuit breakers operate properly, and examine externally for signs of damage.
A12	Perform a continuity test on panel ground.
Note 3	There should be zero ohms between the panel enclosure and the grounding network. If there is not continuity do not proceed until repair has been made.
A13	Perform related task PT&I-05, phase bus insulation test section.
Note 4	For MCC's with motor starter contactors perform steps A14 through A17.
A14	Inspect contactor for burned or damaged arc shields, broken cotter pins, improper alignment, or faulty holding coils.
A15	Inspect contactor for burnt, worn, or loose contacts; check for tightness and weak spring pressure. Clean or replace as required.
A16	Verify anchor bolts supporting contactor are tight. Tighten as required.
A17	Verify overload heater ratings concur with motor nameplate rating, if applicable.

A18	Verify cover and door gaskets are in good condition. Replace as required.
A19	Verify indicator lights operate correctly and lens covers are secure. Repair as required.
A20	Replace covers, close doors.
A21	Remove safety grounds if applicable.
A22	Return unit to service.
Engineer's Notes	
EN1	Connector torque value for cable in a connector, see specification IEEE 576-1989.
EN1a	#10 wire and less, less than 1/4 inch slot, 20 in-lb.
EN1b	#10 wire and less, greater than 1/4 inch slot, 35 in-lb.
EN1c	#8 wire and less, hex head, 80 in-lb.
EN1d	#8 wire, less than 1/4 inch slot, 25 in-lb.
EN1e	#8 wire, greater than 1/4 inch slot, 40 in-lb.
EN1f	#6 wire, less than 1/4 inch slot, 35 in-lb.
EN1g	#6 wire, greater than 1/4 inch slot, 45 in-lb.
EN1h	#6 and #4 wire, hex head, 165 in-lb.
EN1i	#4 wire and greater, over 1/4 inch slot, 50 in-lb.
EN1j	#3,#2,#1 wire, hex head, 275 in-lb.
EN2	For other fasteners if the manufacturers torque values are not available use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	All electrical equipment enclosures should be properly connected to the building grounding system. An improperly grounded panel can become energized during a fault condition because the fault current can not "drain off" through the ground. This results in a serious shock hazard for any personnel in contact with the enclosure or any metal object connected to the enclosure.

Interior Emergency Area Lighting

Procedure Number	Machine/System	Procedure Summary
EmLights-01	Emergency Lights	Inspect/Repair Self Contained Wall/Ceiling Unit
EmLights-02	Emergency Lights	Inspect/Repair 32 Volt System
EmLights-03	Emergency Lights	Operational Test

EmLights-01: Emergency Lights - Inspect/Repair Self Contained Wall/Ceiling Unit

Block Title	Text
Procedure Number	EmLights-01
System Description	Emergency Lights
Procedure Description	Inspect/Repair Self Contained Wall/Ceiling Unit
Related Tasks	EmLights-03
Periodicity	
Labor (Hrs)	
Special Tools	Step Ladder
Materials	
Reference Data	
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect/Repair Self Contained Emergency Light
A1	Inspect fixture for loose or damaged parts.
A2	Inspect batteries and battery connections for cleanliness and corrosion. Clean as required. Treat with corrosion inhibitor if necessary.

A3	Inspect electrical cables and connections for defective insulation, overheating, and looseness. Repair as required.
A4	Inspect charging circuit for proper operation. Repair/replace as required.
A5	Replace failed indicator lights/bulbs.
A6	Perform related task EmLight-03 (Operational Test).
A7	Clean lens and reflector if necessary.
A8	Perform other cleaning and touch-up painting as required.
A9	Return system to service.
A10	Remove debris from work-site.
A11	Repeat procedure for remaining lights on schedule.

EmLights-02: Emergency Lights - Inspect/Repair 32 Volt System

Block Title	Text
Procedure Number	EmLights-02
System Description	Emergency Lights
Procedure Description	Inspect/Repair 32 Volt System
Related Tasks	PT&I-11, EmLights-03
Periodicity	
Labor (Hrs)	
Special Tools	Step Ladder
Materials	Bicarbonate of Soda, Boric Acid
Reference Data	
Warning Summary	Components contain acid.
Caution Summary	Separate tools and equipment used to service lead-acid batteries and nickel cadmium (NiCad) batteries from each other.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect/Repair 32 Volt Emergency Lighting System
A1	Inspect fixtures for loose or damaged parts.

A2	Replace failed indicator lights/bulbs.
Note 1	Observe site safety precautions when working with acid.
Note 2	Use bicarbonate of soda to neutralize acid from lead-acid batteries and boric acid (50 grams per 1 liter distilled water) to neutralize acid from nickel cadmium batteries.
CAUTION	Separate tools and equipment used to service lead-acid batteries and nickel cadmium (NiCad) batteries from each other.
WARNING	Components contain acid.
A3	Inspect batteries and battery connections for electrolyte level, cleanliness, corrosion, and leaks.
A4	Clean lead-acid batteries as required with a bicarbonate of soda and distilled water mixture
A5	Clean nickel cadmium batteries as required with distilled water.
A6	Treat battery connections with corrosion inhibitor.
A7	Add distilled water to cells that have low electrolyte level.
A8	Inspect electrical cables and connections. Repair as required.
A9	Inspect charging circuit for proper operation. Repair or replace as required.
A10	Ensure all indicator lights are operating properly.
A11	Perform a voltage reading and specific gravity reading on each cell. Record results in the Inspection Data section, item ID-1 to ID-6.
A12	Perform related task PT&I-11.
A13	Clean fixture lenses and reflectors.
A14	Perform other cleaning and touch-up painting as required.
A15	Return system to service.
A16	Remove debris from work-site.
Inspection Data	
ID-1	Cell 1 Voltage and Specific Gravity
ID-2	Cell 2 Voltage and Specific Gravity
ID-3	Cell 3 Voltage and Specific Gravity
ID-4	Cell 4 Voltage and Specific Gravity
ID-5	Cell 5 Voltage and Specific Gravity
ID-6	Cell 6 Voltage and Specific Gravity
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.

EN1a	NFPA Standard 101, Life Safety Code, 1999.
EN1b	IEEE Std 1106-1995; IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications.
EN1c	IEEE Std 450-1995; IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.
EN2	Cell Voltage and Specific Gravity readings should be compared to each other and to the last maintenance cycle readings. All reading should be within 10% of each other and within 10% of the previous readings. Readings outside these values should be investigated.

EmLights-03: Emergency Lights - Operational Test

Block Title	Text
Procedure Number	EmLights-03
System Description	Emergency Lights
Procedure Description	Operational Test
Related Tasks	EmLights-01, EmLights-02
Periodicity	
Labor (Hrs)	
Special Tools	Step Ladder, Timer
Materials	
Reference Data	
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Operational Test
A1	De-energize source of normal electric power to lamp.
Note	Source of electrical power must be de-energized. Do not use installed test switch (if installed). Power must remain off for 90 minutes.

A2	Operate lamp on battery power for 90 minutes.
A3	Repair or replace any lamp that fails to light on loss of normal power or does not provide satisfactory illumination after 90 minutes on battery power.
A4	Return system to service.
A5	Remove debris from work-site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	NFPA Standard 101, Life Safety Code, 1999

Electrical Distribution Support Structures

Procedure Number	Machine/System	Procedure Summary
Pole-01	Overhead Distribution	Inspect Wood Power Pole
Vault-01	Underground Distribution	Inspect Cable Vaults

Pole-01: Overhead Distribution - Inspect Wood Power Pole

Block Title	Text
Procedure Number	Pole-01
System Description	Overhead Distribution
Procedure Description	Inspect Wood Power Pole
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Extra Long Screwdriver, Binoculars, Shovel
Materials	Wasp/Hornet Repellent, Wood Plug
Reference Data	
Warning Summary	Maintain minimum safe distance from energized electrical circuits.
Caution Summary	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic

	noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect Wood Power Pole
WARNING	Maintain minimum safe distance from energized electrical circuits.
A1	Visually inspect pole above ground level for decay, excessive cracking, insect or animal damage, preservative condition, and any other damage.
A2	Inspect wood pole below ground level by probing with a long screwdriver.
A3	Perform a Pole Sound Test by striking pole with hammer at various heights. Pole should ring when struck. A dull thud indicates possible rot.
Note 1	Perform step A4 if rot is suspected.
A4	Perform incremental boring test, extract core sample at location of suspected damage. Slant bore upward to minimize moisture accumulation.
Note 2	If pole rot is found notify supervisor.
A5	Seal bore hole with wooden plug.
A6	Inspect pole guywire for corrosion. Ensure guywire has proper tension and strain insulators are not damaged.
A7	Inspect insulators, lightning arresters, and cross arms with binoculars for damage.
A8	Ensure base of pole is surrounded with a mound of lightly packed dirt at least 6" high to eliminate water ponding at base.
A9	Remove debris from work-site.
Engineer's Notes	
EN1	Detailed information regarding safety guidelines is contained in OSHA Regulations Part 1910.
EN1a	See standard 1910.333 for electrical safety including closest approach distances for energized circuits.

Vault-01: Underground Distribution - Inspect Cable Vaults

Block Title	Text
Procedure Number	Vault-01
System Description	Underground Distribution
Procedure Description	Inspect Cable Vaults

Related Tasks	PT&I-02
Periodicity	
Labor (Hrs)	
Special Tools	Portable Sump Pump, Ventilation Fan, Insulation Resistance Test Set (Megger) or Ground Tester
Materials	
Reference Data	
Warning Summary	Do not enter cable vault without confined space entry permit.
Caution Summary	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Obtain confined space entry permit from site safety department.
Procedure	
A	Inspect Cable Vaults
A1	Remove and inspect vault cover. Clean and repair or replace as required.
A2	Inspect ring/collar for misalignment, settlement, or structural damage.
WARNING	Do not enter cable vault without confined space entry permit.
Note	Pump out water from flooded vaults as required.
A3	Inspect interior structure for cracks, deterioration, and structural damage.
A4	Inspect all rack and hanger securing bolts. Tighten as required.
A5	Inspect each rack and hanger for adequate insulators and cable tie-downs. Repair/replace as required.
A6	Inspect cables and cable splices for damage or deterioration.
A7	Perform related task PT&I-02.
A8	Inspect all exposed ground connections. Ensure connections are clean and tight. Treat with corrosion inhibitor.
A9	Perform three point ground test. Report results above 0.5 ohm to supervisor.
A10	Ensure all cables are properly identified.
A11	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A12	Return system to service.
A13	Remove debris from work-site.

Engineer's Notes	
EN1	For fasteners in manholes use the torque values listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN1a	5/32-32: 25 in-lb.
EN1b	5/32-36: 26 in-lb.
EN1c	3/16-32: 42 in-lb.
EN1d	1/4-28: 95 in-lb.
EN1e	5/16-24: 185 in-lb.
EN1f	1/2-20: 800 in-lb.
EN2	All electrical cable vaults must be properly connected to the electrical distribution grounding system. An improperly grounded vault could become energized during a fault condition resulting in an electrical personnel hazard.
EN3	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN3a	OSHA Part 1910 Subpart E Means of Egress

Motors

Procedure Number	Machine/System	Procedure Summary
Motor-01	Motors	Clean and Inspect Motors

Motor-01: Motors - Clean and Inspect Motors

Block Title	Text
Procedure Number	Motor-01
System Description	Motors
Procedure Description	Clean and Inspect Motors
Related Tasks	PT&I-01, PT&I-02, PT&I-03, PT&I-10
Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	

Warning Summary	Test to ensure all circuits are de-energized.
Caution Summary	Do not use compressed air to clean motor.
Preliminary	
1	Review prior maintenance test data including vibration analysis and thermal image (if available).
2	Perform related tasks PT&I-01 and PT&I-02.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Test Motors
A2	De-energize equipment and tag out in accordance with site safety practices.
WARNING	Test to ensure all circuits are de-energized.
A3	Inspect motor for loose mounting bolts, missing shims, and cracked foundation.
Note 1	Motor looseness is often identified by vibration analysis.
A4	Inspect motor termination box and motor lead connections for looseness, overheating, arcing, and corrosion. Repair as required.
Note 2	Steps A5 and A6 are for motors with split-sleeve bearings in an oil bath.
A5	Perform PT&I-10
A6	Change/recondition oil.
CAUTION	Do not use compressed air to clean motor.
A7	Clean grill, fan, and air passages as required.
A8	Perform PT&I-03.
A9	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A10	Perform cleaning and touchup painting as required.
A11	Return motor to service.
A12	Remove debris from work-site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	IEEE Std. 432-1992, IEEE Guide for Insulation Maintenance for Rotating Electrical Machinery (5 hp to less than 10,000 hp)

EN1b	ANSI/IEEE Std. 43-1974, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
EN1c	IEEE Std. 112-1996, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

Pumps

Procedure Number	Machine/System	Procedure Summary
Pumps-01	Pumps	Inspect, Lubricate and Clean

Pumps-01: Pumps - Inspect, Lubricate and Clean

Block Title	Text
Procedure Number	Pumps-01
System Description	Pumps
Procedure Description	Inspect, Lubricate and Clean
Related Tasks	PT&I-01, PT&I-03, PT&I-10
Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	Manufacturer's Operation and Maintenance Manual
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including vibration analysis and thermal image (if available).
2	Notify operators before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect, Lubricate and Clean

A1	Check suction and discharge gauges and pump operating speed to confirm operating point.
A2	Inspect for leaks on piping, pump seals, pump housing, valves and pressure gauge connections.
A3	De-energize equipment and tag-out in accordance with site safety requirements.
A4	Lubricate water pump oiled bearings with SAE 20 weight non-detergent oil containing rust inhibitors.
Note 1	Sealed bearings do not require periodic lubrication. Replace greased bearings with sealed bearings when possible.
A5	Lubricate vacuum pump bearings with a high quality, high boiling range, straight mineral oil, approximately 350 SUS at 100F.
A6	Inspect equipment mounts for corrosion or support cracking. Replace worn or missing rubber/spring feet.
A7	Adjust packing or mechanical seal as necessary.
A8	Tighten any fasteners that may be loose.
A9	Inspect shaft sleeve under packing for wear.
A10	Inspect the impeller, case, suction flange, and wearplate for wear (if applicable).
A11	Inspect shaft for runout and straightness.
A12	Confirm pump alignment and adjust belts or coupling as necessary.
A13	Clean all external parts of pump and motor.
A14	Perform related tasks as required.
A15	Return unit to service, verify proper operation.
A16	Remove debris from work-site.
Engineer's Notes	
EN1	Belts for multi-belted pulley systems are supplied in matched sets. It is important to make replacements with complete sets.
EN2	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN2a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2b	OSHA Regulations (Standards - 29 CFR), Mechanical power-transmission apparatus. - 1910.219
EN3	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN3a	5/32-32: 25 in-lb.
EN3b	5/32-36: 26 in-lb.

EN3c	3/16-32: 42 in-lb.
EN3d	1/4-28: 95 in-lb.
EN3e	5/16-24: 185 in-lb.
EN3f	1/2-20: 800 in-lb.

Valves

Procedure Number	Machine/System	Procedure Summary
Valve-01	Fire Control Valves	Inspect and Clean
Valve-02	Isolation Valves	Inspect and Clean
Valve-03	Automatic Control Valves	Inspect and Clean

Valve-01: Fire Control Valves - Inspect and Clean

Block Title	Text
Procedure Number	Valve-01
System Description	Fire Control Valves
Procedure Description	Inspect and Clean
Related Tasks	
Special Tools	
Materials	Stem Lubricant
Reference Data	
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Notify operators before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Observe site safety precautions for opening fluid systems.
Procedure	

A	Inspect and Clean
A1	Inspect for valve being set plumb so that post valve is vertical.
A2	Inspect for damaged or missing cap, window glass, target, target plate, operating wrench, post, bonnet, and valve tamper.
A3	Remove cap, inspect for corrosion or damage to extension rod, coupling, threads, and signs of leaking valves.
A4	Lubricate threads.
A5	Remove and clean glass.
A6	Clean both target plates. If illegible, replace or repaint.
A7	Close valve and check ease of operation and leakage.
A8	Adjust target plate (shut) so it is centered in window.
A9	Open valve until resistance is felt. Back off valve 1/4 of a turn.
A10	Check position of target (open), and adjust if necessary.
A11	Replace cap, tamper seal and wrench.
A12	Perform cleaning and touchup painting as required.
A13	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A14	Remove debris from work-site.
A15	Notify operators when task is complete.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	NFPA 14: Standard for the Installation of Standpipe, Private Hydrants and Hose Systems, 2000 Edition.
EN1b	NFPA 25: Inspection, Testing and Maintenance of Water-Based Fire Protection Systems, 1998 Edition.
EN1c	NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection, 1996 Edition.
EN1d	ANSI Std. SS-EN 736-1 Valves - Terminology - Part 1: Definition of types of valves
EN1e	ANSI Std. SS-EN 736-2 Valves - Terminology - Part 2: Definition of components of valves
EN1f	ANSI Std. SS-EN 736-3 Valves - Terminology - Part 3: Definition of terms
EN1g	ISO 5209:1977 General purpose industrial valves -- Marking
EN1h	OSHA Part 1910 Subpart I Personal Protective Equipment

EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.

Valve-02: Isolation Valves - Inspect and Clean

Block Title	Text
Procedure Number	Valve-02
System Description	Isolation Valves
Procedure Description	Inspect and Clean
Related Tasks	
Special Tools	
Materials	Stem and Packing Lubricant
Reference Data	
Warning Summary	
Caution Summary	1. Notify operators or other local occupant before changing valve position.
	2. Use caution when opening globe valves to avoid loosening packing nut.
	3. Do not use excessive force or torque to turn a seized valve stem.
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Notify operators or other local occupant before starting test.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Observe site safety precautions for opening fluid systems.
Procedure	
A	Inspect and Clean
A1	Perform visual inspection for corrosion or indication of leaks.

A2	Check insulation for tears, or missing pieces if applicable.
A3	Remove valve box cap, clean access cavity (if applicable).
CAUTION	Notify operators or other local occupant before changing valve position.
CAUTION	Use caution when opening globe valves to avoid loosening packing nut.
CAUTION	Do not use excessive force or torque to turn a seized valve stem.
A7	Check operation of valve. Count number of turns on handle to ensure complete closure (if applicable).
A8	Write repair order if valve stem is seized.
A9	Inspect packing nut and housing bolts for looseness (if applicable).
A10	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A11	Lubricate packing and exposed stem threads as required.
A12	Perform cleaning and touchup painting as required.
A13	Return valve to normal position.
A14	Remove debris from work-site.
A15	Notify operators when task is complete.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	NFPA 14: Standard for the Installation of Standpipe, Private Hydrants and Hose Systems, 2000 Edition.
EN1b	NFPA 25: Inspection, Testing and Maintenance of Water-Based Fire Protection Systems, 1998 Edition.
EN1c	NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection, 1996 Edition.
EN1d	ANSI Std. SS-EN 736-1 Valves - Terminology - Part 1: Definition of types of valves
EN1e	ANSI Std. SS-EN 736-2 Valves - Terminology - Part 2: Definition of components of valves
EN1f	ANSI Std. SS-EN 736-3 Valves - Terminology - Part 3: Definition of terms
EN1g	ISO 5209:1977 General purpose industrial valves -- Marking
EN1h	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.

EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.

Valve-03: Automatic Control Valves - Inspect and Clean

Block Title	Text
Procedure Number	Valve-03
System Description	Automatic Control Valves
Procedure Description	Inspect and Clean
Related Tasks	
Special Tools	4-20 mA Current Source
Materials	Stem and Packing Lubricant
Reference Data	
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Notify operators before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Observe site safety precautions for opening fluid systems.
Procedure	
A	Inspect, Test and Clean
A1	Perform visual inspection for leaks, corrosion, looseness or missing parts.
A2	Grease exposed valve shaft.
A3	Calibrate electronic travel device (if applicable).
A5	Make operational sequence check.
A6	Check voltage level and signal current, where applicable, at 0%, 50% and 100% actuator travel. Note deviations on work order.
A7	Check wiring and cables for cracking, corrosion or looseness.

A8	Check operation of linkage through full cycle.
A9	Inspect mechanical actuators for signs of wear, replace if necessary.
A10	Check air pressure if applicable, adjust if necessary.
A12	Drain, clean and service air line filter if applicable.
A13	Adjust air line lubricator, generally one drop per minute (if applicable).
A14	Check air line lubricator oil reservoir if applicable.
A15	Check instruments (pressure control, gauges).
A16	Report abnormal conditions and recommendations.
A17	Report any corrective actions required.
A18	Remove debris from work-site.
A19	Notify operators when task is complete.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ANSI Std. SS-EN 736-1 Valves - Terminology - Part 1: Definition of types of valves
EN1b	ANSI Std. SS-EN 736-2 Valves - Terminology - Part 2: Definition of components of valves
EN1c	ANSI Std. SS-EN 736-3 Valves - Terminology - Part 3: Definition of terms
EN1d	ISO 5209:1977 General purpose industrial valves -- Marking
EN1e	OSHA Part 1910 Subpart I Personal Protective Equipment
EN1f	ISA S75.11-1985 (R1997) Inherent Flow Characteristics and Rangeability of Control Valves
EN1g	IEC 60534-4 Ed. 2.0 b:1999 Industrial-process control valves - Part 4: Inspection and routine testing
EN1h	IEC 60534-5 Ed. 1.0 b:1982 Industrial-process control valves. Part 5: Marking
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.

Backflow Preventer

Procedure Number	Machine/System	Procedure Summary
BFP-01	Backflow Preventer	Inspect and Clean

BFP-01: Backflow Preventer - Inspect and Clean

Block Title	Text
Procedure Number	BFP-01
System Description	Backflow Preventer
Procedure Description	Inspect and Clean
Related Tasks	
Special Tools	
Materials	
Reference Data	
Warning Summary	Valve may be under pressure. Release internal pressure by opening test cocks.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data (if available).
2	Notify operators or other local occupant before starting inspection.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Observe site safety precautions for opening fluid systems.
Procedure	
A	Inspect and Clean
A1	Close outlet gate valve.
A2	Close inlet gate valve.
WARNING	Valve may be under pressure. Release internal pressure by opening test cocks.
A3	Open test cocks.
Note	Test cocks are to remain open during entire inspection.
A4	Remove access cover clamp.
A5	Remove access cover and cover seal.

A6	Remove #1 check retainer and #1 check assembly.
A7	Inspect check seal surface for pitting or debris. Flush clean as required.
A8	Disassemble #1 check.
A9	Remove poppet retainer and inspect seal ring for cuts, nicks or debris.
A10	Inspect seat sealing surface for cuts, nicks or debris.
A11	Reassemble #1 check.
A12	Reinstall #1 check into valve body.
A13	Remove #2 check retainer and #2 check assembly.
A14	Inspect check seal surface for pitting or debris. Flush clean as required.
A15	Disassemble #2 check.
A16	Remove poppet retainer and inspect seal ring for cuts, nicks or debris.
A17	Inspect seat sealing surface for cuts, nicks or debris.
A18	Reassemble #2 check.
A19	Reinstall #2 check into valve body.
A20	Reinstall access cover seal and access cover.
A21	Reinstall access cover clamp if applicable.
A22	Close test cocks.
A23	Open inlet gate valve.
A24	Open outlet gate valve.
A25	Check for leaks.
A26	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A27	Remove debris from work-site.
A28	Notify operators or other local occupant when inspection complete.
Engineer's Notes	
EN1	Suggested Minimum Requirements for reduced pressure (RP) and RP detector.
EN1a	The first check must close tight, and the minimum static PSID must be 3 PSID greater than the recorded relief valve opening PSID.
EN1b	The second check must close tight, and a have a minimum static of 1 PSID.
EN1c	The relief valve must open at a minimum static 2 PSID.
EN1d	The relief valve must not be leaking upon completion of test.
EN2	Suggested Minimum Requirements for double check (DC) and DC detector.
EN2a	The first check must close tight, and have a minimum static 1 PSID.

EN2b	The second check must close tight, and have a minimum static 1 PSID.
EN3	Suggested minimum requirements for pressure vacuum breaker
EN3a	The air inlet valve must open at a minimum static 1 PSID.
EN3b	The check valve must close tight, and have a minimum static 1 PSID.
EN4	Manual of Cross-Connection Control, published by the Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California (USC Manual)
EN5	Cross-Connection Control Manual, Accepted Procedure and Practice published by the Pacific Northwest Section of the American Water Works Association (PNWS-AWWA Manual).

Heating, Ventilation and Air Conditioning (HVAC) Units

Procedure Number	Machine/System	Procedure Summary
HVAC-01	DX Air Conditioning Unit	Inspect and Clean (DX Coil)
HVAC-02	Air Handler/Package A/C Units	Inspect and Clean (Water Coil)
HVAC-03	Air Handler	Change Filter, Inspect Belts and Pulley
HVAC-04	VAV Unit, Heating Units	Inspect and Clean
Fan-01	Fans	Inspect and Clean
Chiller-01	Chillers	Inspect and Clean, Clean Condenser/Absorber Tubes
Chiller-02	Chillers	Evaporator Tube Inspection and Cleaning

HVAC-01: DX Air Conditioning Unit - Inspect and Clean (DX Coil)

Block Title	Text
Procedure Number	HVAC-01
System Description	DX Air Conditioning Unit
Procedure Description	Inspect and Clean
Related Tasks	Motor-01
Periodicity	
Labor (Hrs)	
Special Tools	Thermometer, Fin Comb, Caulking Gun, Grease Gun, Belt Tensiomometer, Belt Alignment Laser, 4-20 mA Current Source, Hand Pump for Manually Operating Damper Actuators.

Materials	Electrical Contact Cleaner and Solvent, Biological Growth Inhibitor
Reference Data	Manufacturer's Operation and Maintenance Manual
Warning Summary	Exercise caution when working around rotating machinery.
Caution Summary	1. Coil materials are soft and easily punctured.
	2. Do not use leverage bars to stretch belts over pulleys.
Reserved	
Preliminary	
1	Review prior maintenance data including vibration data test results (if available).
2	Notify operators or other local occupant before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Review site safety precautions for opening ventilation systems.
Procedure	
A	Inspect and Clean
A1	Observe unit for proper operation prior to maintenance, check cooling cycle (and heating cycle if applicable).
A2	Inspect thermostat for proper operation, both cooling cycle and heating cycle if applicable.
WARNING	Exercise caution when working around rotating machinery.
A3	Remove access panel(s).
A4	Inspect for water or coolant leaks in and around piping, valves and coils.
A5	Observe refrigerant in sight glass while compressor is operating. Add refrigerant as needed.
A6	For heat pumps, check that reversing valve is energized in heat mode and de-energized in cool mode.
A7	De-energize equipment and tag out in accordance with site safety practices.
Note 1	Sealed bearings do not require periodic lubrication. Replace greased bearings with sealed bearings when possible.
A8	Inspect fan for bent or damaged blades and imbalance, make note on work order.
A9	Remove filter, clean if applicable, replace as necessary.
A10	Replace any missing minor hardware, fasteners and knobs.
A11	Determine compressor oil level, add as required.
CAUTION	Coil materials are soft and easily punctured.
A12	Visually inspect coil for fin damage. Straighten bent fins.

A13	Clean coils, remove all debris.
Note 2	Report any damage to coils or tubing, no matter how slight.
A14	Remove pulley and belt guards.
CAUTION	Do not use leverage bars to stretch belts over pulleys.
A15	Inspect V-belt for wear, cracks, glazing or fraying. Replace if necessary and note on work order.
A16	Measure belt tension with belt tensiometer. Adjust tension as required by manufacturer.
A17	Measure sheave alignment with laser pulley alignment device. Adjust alignment as required.
Note 3	Belts for multi-belted pulley systems are supplied in matched sets. It is important to make replacements with complete sets.
A18	Clean air plenum, remove debris from interior of unit.
A19	Verify operation of damper actuator using portable current source or pneumatic hand pump if applicable.
A20	Lubricate damper motor actuator if applicable.
A21	Perform cleaning and touchup painting as required.
A22	Inspect gages, thermometers, and indicators for proper calibration. Note any overdue items on work order.
Note 3	Related task Motor-01 includes use of PT&I techniques.
A23	Perform related tasks (if applicable).
A24	Re-install access panels.
A25	Return unit to service.
A26	Remove debris from work-site.
Engineer's Notes	
EN1	Small motors are often run-to-fail. For these units, do not specify PT&I procedures.
EN2	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN2a	ASHRAE B26E STD 87.1-1992 Method of Testing Fan Vibration, Blade Vibrations and Critical Speeds
EN2b	OSHA Part 1910 Subpart O Machinery and Machine guarding
EN2c	OSHA Part 1910.219 Subpart O Mechanical Power Transmission Apparatus.
EN2d	OSHA Part 1910 Subpart I Personal Protective Equipment

HVAC-02: Air Handler/Package A/C Units - Inspect and Clean (Water Coil)

Block Title	Text
Procedure Number	HVAC-02
System Description	Air Handler/Package A/C Unit
Procedure Description	Inspect and Clean
Related Tasks	HVAC-03, Motor-01
Periodicity	
Labor (Hrs)	
Special Tools	Vacuum Cleaner, Grease Gun, Fin Comb, Thermometer, 4-20 mA Current Source, Hand Pump for Manually Operating Damper Actuators.
Materials	Biological Growth Control Tablets, Caulk
Reference Data	Manufacturer's Operation and Maintenance Manual
Warning Summary	1. Observe site safety precautions when working on elevated structures or roofs.
	2. Exercise caution around dampers; avoid pinch points.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance data including vibration data test results (if available).
2	Notify operators or other local occupant before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Review site safety precautions for opening ventilation systems.
Procedure	
A	Inspect and Clean
WARNING	Observe site safety precautions when working on elevated structures or roofs.
A1	Inspect operation while unit is running. Make a note of any unusual sounds.
A2	Inspect for water or air leaks around unit.
A3	De-energize equipment and tag out in accordance with site safety practices.
A4	Clean and inspect coils (cooling, heating, preheat, reheat). Note any corrosion on work order.

A5	Straighten bent fins on heating and cooling coil(s).
A6	Lubricate damper motor(s).
A7	Verify operation of damper actuator using portable current source or pneumatic hand pump if applicable.
A8	Inspect and clean fan blades. Ensure free movement.
A9	Verify fan safety switch operation (if applicable).
A10	Inspect condensate pan and drain, flush out and clean as needed.
A11	Remove rust and corrosion, spot paint condensate pan with corrosion resistant paint.
A12	Renew biological growth control tablet (if required).
A13	Close chilled water supply valve. Clean chilled water strainers.
Note 1	Do not force frozen/corroded bolts. Submit work order to remove and replace.
A14	Reinstall strainers/insulation. Open chilled water supply valve.
A15	Inspect all gaskets and seals, repair as required.
A16	Verify operation of humidifier for proper water/steam flow, if applicable.
A17	Inspect infrared lamps for proper operation (if installed); replace as required.
A18	Open steam canister (if installed) and remove deposits.
A20	Inspect all gaskets and seals, repair as needed.
WARNING	Exercise caution around dampers; avoid pinch points.
A24	Operate duct fire damper (if applicable).
A25	Inspect damper control linkage and damper blade mounts for looseness, cracking, missing parts and excessive wear. Repair as required
A26	Inspect gages, thermometers, and indicators for proper calibration. Note any overdue items on work order.
A27	Replace any missing minor hardware, fasteners and knobs.
A28	Test light switches, replace burned out light bulbs.
Note 2	Related task Motor-01 includes use of PT&I techniques.
A29	Perform related tasks (if applicable).
A30	Close access covers and doors and return air handler to service.
A31	Remove debris from work-site.
Engineer's Notes	
EN1	Small motors are often run-to-fail. For these units, do not specify PT&I procedures.
EN2	Biological growth control tablets are used to control fungus and bacterial growth in the condensate pan. Contact environmental control for the proper agents/tablets.

EN3	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN3a	OSHA Part 1910 Subpart O Machinery and Machine guarding
EN3b	OSHA Part 1910.219 Subpart O Mechanical Power Transmission Apparatus
EN3c	OSHA Part 1910 Subpart I Personal Protective Equipment

HVAC-03: Air Handler - Change Filter, Inspect Belts and Pulley

Block Title	Text
Procedure Number	HVAC-03
System Description	Air Handler
Procedure Description	1. Change Filters
	2. Inspect Belts and Pulleys
Related Tasks	HVAC-02, PT&I-01
Periodicity	
Labor (Hrs)	
Special Tools	Vacuum Cleaner, Fin Comb, Pulley Alignment Tool, Dial Indicator, Belt Tensiomometer
Materials	New Filters, Caulk, Containment Bag for Used Filters
Reference Data	Manufacturer's Operation and Maintenance Manual
Warning Summary	1. Observe site safety precautions when working on elevated structures or roofs.
	2. Test to ensure all circuits are de-energized.
Caution Summary	Do not use leverage bars to stretch belts over pulleys.
Reserved	
Preliminary	
1	Review prior maintenance data including vibration data test results (if available).
2	Notify operators or other local occupant before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Review site safety precautions for opening ventilation systems.
Procedure	
A	Change Filters

WARNING	Observe site safety precautions when working on elevated structures or roofs.
A1	De-energize equipment and tag out in accordance with site safety procedures.
WARNING	Test to ensure all circuits are de-energized.
A2	Remove filter retaining device(s), remove old filter(s), immediately place filters into containment bag.
A3	Clean filter support and plenum area.
A4	Install new filter(s), replace filter retention device(s).
Note 1	Inspect new filter for defects. Do not use any filter that appears to have a manufacturing defect.
A5	Inspect fan wheel for signs of fatigue, cracking or corrosion. Note conditions on work order.
B	Inspect Belts and Pulleys
B1	Remove pulley and belt guards.
CAUTION	Do not use leverage bars to stretch belts over pulleys.
Note 2	When replacing belts, loosen the motor mounts sufficiently to easily place belts over pulleys. Replace all belts on multi-belt pulley with matching set. Note on work order.
B2	Inspect V-belt for wear, cracks, glazing or fraying. Replace if necessary and note on work order.
B3	Measure belt tension with belt tensiometer. Adjust tension as required by manufacturer.
B4	Measure sheave alignment with laser pulley alignment device. Adjust alignment as required.
Note 3	Sheave gauges measure the wear of pulley groove(s). If sheave gauge markings indicate excessive wear, or if bottom of pulley groove shows signs of belt contact then pulleys must be replaced.
B5	Inspect pulleys for damage and measure wear with sheave gauge. Replace if necessary.
Note 4	Radial pulley runout (TIR) should not exceed 0.005" and face (axial) runout should not exceed 0.0005"/in-dia.
B6	Check radial and axial pulley runout with dial indicator after replacement.
B7	Align shafts with pulley alignment tool. Tighten belts according to manufacturers suggested tension.
B8	Reinstall belt and pulley cover(s).
B9	Return unit to service.
B10	Remove debris from work-site.
Engineer's Notes	

EN1	Biological growth control tablets are used to control fungus and bacterial growth in the condensate pan. Contact environmental control for the proper agents/tablets.
EN2	Belts for multi-belted pulley systems are supplied in matched sets. It is important to make replacements with complete sets.
EN3	Belt tension varies by manufacturer. Proper belt tension ensures appropriate loading on support bearings while maintaining friction required to minimize belt slippage. Check manufacturers suggested tension for each application.
EN4	Proper pulley alignment reduces belt slippage, belt/pulley wear and slightly improves energy efficiency.
EN5	Notify PT&I group if belts are changed or aligned.
EN6	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN6a	OSHA Part 1910 Subpart O Machinery and Machine guarding
EN6b	OSHA Part 1910.219 Subpart O Mechanical Power Transmission Apparatus
EN6c	OSHA Part 1910 Subpart I Personal Protective Equipment
EN7	Coarse filters (50%, 65%) are often disposable filters. Cost effective change-out is often done on a calendar basis.
EN7a	High efficiency filters (i.e. HEPA, ULPA, >95% filtration) are often expensive, should be changed based on pressure differential across the filter. Manufacturer specifies maximum allowable pressure differential pressure.

HVAC-04: VAV Unit, Heating Units - Inspect and Clean

Block Title	Text
Procedure Number	HVAC-04
System Description	Variable Air Volume (VAV) Unit, Heating Unit
Procedure Description	1. Inspect and Clean VAV Unit
	2. Inspect and Clean Heating Unit
Related Tasks	Motor-01
Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	Equipment Operation and Maintenance Manual
Warning Summary	

Caution Summary	
Reserved	
Preliminary	
1	Notify operators or other local occupant before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Review site safety precautions for opening ventilation systems.
5	Perform related task Motor-01.
Note 1	Related task Motor-01 includes use of PT&I techniques.
Procedure	
A	Inspect and Clean VAV Unit
A1	De-energize equipment and tag out in accordance with site safety procedures.
A2	Remove ceiling tile to expose VAV device and remove access cover if required.
A3	Inspect heating or cooling coils and valves for indications of leaking, repair as required.
A4	Inspect condensate tray and drain line for indications of blockage or overflow. Repair as required.
A5	Return unit to service.
Note 2	VAV device should not close completely to ensure that fresh air is continuously supplied.
A6	Confirm that VAV damper is not entirely closed at 0% setting.
A7	Close access cover and replace ceiling tiles if necessary.
B	Inspect and Clean Heating Unit
B1	De-energize equipment and tag out in accordance with site safety procedures.
B2	Remove pulley and belt cover.
B3	Inspect V-belt for wear, cracks, glazing or fraying. Replace if necessary and note on work order.
B4	Inspect pulleys for damage and measure wear with sheave gauge. Replace if necessary.
Note 3	When replacing belts, loosen the motor mounts sufficient to easily place belts over pulleys.
B5	Check pulley runout after replacement.
B6	Clean machinery and belt covers, remove all belt-dust residue.

B7	Align shafts with pulley alignment tool. Tighten belts according to manufacturers suggested tension.
B8	Reinstall belt and pulley cover(s).
B9	Replace or clean filter as required (if applicable).
B10	Inspect heater and motor/fan assembly for loose mounting supports, repair as required.
B11	Inspect exhaust duct for indications of corrosion or looseness (if applicable). Repair as required.
B12	Close access doors and panels.
B13	Clear safety tags and restore electrical power.
B14	Test pilot light thermocouple for proper operation, replace if required (if applicable).
B15	Test ignition device for proper operation, repair as required (if applicable).
B16	Perform operational test of unit.
B17	Return unit to service.
B18	Remove debris from work-site.
Engineer's Notes	
EN1	Small motors are often run-to-fail. For these units, do not specify PT&I procedures.
EN2	Belt tension varies by manufacturer. Proper belt tension ensures appropriate loading on support bearings while maintaining friction required to minimize belt slippage. Check manufacturers suggested tension for each application.
EN3	Proper pulley alignment reduces belt slippage, belt/pulley wear and slightly improves energy efficiency.
EN4	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN4a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN4b	OSHA Part 1910 Subpart O Machinery and Machine Guarding

Fan-01: Fans - Inspect and Clean

Block Title	Text
Procedure Number	Fan-01
System Description	Fans
Procedure Description	Inspect and Clean
Related Tasks	HVAC-03, Panel-01, Motor-01

Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	Equipment Operation and Maintenance Manual
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance data including vibration data test results (if available).
2	Notify operators or other local occupant before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Review site safety precautions for opening ventilation systems.
6	Perform related tasks Panel-01 and Motor-01.
Note	Related tasks Panel-01 and Motor-01 include the use of PT&I techniques.
Procedure	
A	Inspect and Clean
A1	De-energize equipment and tag-out in accordance with safety requirements.
A2	Remove panels to gain access to motor, fan and filter if applicable.
A3	Perform related task HVAC-03 (if applicable).
A4	Inspect for looseness at bearing mounts and shaft set screws.
A5	Inspect and clean fan blades. Ensure free movement.
A6	Verify fan blade pitch (where applicable).
A7	Inspect fan blade pitch adjustment linkage for looseness and missing parts (where applicable).
A8	Verify operation of damper actuator using portable current source or pneumatic hand pump (if applicable).
A9	Inspect unit visually for corrosion or damage. Clean, paint and repair damaged or corroded surfaces and insulation as necessary.
A10	Clean out fan housing, remove all dust and wipe down interior.
A11	Inspect seals, valves, gauges, fittings and ducts for corrosion, leaks, looseness, and damage. Note any observations on work order.
A12	Operate duct fire damper (if applicable).

A13	Inspect fire damper control linkage and damper blade mounts for looseness, cracking, missing parts and signs of wear. Note any observations on work order.
A14	Inspect operating mechanism, for loose nuts, bolts, and pins.
A15	Test light switches, replace burned out light bulbs (if applicable).
A16	Perform related task (if applicable).
A17	Replace belt guard and close access covers and doors.
A18	Return unit to service.
A19	Remove debris from work-site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ASHRAE STD 87.1-1992 Method of Testing Fan Vibration, Blade Vibrations and Critical Speeds
EN1b	OSHA Part 1910 Subpart O Machinery and Machine Guarding
EN1c	OSHA Part 1910.219 Subpart O Mechanical Power Transmission Apparatus
EN1d	OSHA Part 1910 Subpart E Means of Egress
EN2	For testing fan performance, see the guidance in ANSI/ASME Performance Test Code (PTC) 11-1984, Fans. The PTC provides standard procedures for conducting and reporting tests on fans, including centrifugal, axial, and mixed flow type fans.
EN3	Belts for multi-belted pulley systems are supplied in matched sets. It is important to make replacements with complete sets.
EN4	Small motors are often run-to-fail. For these units, do not specify PT&I procedures.

Chiller-01: Chiller - Operation Inspection, Clean Condenser/Absorber Tubes

Block Title	Text
Procedure Number	Chiller-01
System Description	Centrifugal, Reciprocating, Screw and Absorption Chiller
Procedure Description	1. Readiness Inspection and Cleaning
	2. Clean Condenser/Absorber Tubes
Related Tasks	PT&I-01, PT&I-02, PT&I-10
Periodicity	

Labor (Hrs)	
Special Tools	Eddy Current Tube Inspection System, Tube Cleaning Tool, Laser Alignment Tool.
Materials	
Reference Data	Chiller Operation and Maintenance Manual, Eddy Current Test Operation Manual
Warning Summary	1. Acidic refrigerant may be present.
	2. Ensure condenser/absorber shell fully de-pressurized before opening.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance data including vibration data test results (if available).
2	Notify operators or other local occupant before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Readiness Inspection and Cleaning
WARNING	Acidic refrigerant may be present.
A1	Perform related procedure PT&I-10 (if applicable).
A2	De-energize equipment and tag out in accordance with site safety practices.
A3	Inspect valves for leaks. Replace gaskets if leaks are found.
A4	Check the refrigerant/solvent level.
A5	Inspect equipment mounts for corrosion or support cracking.
A6	Clean line strainers for the lubricating pump (if applicable).
A7	Inspect and clean air cooling filters and coils (if applicable).
A8	Clean purge oil separator, purge drum and purge condensing coil (if applicable).
A9	Remove coupling guard (if applicable) and check alignment of flexible coupling on compressor drive with laser alignment tool.
A10	Remove belt guard (if applicable) inspect belts for cracks, glazing, fraying or wear.
A11	Replace coupling guard or belt guard (if applicable)
A12	Change compressor oil and filter (if applicable).
A13	Inspect all moving linkages for missing parts or excessive looseness.
Note	Steps A14 and A15 for absorber chillers only.

A14	Test the operation of the steam valve.
A15	Test the lithium bromide solution concentration and record results in Inspection Data Section, ID-1.
B	Clean Condenser/Absorber Tubes
B1	Close condenser/absorber water inlet and outlet valves and drain condenser/absorber shell.
WARNING	Ensure condenser/absorber shell fully de-pressurized before opening.
B2	Open condenser/absorber.
B3	Clean condenser/absorber tubes.
B4	Remove dirt and debris from condenser/absorber.
B5	Perform eddy current tube test and boroscope inspection for cracks, deposits and tube discontinuities. Record defect data in Inspection Data Section, ID-2.
B6	Compare eddy current results with manufacturer's recommended allowable defect depth/density. Plug unusable tubes.
B7	Reinstall condenser shell cover. Torque bolts in accordance with manufacturer's suggested tightening pattern and torque level.
B8	Remove condenser water strainers, inspect for erosion, corrosion or damage, clean and reinstall.
B9	Inspect chiller case for rust, erosion or signs of poor water treatment such as mineral deposits.
B10	Inspect chiller insulation for tears and missing sections. Replace/repair insulation as necessary.
B11	Perform related procedures.
B12	Perform operational test of unit.
B13	Return system to service.
B13	Remove debris from work-site.
Inspection Data	Fill in all applicable.
ID-1	Record lithium bromide solution concentration.
ID-2	Record defect depth and wall loss results from eddy current test for each tube. Provide diagram of blocked tubes.
Engineer's Notes	
EN1	Perform PT&I-10,Extract Lubricant Sample, before changing oil.
EN1a	Analysis of chiller oil, monitor changes in pH (Total Acid Number) to detect vacuum leaks through increased acidity.
EN1b	Analysis of chiller oil, test for wear particles, oil condition (depletion of additive package). Results are used to modify oil-change schedule.

EN1c	Analysis of chiller oil, test for water. Results are used to perform further analysis if water is present. See equipment manufacturer for the equipment water tolerance.
EN1d	If presence of water is specified to be less than 100ppm (0.01 percent), then use ASTM D1744, Karl Fischer method (detect presence of water to 10ppm (0.001 percent)).
EN2	Efficiency of chiller falls by 2 percent for each degree of temperature rise (F) in condenser water.
EN3	See American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Guideline 3 for design of refrigerant logs.
EN3a	Monitor log data for trends in acidity or refrigerant replenishment amounts that indicate slowly developing problems.
EN4	A new high-efficiency purge unit is highly recommended as an upgrade to older low-pressure centrifugal chillers.
EN5	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN5a	ASHRAE Guideline 3-1996 Reducing Emission of Halogenated Refrigerants in Refrigeration and Air-Conditioning Equipment and Systems
EN5b	ASHRAE Std 15-1994 Safety Code for Mechanical Refrigeration
EN5c	ASHRAE Std 34-1997 Designation and Safety Classification of Refrigerants
EN5d	OSHA Part 1910 Subpart O Machinery and Machine Guarding
EN5e	OSHA Part 1910 Subpart I Personal Protective Equipment
EN5f	American Refrigeration Institute, ARI 700-99 Specification for Fluorocarbon Refrigerants
EN5g	ASTM B244, ISO 2360, DIN 50984, Eddy Current Method
EN6	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN6a	5/32-32: 25 in-lb.
EN6b	5/32-36: 26 in-lb.
EN6c	3/16-32: 42 in-lb.
EN6d	1/4-28: 95 in-lb.
EN6e	5/16-24: 185 in-lb.
EN6f	1/2-20: 800 in-lb.

Chiller-02: Chiller - Evaporator Tube Inspection and Cleaning

Block Title	Text
Procedure Number	Chiller-02
System Description	Chillers
Procedure Description	Evaporator Tube Inspection and Cleaning
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Eddy Current Tube Inspection System, Tube Cleaning Tool
Materials	
Reference Data	Chiller Manufacturer's Operation and Maintenance Manual, Eddy Current Test Operation Manual
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Notify operators or other local occupant before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect and Clean Evaporator Tubes
A1	De-energize equipment and tag out in accordance with site safety practices.
A2	Drain water from evaporator.
A3	Remove evaporator shell cover.
A4	Inspect shell interior for indications of corrosion, erosion, thermal stress cracks or dirt.
Note1	Tubes with interior baffles should be cleaned according to manufacturer's suggested procedures.
A5	Clean tubes with tube cleaning system.
A6	Flush cleaned tubes with clean water.
Note2	Eddy Current Tube Inspection requirements vary by design of heat exchanger (wall thickness, tube material and tube diameter). Follow Eddy Current Test Operation Manual procedures.
A7	Perform eddy current tube test and boroscope inspection for cracks, deposits and tube discontinuities. Record defect data in Inspection Data Section, ID-1.

A8	Compare eddy current results with manufacturer's recommended allowable defect depth/density. Plug unusable tubes.
A9	Clean debris and dirt thoroughly from shell .
A10	Inspect evaporator lining for signs of blistering, cracking or corrosion.
A11	Reinstall evaporator shell cover.
A12	Tighten cover bolts according to manufacturer's suggested pattern and torque levels.
A13	Purge air from system.
A14	Perform operational test of unit.
A15	Return system to service.
A16	Remove debris from work site.
Inspection Data	
ID-1	Record defect depth and wall loss results from eddy current test for each tube. Provide diagram of blocked tubes.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN1b	ASTM B244, ISO 2360, DIN 50984, Eddy Current Method
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.

Filters

Procedure Number	Machine/System	Procedure Summary
Filter-01	Drinking Water Cooler	Change Filter

Filter-02	Process Water Filter	Change Filters
Filter-03	Air Cooled Equipment/Air Compressors	Change Intake Air Filters

Filter-01: Drinking Water Cooler - Change Filter

Block Title	Text
Procedure Number	Filter-01
System Description	Drinking Water Cooler
Procedure Description	Change Filter
Related Tasks	
Special Tools	
Materials	New Filter
Reference Data	
Warning Summary	
Caution Summary	Use caution to ensure proper seating of sealing surfaces during reassembly.
Reserved	
Preliminary	
1	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
2	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Change Filter
A1	Remove filter cover panel from water cooler (if applicable).
A2	Close inlet water valve.
A3	Drain filter housing.
A4	Disassemble filter housing and remove old filter.
A5	Inspect o-ring, seals and gaskets for cracking or hardening, replace as necessary.
A6	Install new filter. Record date of filter replacement as required in ID-1
CAUTION	Use caution to ensure proper seating of sealing surfaces during reassembly.
A7	Reassemble filter housing.
A8	Close filter housing drain.
A9	Open inlet water valve.

A10	Open bubblier valve and allow water to circulate until air is out of system.
A11	Check system for leaks.
A12	Replace filter cover panel (if applicable).
A13	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A14	Remove debris from work-site.
Inspection Data	
ID-1	Record date of filter change in log book or on adhesive sticker at filter.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	Filters may require a tag showing the date and type of latest filter change. This is especially important for potable water systems and systems where bacterial build-up might present process or health problems.

Filter-02: Process Water Filter - Change Filters

Block Title	Text
Procedure Number	Filter-02
System Description	Process Water Filter
Procedure Description	Change Filters
Related Tasks	
Special Tools	
Materials	Filter Cartridges
Reference Data	

Warning Summary	Do not open canister until drain stops running.
Caution Summary	1. When opening bypass or inlet valves, do not open gate more than 1/4". Allow valve to control flow rate until piping has reached service pressure.
	2. Ensure proper seat on seal to avoid distorting sealing gaskets.
Reserved	
Preliminary	
1	Notify operators before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Change Filters
A1	Record operating pressures prior to closing valves.
A2	Record pressure upstream of filter housing.
A3	Record pressure downstream of filter housing.
CAUTION	When opening bypass or inlet valves, do not open gate more than 1/4". Allow valve to control flow rate until piping has reached service pressure.
A4	Open filter bypass valve.
A5	Close filter canister inlet and outlet valves.
A6	Open canister drain and allow filter canister to drain.
WARNING	Do not open canister until drain stops running.
A7	Recheck inlet valve for proper seating if drain does not stop running or drain pressure is high at drain.
A8	Unlatch top of canister.
A9	Raise top of canister and swing top to the side.
A10	Remove filter cartridges.
A11	Back-flush canister.
A12	Remove sediment from canister.
A13	Remove interior of filter canister, clean as necessary.
A14	Remove and inspect o-ring seal, replace as necessary.
A15	Lubricate o-ring using silicone lubricant and replace seal.
A16	Install new filter cartridges.
A17	Note and record number of filters, type and date in the Inspection Data section, Item ID-1.
A18	Reposition canister lid over canister body.
CAUTION	Ensure proper seat on seal to avoid distorting sealing gaskets.

A19	Close and tighten lid latches.
A20	Close canister drain valve.
A21	Open canister inlet valve slowly.
A22	Open air purge valve, if applicable.
A23	Allow canister to fill with water.
A24	Close air purge valve when canister is full.
A25	Open canister outlet valve.
A26	Close bypass valve.
A27	Record pressure upstream of filter housing.
A28	Record pressure downstream of filter housing.
A29	Calculate and record pressure differential (upstream pressure minus downstream pressure) in the Inspection Data section, Item ID-2.
A30	Close valves and check filter for blockage or missing filter cartridge if pressure differential is not within expected range.
A31	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A32	Return system to service.
A33	Remove debris from work-site.
Inspection Data	
ID-1	Record date of filter installation, quantity of filters installed, type of filter and particle size filtration for filter media.
ID-2	Record pressure differential across filters after installation.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ISO 5209:1977 General purpose industrial valves -- Marking
EN1b	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.

EN3	Filters may require a tag showing the date and type of latest filter change. This is especially important for potable water systems and systems where bacterial build-up might present process or health problems.

Filter-03: Air Cooled Equipment/Air Compressors - Change Intake Air Filters

Block Title	Text
Procedure Number	Filter-03
System Description	Air Cooled Equipment/Air Compressors
Procedure Description	Change Intake Air Filter
Related Tasks	
Special Tools	Vacuum Cleaner
Materials	New Filter
Reference Data	
Warning Summary	
Caution Summary	Use caution to ensure proper seating of sealing surfaces during reassembly.
Reserved	
Preliminary	
1	Notify operators before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Change Intake Air Filter
A1	De-energize and tag out in accordance with site safety practices.
A2	Remove equipment cabinet access panel, if applicable.
A3	Remove old filter.
A4	Vacuum intake area to remove dirt and dust.
A5	Clean old filter if reusable.
A6	Re-install cleaned filter (if applicable).
A7	Install new filter. Record date of filter replacement as required in ID-1.
A8	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A9	Re-install equipment cabinet access panel, if applicable.

A10	Return equipment to service.
A11	Remove debris from work-site.
Inspection Data	
ID-1	Record date of filter change in log book or on adhesive sticker at filter.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	Filters may require a tag showing the date and type of latest filter change. This is especially important for potable water systems and systems where bacterial build-up might present process or health problems.

Steam Traps

Procedure Number	Machine/System	Procedure Summary
Strap-01	Steam Trap	Test and Purge

Strap-01: Steam Trap - Test and Purge

Block Title	Text
Procedure Number	Strap-01
System Description	Steam Trap
Procedure Description	1. Test Steam Trap with Sight Method
	2. Test Steam Trap with Sound Method
	3. Test Steam Trap with Temperature Method

	4. Purge Steam Trap
Related Tasks	
Special Tools	Thermometer, Ultrasonic Listening Device
Materials	
Reference Data	Manufacturer's Manuals
Warning Summary	1. Avoid locations where steam is released. Defective steam traps can expel high velocity and high temperature steam causing burns.
	2. Do not loosen valve body assembly nut.
Caution Summary	
Reserved	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Notify operators before starting inspection.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Test Steam Trap with Sight Method
WARNING	Avoid locations where steam is released. Defective steam traps can expel high velocity and high temperature steam causing burns.
Note 1	Review manufacturer's manuals before working on device.
A1	Open trap test port.
Note 2	Flash steam is indicated by intermittent, low pressure steam mixed with condensate.
A2	Visually inspect discharge for flash steam.
Note 3	Live steam is indicated by high temperature, high velocity discharge with a transparent space between the discharge port and the visible portion of the discharge.
A3	Write repair order for steam traps with live steam discharge or no discharge.
A4	Close trap discharge test port.
B	Test Steam Trap with Sound Method
WARNING	Avoid locations where steam is released. Defective steam traps can expel high velocity and high temperature steam causing burns.
Note 4	Review manufacturer's manuals before working on device.

Note 5	The sound method checks the dynamics of a steam trap. A stethoscope or ultrasound instrument is used to listen to the action of the trap and for the sound of flow through the trap.
B1	Close the inlet valve to the steam trap for one minute.
B2	Place listening device on trap (stethoscope), or at trap discharge (ultrasonic).
B3	Open trap inlet valve and listen for proper trap opening.
B4	Listen for proper closing after condensate has discharged.
B5	Write repair order for steam traps that do not open or close properly.
C	Test Steam Trap with Temperature Method
WARNING	Avoid locations where steam is released. Defective steam traps can expel high velocity and high temperature steam causing burns.
Note 6	Review manufacturer's manuals before working on device.
C2	Measure and record temperature of steam pipe 12 inches downstream of trap.
C3	Convert temperature measurements to pressure measurements.
C4	Check that upstream temperature measurement corresponds with known inlet pressure. Report temperatures that are lower than expected. (Trap is failed closed or clogged).
C5	Report downstream temperatures that indicate high downstream pressure.
D	Purge Steam Trap
WARNING	Avoid locations where steam is released. Defective steam traps can expel high velocity and high temperature steam causing burns.
D1	Isolate the trap from the piping system using the inlet and outlet valves.
WARNING	Do not loosen valve body assembly nut.
D2	Open the trap blow down valve slowly to bleed off any pressure left in the trap.
D3	Check that blow down valve has reached full open position.
D4	Open inlet valve slowly to provide steam flow sufficient to blow dirt from strainer.
D5	Close the steam inlet valve.
D6	Close the trap blow down valve.
D7	Open the inlet and outlet steam valves to return the trap to service.
D8	Discard blow down products in approved location.
D9	Remove debris from work-site.
Engineer's Notes	

EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ANSI/ASME PTC 39.1-1980, "Performance Test Code for Condensate Removal Devices for Steam Systems"
EN1b	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2	Sight Method for testing steam traps should only be used for steam traps that open to atmosphere or when a test tee is available.
EN3	Manufacturer's information determines what to look for; heavy, steady condensate flow, or light intermittent discharge, the modulating action of a float and thermostatic trap, or the snap action of a disc trap. It is important to know if you are working with a saturated steam system or a superheated steam system.

Air Compressors

Procedure Number	Machine/System	Procedure Summary
AirComp-01	Air Compressor	Operation Inspection
AirComp-02	Air Compressor	Belt Inspection and Replacement.

AirComp-01: Air Compressor - Operation Inspection

Block Title	Text
Procedure Number	AirComp-01
System Description	Air Compressor
Procedure Description	Operation Inspection
Related Tasks	PT&I-01, PT&I-10
Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	Manufacturer's Operation and Maintenance Manual
Warning Summary	
Caution Summary	Do not overfill oil reservoir.
Reserved	
Preliminary	

1	Notify operators or other local occupant before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Note 1	Related task PT&I-01 is applicable for centrifugal and rotary screw type compressors, PT&I-10 is applicable for reciprocating compressors.
4	Perform related tasks PT&I-01 and PT&I-10.
Procedure	
A	Operation Inspection
A1	Ensure compressor temperature is within manufacturer's specifications. If not, note on work order.
A2	Inspect oil and coolant system (air/water) for flow restrictions.
A3	Inspect for leaks on piping and flexible joint packing, control lines, control line fittings, clamps and connectors, valves, air pressure safety relief valves, and pressure gauge connections.
A4	De-energize equipment and tag-out in accordance with site safety requirements.
CAUTION	Do not overfill oil reservoir.
Note 2	Change oil based upon oil analysis results.
A5	If required, change oil according to manufacturer's recommendations.
A6	Record service hours and load hours in Inspection Data Section ID-1.
A7	Check water level in coolant reservoir (if applicable). Add as required.
A8	Drain any condensate from receiver, traps and pulsation chamber.
A9	Verify operation of automatic drain taps. Repair or replace as needed.
A10	Remove and clean inlet air filter cartridges. Replace as required.
A11	Inspect and clean air cooling filters (prefilters) and coils (if applicable).
A12	Clean all external parts of compressor and motor.
A13	Tighten all hardware including motor pulley and flywheel (if applicable)
A14	Test safety valve manually to ensure it operates properly.
A15	Clean line strainers for the lubricating pump (if applicable).
A16	Inspect equipment mounts for corrosion or support cracking. Replace worn or missing rubber/spring feet.
A17	Return unit to service, verify proper operation.
A18	Remove debris from work site.
Inspection Data	
ID-1	Record service and load hours.

Engineer's Notes	
EN1	Use a straight weight non-detergent oil in compressors. For temperatures above 55°F, use 30 weight oil; 20 weight oil for temperatures from 32° to 55°F, and 10 weight oil for temperatures below 32°F.
EN2	Ratio of run hours to loaded hours can be used to adjust idle settings. Readings taken should be forwarded to Operations for proper idle-time setting and equipment cycling schedule.
EN3	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN3a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN3b	OSHA Regulations (Standards - 29 CFR), Mechanical power-transmission apparatus. - 1910.219
EN4	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN4a	5/32-32: 25 in-lb.
EN4b	5/32-36: 26 in-lb.
EN4c	3/16-32: 42 in-lb.
EN4d	1/4-28: 95 in-lb.
EN4e	5/16-24: 185 in-lb.
EN4f	1/2-20: 800 in-lb.

AirComp-02: Air Compressor - Belt Inspection and Replacement.

Block Title	Text
Procedure Number	AirComp-02
System Description	Air Compressor
Procedure Description	Belt Inspection and Replacement.
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	Belt Tensiomometer, Belt Alignment Laser
Materials	
Reference Data	Manufacturer's Operation and Maintenance Manual
Warning Summary	
Caution Summary	Do not use leverage bars to stretch belts over pulleys.

Reserved	
Preliminary	
1	Notify operators or other local occupant before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Belt Inspection and Replacement.
A1	De-energize equipment and tag-out in accordance with site safety requirements.
A2	Remove pulley and belt guards.
CAUTION	Do not use leverage bars to stretch belts over pulleys.
A3	Inspect belt for wear, cracks, glazing or fraying. Replace if necessary and note on work order.
Note	Belts for multi-belted pulley systems are supplied in matched sets. It is important to make replacements with complete sets.
A4	Inspect pulleys for damage and measure wear with sheave gauge, replace if necessary.
A5	Measure sheave alignment with laser pulley alignment device. Adjust alignment as required.
A6	Measure belt tension with belt tensiometer. Adjust tension as required by manufacturer.
A7	Replace belt and pulley cover(s).
A8	Perform cleaning and touchup painting as required.
A9	Perform operational test of unit.
A10	Return air compressor to service.
A11	Notify operators or other local occupant when task is complete.
A12	Remove debris from work site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN1b	OSHA Regulations (Standards - 29 CFR), Mechanical power-transmission apparatus. - 1910.219

Cranes, Elevators, and Lifts

Procedure Number	Machine/System	Procedure Summary
Hoist-01	Cranes and Hoists	Inspect, Lubricate, Test and Clean
Hoist-02	Lift Platforms	Inspect, Lubricate, Test and Clean
Elevator-01	Elevators	Inspect, Lubricate, Test and Clean
Sling-01	Slings	Inspect

Hoist-01: Cranes and Hoists - Inspect, Lubricate, Test and Clean

Block Title	Text
Procedure Number	Hoist-01
System Description	Cranes; Gantry, Monorail & Bridge
Procedure Description	Inspect, Lubricate, Test and Clean
Related Tasks	Panel-01, Motor-01
Special Tools	
Materials	
Reference Data	NSS/GO-1740.9B, NASA Safety Standard For Lifting Devices and Equipment
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Coordinate performance of this task concurrent with government specified inspection and certification (if any).
2	Review applicable crane inspection requirements and standards.
3	Notify operators or other local occupant before starting task.
4	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
5	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
6	Perform related tasks Panel-01 and Motor-01.
Note	Related tasks Panel-01 and Motor-01 include the use of PT&I techniques.
Procedure	
A	Inspect, Lubricate, Test and Clean
A1	Perform complete visual inspection of entire crane.

A2	Inspect all equipment oil and lubrication reservoir levels. Add or change lubricant or oil as needed.
A3	Lubricate pivot points, anchors, clevis attachments and accessories per manufacturer's specifications.
A4	Grease or lubricate drive system as required.
A5	Inspect flex couplings and guards.
A6	Inspect cables, sheaves and drums for wear, proper spooling and lubrication.
A7	Inspect hoist, trolley, bridge, catwalks and alignment of rails.
A8	Inspect wire ropes and chains for broken stands, fraying, loose joints, and loose connections.
A9	Inspect all safety devices for proper operation. Adjust as required.
A10	Inspect the general condition of all accessory equipment and devices.
A11	Inspect all rail stops, sweeps, drop lugs, and shock absorbing bumpers.
A12	Inspect all control functions for smoothness of travel and proper stops.
A13	Verify that hand signal and warning labels are attached properly.
A14	Verify operation of limit switches.
A15	Inspect for oil leaks and mechanical irregularities.
A16	Check for loose bolts, parts and fittings.
A17	Adjust motor brakes as required, inspect linings, shoes and discs.
A18	Inspect collector shoes, brushes or wheels for wear.
A19	Inspect crane hooks for wear and perform non-destructive examination for cracks.
A20	Perform load test, test brake holding power.
A21	Perform general cleaning of equipment and area.
A22	Perform government specified inspection and certification if required.
A23	Complete and sign mechanical inspection form as required in Inspection Data section, Item ID-1.
A24	Return system to service.
A25	Remove debris from work-site.
Inspection Data	
ID-1	Make entries into required inspection log and file required inspection documents with proper authorities.
Engineer's Notes	

EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ANSI Std. HST-5-1999 Performance Standard For Air Chain Hoists
EN1b	ANSI Std. HST-6-1999 Performance Standard For Air Wire Rope Hoists
EN1c	ANSI Std. HST-1-1999 Performance Standard For Electric Chain Hoists
EN1d	ANSI Std. HST-2-1999 Performance Standard For Hand Chain Manually Operated Chain Hoists
EN1e	ANSI Std. HST-3-1999 Performance Standard For Manually Lever Operated Chain Hoists
EN1f	ANSI Std. HST-4-1999 Performance Standard For Overhead Electric Wire Rope Hoists
EN1g	ASME B30.10-1999, Hooks (revision of ANSI/ASME B30.10-1993)
EN1h	ASME B30.11a-1999, Monorails and Underhung Cranes (supplement to ANSI/ASME B30.11-1998)
EN1i	ASME B30.17-1998, Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist), (supplement to ANSI/ASME B30.17-1998)
EN1j	OSHA Regulations 29 CFR, Part 1910 Subpart N - Materials Handling and Storage; 1910.179 - Overhead and gantry cranes.
EN1k	OSHA Regulations 29 CFR, Part 1910 Subpart N - Materials Handling and Storage; 1910.184 - Slings.
EN1l	Federal Register; Overhead and Gantry Cranes (Inspection Certification Records); Extension of the Office of Management and Budget's (OMB) Approval of an Information Collection (Paperwork) Requirement. - 64:48208-48209
EN1m	ANSI A17.1-71 Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks
EN1n	ANSI B30.2-76 Safety Code for Overhead and Gantry Cranes.
EN1o	ANSI B30.3-75 Hammerhead Tower Cranes.
EN1p	ANSI B30.4-73 Safety Code for Portal, Tower, and Pillar Cranes.
EN1q	ANSI B30.5-68 Safety Code for Crawler, Locomotive, and Truck Cranes.
EN1r	ANSI B30.6-77 Derricks.
EN1s	ANSI B30.7-77 Base Mounted Drum Hoists.
EN1t	ANSI B30.8-71 Safety Code for Floating Cranes and Floating Derricks.
EN1u	ANSI B30.11-73 Monorail Systems and Underhung Cranes.
EN1v	ANSI B30.12-75 Handling Loads Suspended from Rotorcraft.
EN1w	ANSI B30.13-77 Controlled Mechanical Storage Cranes.
EN1x	ANSI B30.15-73 Safety Code for Mobile Hydraulic Cranes.
EN1y	ANSI B30.16-73 Overhead Hoists.

EN1z	OSHA Part 1910 Subpart I Personal Protective Equipment
EN1aa	ANSI A10.4-1963, Safety Requirements for Workmen's Hoists
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	Crane and Hoist inspection requirements are governed by OSHA and local governments and vary depending on state, use, type and lifting capacity. Check with local government authorities for current requirements.

Hoist-02: Lift Platforms - Inspect, Lubricate, Test and Clean

Block Title	Text
Procedure Number	Hoist-02
System Description	Lift Platforms
Procedure Description	Inspect, Lubricate, Test and Clean
Related Tasks	Panel-01, Motor-01
Special Tools	
Materials	
Reference Data	NSS/GO-1740.9B, NASA Safety Standard For Lifting Devices and Equipment
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Notify operators or other local occupant before starting task.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
4	Perform related tasks Panel-01 and Motor-01.
Note	Related tasks Panel-01 and Motor-01 include the use of PT&I techniques.

Procedure	
A	Inspect, Lubricate, Test and Clean
A1	Tighten all fastening anchors.
A2	Inspect ramp for proper operation.
A3	Lubricate ramp linkage and hinges.
A4	Lubricate gate hinges and adjust speed of door/gate closer.
A5	Inspect all travel cables for excessive wear.
A6	Check level of hydraulic fluid with platform in down position.
A7	Lubricate ropes with SAE-20W oil.
A8	Check hydraulic plumbing for leaks.
A9	Verify operation of slack rope device (if applicable).
A10	Lubricate linkage of slack rope device (if applicable).
A11	Equalize tension of ropes (if applicable).
A12	Clean guide channels and apply grease.
A13	Remove debris from work-site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN1b	ANSI A10.4-1963, Safety Requirements for Workmen's Hoists
EN1c	OSHA Regulation Cranes and derricks. - 1926.550
EN1d	Federal Register; Overhead and Gantry Cranes (Inspection Certification Records); Extension of the Office of Management and Budget's (OMB) Approval of an Information Collection (Paperwork) Requirement. - 64:48208-48209
EN1e	ANSI A17.1-71 Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks
EN1f	ANSI B30.2-76 Safety Code for Overhead and Gantry Cranes.
EN1g	ANSI B30.3-75 Hammerhead Tower Cranes.
EN1h	ANSI B30.4-73 Safety Code for Portal, Tower, and Pillar Cranes.
EN1i	ANSI B30.5-68 Safety Code for Crawler, Locomotive, and Truck Cranes.
EN1j	ANSI B30.6-77 Derricks.
EN1k	ANSI B30.7-77 Base Mounted Drum Hoists.
EN1l	ANSI B30.8-71 Safety Code for Floating Cranes and Floating Derricks.
EN1m	ANSI B30.11-73 Monorail Systems and Underhung Cranes.

EN1n	ANSI B30.12-75 Handling Loads Suspended from Rotorcraft.
EN1o	ANSI B30.13-77 Controlled Mechanical Storage Cranes.
EN1p	ANSI B30.15-73 Safety Code for Mobile Hydraulic Cranes.
EN1r	ANSI B30.16-73 Overhead Hoists.
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	Crane and Hoist inspection requirements are governed by OSHA and local governments and vary depending on state, use, type and lifting capacity. Check with local government authorities for current requirements.

Elevator-01: Elevators - Inspect, Lubricate, Test and Clean

Block Title	Text
Procedure Number	Elevator-01
System Description	Elevators
Procedure Description	Inspect, Lubricate, Test and Clean
Related Tasks	Panel-01, Motor-01
Special Tools	
Materials	
Reference Data	
Warning Summary	
Caution Summary	
Reserved	
Preliminary	
1	Coordinate performance of this task concurrent with government specified inspection and certification (if any).
2	Notify operators or other local occupant before starting task.
3	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.

4	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
5	Perform related tasks Panel-01 and Motor-01.
Note	Related tasks Panel-01 and Motor-01 include the use of PT&I techniques.
Procedure	
A	Inspect, Lubricate, Test and Clean
A1	Check operation of doors at each floor.
A2	De-energize equipment and tag out in accordance with site safety practices.
A3	Clean and lubricate motor bearings.
A4	Check and adjust controllers and selectors.
A5	Clean and lubricate worm and gear bearings.
A6	Check car door hangers and gibes, adjust if required.
A7	Check and adjust guide rails.
A8	Clean and lubricate door closer checks and interlocks.
A9	Check and clean machine room car top and pit-pit can.
A10	Inspect structure for signs of stress, wear, cracking or corrosion.
A11	Check hydraulic reservoir for fluid level. Refill if required (if applicable).
A12	Inspect jack packing (if applicable).
A13	Inspect hydraulic system for leaks.
A14	Inspect drive belts and pulleys. Tighten or replace as required.
A15	Check and clean pushbuttons, position indicator lights and hall lanterns.
A16	Check and adjust safety edge and light rays.
A17	Check lamp hatchway, hall landings, position indicators, car stations and domes. Re-lamp, as required
A18	Check emergency procedure sign.
A19	Check top and side exits.
A20	Test alarm bell, emergency stop switch and communications system.
A21	Test fire recall system and any other recall features.
A22	Perform operation of elevator and adjust if necessary.
A23	Fill out maintenance record and report as required by Inspection Data Section, Item ID-1.
A24	Perform government specified inspection and certification if required.
A25	Remove debris from work-site.
Inspection Data	

ID-1	Make entries into required inspection log and file required inspection documents with proper authorities.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	OSHA Part 1910 Subpart I Personal Protective Equipment
EN1b	ANSI A17.1-71 Safety Code for Elevators, Dumbwaiters, Escalators and Moving Walks
EN1c	ANSI A10.4-1963, Safety Requirements for Workmen's Hoists
EN2	For fasteners, if the manufacturers torque values are not available, use those listed below. See specification SAE AIR1471. All values are + or - 12.5%.
EN2a	5/32-32: 25 in-lb.
EN2b	5/32-36: 26 in-lb.
EN2c	3/16-32: 42 in-lb.
EN2d	1/4-28: 95 in-lb.
EN2e	5/16-24: 185 in-lb.
EN2f	1/2-20: 800 in-lb.
EN3	Elevator inspection requirements are governed by OSHA and local governments and vary depending on state, use, type and lifting capacity. Check with local government authorities for current requirements.

Sling-01: Slings - Inspect

Block Title	Text
Procedure Number	Sling-01
System Description	Flat Lifting Sling or Web
Procedure Description	Inspect
Related Tasks	
Special Tools	
Materials	
Reference Data	OSHA standard 1910.184 - Slings, ASME B30.10-1999, Hooks
Warning Summary	Slings removed from service that are not capable of repair shall be destroyed.
Caution Summary	
Reserved	

Preliminary	
1	Review applicable sling inspection requirements and standards.
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to sling. Destroy sling if label is unreadable.
Procedure	
A	Inspect Sling
Note 1	OSHA mandates that "Each day before being used, the sling and all fastenings and attachments shall be inspected for damage or defects by a competent person designated by the employer. Additional inspections shall be performed during sling use, where service conditions warrant."
WARNING	Slings removed from service that are not capable of repair shall be destroyed.
Note 2	Critical areas of sling to inspect are wear to body of sling, selvage edge of webbing, and condition of lift eyes.
A1	Inspect sling per OSHA standard 1910.184 - Slings.
A2	Inspect hooks and hangers per ASME B30.10-1999, Hooks.
A3	Destroy or render useless any sling, web or hook determined to be defective.
A4	Report sling inspection in Inspection Data section ID-1.
Inspection Data	
ID-1	Make entries into required inspection log and file required inspection documents with proper authorities.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	ASME B30.10-1999, Hooks (revision of ANSI/ASME B30.10-1993)
EN1b	ASME B30.9-1996 Slings (revision of ANSI/ASME B30.9-1990, ANSI/ASME B30.9a-1991,ANSI/ASME B30.9a-1991, ANSI/ASME B30.9b-1991)
EN1c	OSHA Regulations 29 CFR, Part 1910 Subpart N - Materials Handling and Storage; 1910.184 - Slings.
EN1d	OSHA Part 1910 Subpart I Personal Protective Equipment
EN2	Three inspections are required during the normal life of a flat sling. These inspections are performed as follows:

EN2a	INITIAL - This inspection is done at the time the product is first received to insure that damage has not occurred during shipment. Also verify the goods are in compliance with the specifications of not only your purchase order, but also with the specifications of the manufacturer. Written inspection records documenting the condition of the new sling should be initiated at this level of inspection.
EN2b	FREQUENT-This level of inspection should be done by the person handling the sling, every time the sling is used. The entire sling should be thoroughly examined and removed from service if damage is detected. OSHA stipulates that, "each day before being used, the sling and all fastenings and attachments shall be inspected for damage and defects by a competent person designated by the employer." The sling user must also determine that the sling is proper for the hitch, load and environment.
EN2c	PERIODIC-The periodic level of inspection should be done by designated personnel at regular internals. The interval is based upon the frequency of use, severity of the service conditions, and information derived through the inspection process. Recommendations to prevent damage must be evaluated to improve the service life of the replacement slings. Periodic inspections must always reference the unique sling identification number. Records and documentation should be kept in the safety office or sling storage area.

Fire Detection/Protection

Procedure Number	Machine/System	Procedure Summary
Fire-01	Fire Detection/Protection Systems	Inspect Fire Detection Systems
Fire-02	Fire Detection/Protection Systems	Inspect Water Fire Protection Systems and Fire Hydrants
Fire-03	Fire Detection/Protection Systems	Inspect Chemical Fire Protection Systems

Fire-01: Fire Detection/Protection Systems - Inspect Fire Detection Systems

Block Title	Text
Procedure Number	Fire-01
System Description	Fire Detection/Protection Systems
Procedure Description	Inspect Fire Detection Systems
Related Tasks	
Periodicity	

Labor (Hrs)	
Special Tools	
Materials	
Reference Data	Manufacturers Instructions
Warning Summary	Notify building occupants before starting test. Consult with Fire or Safety Department on proper notification methods.
Caution Summary	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect Fire Detection Systems
A1	Notify Fire or Safety Department of testing location.
WARNING	Notify building occupants before starting test. Consult with Fire or Safety Department on proper notification methods.
A2	Disable Fire Detection panel.
A3	Inspect fire detection panel cover for proper seal.
A4	Inspect fire detection panel internal circuitry for loose connections, frayed or burnt wiring, and dirt or foreign materials.
	Perform minor repair. Contact supervisor if repairs are not possible. Note on work order.
A5	Remove positive lead from stand-by battery; observe trouble light and alarm. Clear or silence alarm, reconnect battery, and reset system. Notify supervision if alarm does not function.
A6	Check battery for proper voltage. Replace as necessary.
A7	Check operation of all visual alarms. Refer to manufacturers instructions.
Note	Modern fire alarm systems contain self diagnostics which indicate failed or malfunctioning detectors/sensors. Use this information to help determine which detectors need to be repaired or replaced.
A8	Inspect detectors/sensors. Clean or repair sensors as needed. Refer to manufacturers instructions.
A9	Test all pullstations. Repair or replace pullstations as needed.
A10	Return system to service.
A11	Notify building occupants when system is returned to service.
A12	Notify Fire or Safety Department when system is returned to service.

A13	Remove debris from work-site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	NFPA 25; Inspection, Testing and Maintenance of Water-Based Fire Protection Systems, 1998 Edition.
EN1b	NFPA 72; National Fire Alarm Code, 1999 Edition

Fire-02: Fire Detection/Protection Systems - Inspect Water Fire Protection Systems and Fire Hydrants

Block Title	Text
Procedure Number	Fire-02
System Description	Fire Detection/Protection Systems
Procedure Description	1. Inspect Water Fire Protection Systems
	2. Inspect and Test Fire Hydrants
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	NFPA 25; Inspection, Testing and Maintenance of Water-Based Fire Protection Systems
Warning Summary	Notify building occupants before starting test. Consult with Fire or Safety Department on proper notification methods.
Caution Summary	Ensure water discharge is directed away from areas that could be damaged.
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect Water Fire Protection Systems

A1	Notify Fire or Safety Department of testing location.
WARNING	Notify building occupants before starting test. Consult with Fire or Safety Department on proper notification methods.
A2	Disable all facility and local alarms.
A3	Inspect pipes, hoses, and connections for leaks, corrosion, and mechanical damage.
A4	Ensure sprinkler pipes are not subjected to external loads by materials resting on them or other loads hung from pipe.
A5	Remove positive lead from stand-by battery; observe trouble light and alarm. Clear or silence alarm, reconnect battery, and reset system. Notify supervision if alarm does not function.
A6	Ensure sprinkler head is not obstructed. Report any obstruction to supervisor.
A7	Check operation of all visual alarms. Refer to manufacturers instructions.
A8	Record water supply pressure and system static pressure in Inspection Data section, items ID-1 and ID-2.
A9	Ensure fire department connection, if installed, is accessible.
A10	Perform operational test of check valves, drain valves, control valves, and test valves. Refer to NFPA 25 and manufacturers instructions.
A11	Inspect and clean all strainers, filters, and diaphragm chambers.
A12	Test alarm devices per manufacturers instructions. Repair or replace as required.
A13	Test pressure, flow, and supervisory switches per manufacturers instructions. Repair/replace/recalibrate as required.
A14	Return system to service.
A15	Notify building occupants when system is returned to service.
A16	Notify Fire or Safety Department when system is returned to service.
A17	Remove debris from work-site.
B	Inspect and Test Fire Hydrants
B1	Notify Fire or Safety Department of testing location.
B2	Inspect hydrant for damage and/or leaks.
B3	Remove caps. Inspect caps and threads for any damage. Repair and lubricate as necessary.
CAUTION	Ensure water discharge is directed away from areas that could be damaged.
Note 1	Consult NFPA 25 for proper water flow.
B4	Open hydrant and verify proper water flow.
B5	Reinstall caps.
B6	Notify Fire or Safety Department upon completion of testing.
B7	Remove debris from work-site.

Inspection Data	Fill in all applicable.
ID-1	Water supply pressure
ID-2	System static pressure
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	NFPA 25; Inspection, Testing and Maintenance of Water-Based Fire Protection Systems, 1998 Edition.
EN1b	NFPA 72; National Fire Alarm Code, 1999 Edition

Fire-03: Fire Detection/Protection Systems - Inspect Chemical Fire Protection Systems

Block Title	Text
Procedure Number	Fire-03
System Description	Fire Detection/Protection Systems
Procedure Description	Inspect Chemical Fire Protection Systems
Related Tasks	
Periodicity	
Labor (Hrs)	
Special Tools	
Materials	
Reference Data	Manufacturers Instructions
Warning Summary	Notify building occupants before starting test. Consult with Fire or Safety Department on proper notification methods.
Caution Summary	
Preliminary	
1	Review prior maintenance test data including thermal image and ultrasonic noise test results (if available).
2	Ensure equipment/component identification (name and/or number) is legible and securely affixed to equipment. Repair as required.
3	For any step in procedure, record unsatisfactory conditions on work order and report them to supervisor.
Procedure	
A	Inspect Chemical Fire Protection Systems

A1	Notify Fire or Safety Department of testing location.
WARNING	Notify building occupants before starting test. Consult with Fire or Safety Department on proper notification methods.
A2	Disable fire protection panel.
A3	Inspect fire protection panel cover for proper seal.
A4	Inspect fire protection panel internal circuitry for loose connections, frayed or burnt wiring, and dirt or foreign materials.
A5	Lockout fire protection system. Refer to manufacturers instructions for proper valves and sequence.
A6	Remove positive lead from stand-by battery; observe trouble light and alarm. Clear or silence alarm, reconnect battery, and reset system. Notify supervision if alarm does not function.
A7	Inspect all system actuation and discharge flex hoses. Verify they are clean with no signs of corrosion or external damage.
A8	Check operation of all visual alarms. Refer to manufacturers instructions.
A9	Perform operational checks and tests per NFPA 17 or 17A and manufacturers instructions.
A10	Test alarm devices per manufacturers instructions. Repair or replace as required.
A11	Test pressure, flow, and supervisory switches per manufacturers instructions. Repair/replace/recalibrate as required.
A12	Return system to service.
A13	Notify building occupants when system is returned to service.
A14	Notify Fire or Safety Department when system is returned to service.
A15	Remove debris from work-site.
Engineer's Notes	
EN1	Technical standards are updated by the sponsoring organization (such as ASTM and IEEE). Often the update year is part of the standard number. Check with the sponsoring organization for the current standard.
EN1a	NFPA 12; Standard on Carbon Dioxide Extinguishing Systems, 2000
EN1b	NFPA 12A; Standard on Halon Fire Extinguishing Systems, 1997
EN1c	NFPA 17; Standard for Dry Chemical Extinguishing Systems, 1998
EN1d	NFPA 17A; Standard for Wet Chemical Extinguishing Systems, 1998

Appendix B - Equipment Selection Analysis

The listing that follows categorizes machinery systems and equipment from all of the NASA Centers.

- EQP is the number of equipment items in the classification.
- HRS is the total number of labor-hours expended.
- PM is the number of scheduled tasks performed for that classification.

The 20% of the items with the most actual hours are bolded (excludes Miscellaneous and Vehicles). And the bolded items account for approximately 80% of the actual labor hours expended on scheduled maintenance.

	Equipment Classification	Totals				
		EQP	HRS	PM	% TOTAL HRS	
1	A-FRAMES	0	0	8	0.0%	
2	ACCUMULATOR	0	0	104	0.0%	
3	ACTUATOR - ELECTRIC	0	0	128	0.0%	
4	ACTUATOR - HYDRAULIC	0	0	2	0.0%	
5	**AIR DAMPERS**	**604**	**87,167**	**34**	**6.1%**	**87,167**
6	**AIR HANDLER/UNIT**	**6,235**	**70,471**	**6,260**	**4.9%**	**70,471**
7	ANNUNCIATOR PANEL	2	14	4	0.0%	
8	AREA LIGHTING	6	67	30	0.0%	
9	AUTOCLAVE	3	0	5	0.0%	
10	BACKFLOW PREVENTER	893	4,768	684	0.3%	
11	BASE WARNING SIREN	0	0	11	0.0%	
12	BEARING/BABBITT/JOURNAL	0	0	242	0.0%	
13	BLOWER	208	1,212	321	0.1%	
14	BOILER	344	7,750	716	0.5%	
15	**BREAKER (ALL VOLTAGES)**	**2,154**	**98,453**	**3,011**	**6.9%**	**98,453**
16	BUILDING CONDENSER H2O	0	0	16	0.0%	
17	CANALS	0	0	2	0.0%	
18	CAPACITOR BANK	6	0	14	0.0%	
19	CATHODIC PROTECTION	16	761	35	0.1%	
20	CHILLER	752	7,011	1,835	0.5%	
21	COMPRESSED AIR DRYER	3	3	4	0.0%	
22	**COMPRESSOR**	**1,338**	**18,629**	**1,196**	**1.3%**	**18,629**
23	COMPUTER ROOM A/C	203	403	202	0.0%	
24	CONDENSER UNIT	451	2,316	660	0.2%	

	Equipment Classification	Totals				
		EQP	HRS	PM	% TOTAL HRS	
25	CONTROL PANEL	276	1,031	248	0.1%	
26	CONTROLER/PNEUMATIC	198	1,360	137	0.1%	
27	COOLING TOWER	164	3,450	370	0.2%	
28	COUPLING	1	0	34	0.0%	
29	**CRANE/HOIST**	**1,887**	**112,273**	**1,955**	**7.9%**	**112,273**
30	CURRENT TRANSFORMER	1	0	11	0.0%	
31	DEHUMIDIFIER	17	28	17	0.0%	
32	DIAL PRESSURE GAUGE	1,113	1,392	139	0.1%	
33	DOOR - ALL TYPES	978	2,660	589	0.2%	
34	DRYER - AIR	414	2,252	410	0.2%	
35	DUMB WAITER	1	0	5	0.0%	
36	**ELECTRICAL L/V/PANELS/SWG/MCC**	**3,619**	**57,250**	**3,626**	**4.0%**	**57,250**
37	**ELEVATOR**	**457**	**19,145**	**749**	**1.3%**	**19,145**
38	EMERGENCY LIGHT/EXIT	1,858	9,480	2,837	0.7%	
39	EMERGENCY SHOWER/EYEWASH	1,032	2,946	741	0.2%	
40	ENGINE/DIESEL/FIREPUMP	42	762	97	0.1%	
41	ENVIRONMENTAL CONTROL UNIT	11	21	150	0.0%	
42	EVAPORATOR UNIT	0	0	6	0.0%	
43	EXCITER	1	1	26	0.0%	
44	EXPANSION JOINT	0	0	14	0.0%	
45	**FANS - ALL**	**3,077**	**72,085**	**2,250**	**5.1%**	**72,085**
46	**FAN COIL UNITS**	**1,972**	**155,631**	**450**	**10.9%**	**155,631**
47	FILTERS	1,913	13,365	2,273	0.9%	
48	**FIRE DETECTION / SUPPRESSION**	**2,844**	**115,391**	**3,830**	**8.1%**	**115,391**
49	FIRE HYDRANT	669	10,062	617	0.7%	
50	FLOW METERS	28	155	80	0.0%	
51	FURNACE	11	9	19	0.0%	
52	GAS ANALYZER	73	18	55	0.0%	
53	GEARBOX/COOLING TWR	37	111	193	0.0%	
54	GENERATOR	487	7,751	634	0.5%	
55	H2O SYSTEM/GARDEN	0	0	1	0.0%	

	Equipment Classification	Totals				
		EQP	HRS	PM	% TOTAL HRS	
56	HAZGAS ALARM	122	6,613	154	0.5%	
57	HEAT EXCHANGER/COOLER	155	1,633	240	0.1%	
58	**HEATER - HOT H2O/GAS**	**925**	**20,136**	**506**	**1.4%**	**20,136**
59	HUMIDIFIER	122	2,250	42	0.2%	
60	HYDRAULIC POWER UNIT	0	0	48	0.0%	
61	HYDROMETER	0	0	7	0.0%	
62	ICE MACHINE/FREEZER	94	745	56	0.1%	
63	INDICATOR/DIGITAL/ANALOG	12	101	55	0.0%	
64	LIFTING/PULLING TOOLS	415	3,088	837	0.2%	
65	LIGHTNING/GROUNDING	383	9,045	192	0.6%	
66	MANIFOLD	0	0	4	0.0%	
67	**MANHOLES**	**258**	**37,751**	**54**	**2.6%**	**37,751**
68	MISCELLANEOUS	8,244	128,887	3,726	9.0%	
69	MOORING DEVICE	0	0	67	0.0%	
70	MOTOR STARTER ASSEMBLY	0	0	2,085	0.0%	
71	**MOTORS**	**1,151**	**39,744**	**3,063**	**2.8%**	**39,744**
72	O2 ALARM	138	0	198	0.0%	
73	**PACKAGE UNIT/HEAT/COOL (INCLUDING PORTABLE)**	**1,124**	**40,328**	**1,263**	**2.8%**	**40,328**
74	PIPING/VACUUM JACKETED	0	0	23	0.0%	
75	PLC	10	12	12	0.0%	
76	PNEUMATIC MOTOR	0	0	1	0.0%	
77	POWER POLE	0	0	777	0.0%	
78	**PUMP (ALL KINDS)**	**3,323**	**21,939**	**3,342**	**1.5%**	**21,939**
79	RADIOS	7	15	75	0.0%	
80	RECTIFIER UNIT	0	0	14	0.0%	
81	REFRIGERANT COMPRESSOR	0	0	9	0.0%	
82	REFRIGERANT UNIT (INCL WALKIN)	381	2,699	256	0.2%	
83	**RELAY/METERS**	**778**	**17,927**	**1,810**	**1.3%**	**17,927**
84	RHEOSTAT (MOTOR)	2	106	3	0.0%	
85	SEWAGE LIFT STATIONS	35	0	92	0.0%	
86	SHOP LIFT	183	1,298	242	0.1%	
87	SIDE WALL UNIT	0	0	525	0.0%	

	Equipment Classification	Totals				
		EQP	HRS	PM	% TOTAL HRS	
88	**SLINGS**	**1,436**	**18,026**	**57**	**1.3%**	**18,026**
89	**STEAM TRAP**	**1,084**	**23,331**	**1,365**	**1.6%**	**23,331**
90	STRAINER	78	1,862	119	0.1%	
91	**SWITCH, HV**	**1,195**	**19,291**	**1,211**	**1.4%**	**19,291**
92	SWITCH/PRESSURE/TEMPERATURE	76	440	642	0.0%	
93	TANK/OIL/H2O/HYDRAULIC	91	92	156	0.0%	
94	TEMPERATURE CONTROLLER	87	322	109	0.0%	
95	TRANSDUCER	449	14,500	32	1.0%	
96	**TRANSFORMER**	**1,984**	**34,424**	**1,956**	**2.4%**	**34,424**
97	TRANSMITTER/TEMP/PRESSURE	147	455	358	0.0%	
98	UNIT HEATER	41	28	108	0.0%	
99	UNIT SUBSTATION	929	5,201	222	0.4%	
100	UPS/BATTERIES (INCLUDING ATS)	419	10,068	274	0.7%	
101	**VALVES - MOV/CHECK/REGULATING/RELIEF**	**3,202**	**57,211**	**3,537**	**4.0%**	**57,211**
102	VEHICLES (BUS, TRUCK,CART,ECT)	1,342	16,345	675	1.1%	
103	WHEELCHAIR LIFT	0	0	8	0.0%	
104	WINDOW A/C	145	925	609	0.1%	
105	WORK PLATFORM	331	1,612	46	0.1%	
	GRAND TOTALS	**67,297**	**1,426,104**	**69,349**	79.7%	**1,136,603**
	TOTAL OCCURANCES		**105**		20.0%	**21**