Mechanical Maintenance and the Operator

Maryland Center for Environmental Training
301-934-7500
info@mcet.org
www.mcet.org

Mechanical Maintenance and the Operator

WWW 5850

7 contact hours

9 CC10 hours

This training is designed to provide operators with a greater understanding of mechanical maintenance and the effect it has on process operations. The course will identify how maintenance activities directly affect process control and the effects that poor maintenance can have on the ability to properly treat wastewater and drinking water. During the course we will discuss common tools and equipment that are utilized in effective equipment maintenance and troubleshooting to help identify items that should be in every operator's tool kit. We will also cover predictive maintenance technology and its applications to water and wastewater treatment equipment; including thermography, vibration analysis, and proper lubrication.

1. Identify common tools and equipment in every operator's tool kit.
2. Describe predictive maintenance technology and its applications.
3. Recognize proper lubrication selection, application, and analysis.
4. Identify how proper maintenance activities directly affect process control.

Agenda:

8:00 – 8:30 Predictive maintenance technology and its applications Introduction

8:30 – 9:00 Corrective Maintenance

- Main Repair
- Motor or Pump Replacement
- Impeller Cleaning

9:00 – 9:30 Preventative Maintenance

- Oil Changes
- Greasing
- Belt Tensioning

9:30 – 10:00 Predicative Maintenance

- Vibration Analysis
- Infrared Thermography
- Visual Inspections

10:00 – 10:30 Reliability Centered Maintenance

- Fail Mode
- Effects Analysis

10:30 – 11:00 Common tools and equipment in the operators' toolkit

- Hand Tools
- Power Tools
- Shop Tools
- Specialty Tools

9:30 – 10:30	Proper lubrication • Selection • Application • Analysis
10:30 – 11:30	Process control and the part maintenance plays in it • Benefits • Stand Processes
11:30 – 12:30	Lunch
12:30 – 1:30	Process control and the part maintenance plays in it (continued) • Modified Processes
1:30 – 2:30	Vibration Analysis; Infrared Inspection
2:30 – 3:30	Ultrasound; Precision Alignment • Audible Sound • Airborne Detection • Structure Borne Detection • Thermographic Inspection
3:30 – 4:00	Post-test and evaluations

Mechanical Maintenance and the Operator

James Ritter

Agenda

- Introductions / Objectives
- Maintenance Theory
- Common Tools
- Lubrication Technology
- Vibration Analysis
- Infrared Inspection
- Ultrasound
- Precision Alignment
- Post Test
- Evaluation

Purpose of This Training

- Provide an overview of maintenance practices and theory used in water and wastewater treatment
- Describe basic tools that should be part of an operators tool bag
- Review predictive maintenance technologies
- Discuss the operational impact of proper maintenance

Types of Maintenance

- Corrective Maintenance
- Preventative Maintenance
- Predicative Maintenance
- Reliability Centered Maintenance

Corrective Maintenance

- Maintenance tasks initiated as a result of the observed or measured condition of an asset or system, before or after functional failure, to correct the problem. Corrective maintenance (CM) can be planned or unplanned. Synonymous with corrective work.
- Work performed to repair an asset to operable condition
  - Main Repair
  - Motor Replacement
  - Pump Replacement
  - Impeller Cleaning

Preventative Maintenance

- Scheduled maintenance task with the goal of preventing breakdowns and failures
  - Primary drive is the preservation and enhancement of equipment reliability
- Oil Changes
- Greasing
- Filter Changes
- Belt Tensioning
- Task that increase the life of equipment and efficient operation.

Preventative Maintenance

- Maintenance should be performed on equipment as recommended by the manufacturer
- Determination needs to be made as to when the time spent doing PM task is greater then the cost of replacement
- PM Task guidelines are provided in manufacturer O&M documentation
  - Oil/Grease Types and Quantity
  - Time Intervals (weekly, monthly, annually)
  - Inspections
  - Torque specification

Preventative Maintenance

- Benefits
  - Increased equipment life
  - Reduced failures and breakdowns
  - Reduced costly downtime
  - Decreased replacement cost

Preventative Maintenance

- Who does PM?
  - Organization Specific
  - Operators and Maintenance staff
  - Operator PMs

Preventative Maintenance

- Training
- Provides the skills necessary to perform the task without introducing unnecessary defects
  - Over greasing is often worse then not enough
  - Improper tightening of packing increases wear and shortens life
  - Improper lubricants can shorten the equipment life
- Can be available from vendors, local schools, and seminars
- A training program should be developed to outline needs
- An On The Job training program should be used to cultivate skills

Predictive Maintenance

- Techniques used to determine the condition of in-service equipment in order to predict when maintenance should be performed
- Primary goal is to minimize disruption to normal operations, while allowing for budgeted scheduled repairs
  - Vibration Analysis
  - Infrared Thermography
  - Oil Analysis
  - Visual Inspection

Predictive Maintenance

- Identifies trends and provides historical data
  - Task such as oil analysis can show an increase in metals in the sample which would indicate a breakdown of internal parts
- The data captured from in-service equipment is used to perform corrective maintenance when the equipment can be taken out of service at a planned time before failure occurs
- Predictive maintenance task require skilled personnel who must be familure with the equipment, tools, and hazards of the task

Predicative Maintenance

- Benefits
- Provide increased operational time
- Results in decrease downtime
- Allows for scheduled downtime
- Allows for money to be budgeted for repairs
- Lowers need for extensive parts inventory
- The Department of Energy estimates an 8 – 12% cost savings by having a PdM program

Predicative Maintenance

- DOE also estimates
  - Reduction in maintenance cost by 25 – 30%
  - Elimination of breakdowns of 70 – 75%
  - Reduction of downtime by 35 – 45%
  - Increase in production of 20 – 25%

Reliability Centered Maintenance

- Reliability centered maintenance (RCM) is a reliability tool that is used to ensure the inherent designed reliability of a process or piece of equipment through the understanding and discovery of equipment functions, functional failures, failure modes and failure effects. In performing a RCM analysis, the RCM team uses a structured decision process to develop mitigating tasks for each failure mode identified during the analysis.
- Can be performed in the design phase of a project. Commonly performed on existing equipment to develop complete maintenance strategy to improve reliability

Reliability Centered Maintenance

- A good RCM process also addresses what should be done if there is not an applicable or effective maintenance task or redesign to address each failure mode. Here we look to reduce failure consequences' mean time to restore (MTTR) by identifying and implementing consequence reduction tasks (detailed job plans and spare parts assessment). This is not addressed as part of FMEA.
- RCM was designed to discover and asses failure modes. The facilitators are certified in a given methodology. Insuring that the facilitator has both knowledge and experience in the RCM process and has the same level of understanding and experience in maintenance techniques and methods. FMEA, in contrast is an engineering tool designed to reduce risk before an asset is installed.

Failure Mode and Effects Analysis

- Used for many years in the maintenance and repair community because of their effective and exhaustive application across many industries.
- The basic process involves a number of major steps to complete a value-added FMEA, regardless of the type or purpose of that FMEA.
  - Once a FMEA team has been established, the first step is to scope the FMEA effort
  - the team defines the interfaces of the focused FMEA effort so the effects can be identified
  - Then the major components of the FMEA focus are defined (and broken down further as needed), along with each of their failure modes, root causes, failure indicators, failure criticalities, failure probabilities and effects using both team member experiences with the FMEA focus area as well as any available failure history.

Failure Mode and Effects Analysis

- Probably the most common use of FMEA is for maintenance strategy development for a specific piece of equipment, product line, or facility
- Once the appropriate mitigation tasks have been selected, formally documenting these tasks has proven to be a key factor to a successful implementation of the tasks. This formal document is the basis for an optimal predictive maintenance (PdM) and preventive maintenance (PM) plan.
- this formal document should also include any spares or specialized training needed for personnel (operations and maintenance) to execute the maintenance plan. The more formal this document is in your organization (for instance, an ISO-certified process document), the more likely the document will be followed once implemented

Tools

- Common Hand tools
  - Plyers
  - Screwdrivers
  - Wrenches
  - Sockets
  - Allen Keys
  - Hammers
  - Knife
  - Vise Grips

Tools

- Power Tools
  - Grinder
  - Recripicating Saw
  - Impact Wrench
  - Drill
  - Impact Driver
  - Air Compressor
  - Hammer Drill

Tools

- Shop
  - Drill Press
  - Band Saw
  - Bearing Heater
  - Gear Puller
  - Porta Power
  - Press
  - Parts Washer
  - Bench Grinder

Tools

- Specialty
  - Stethoscope
  - Infrared Temperature Gun
  - Multimeter
  - Seal and Baring Seater
  - Stroboscope
  - dB Meter

Lubrication

- There is a significant cost savings that can be accomplished through optimized plant lubrication
- 1. Sump Contamination Control
  - At the time of machine installation
  - During and following lubrication installation – ongoing activity
- Product Selection
  - Improving the match-up of lubrication performance with machine and labor objectives
    - Viscometric properties
    - Surface protection technologies
    - Long term stability

Lubrication

- 3 Man Hours Per Year
  - Improved Longevity in lubricants
  - Improved delivery efficiency
    - Multipoint systems
    - Singlepoint systems
    - Things in between
- 4 Analysis Practices
  - Sample collection
  - Test slate selection, interpretation of data
  - Response to data, scheduling and follow through

Lubrication

- 5 Material Use / Waste Control
  - Leakage 80 – 90% controllable
  - Product handling – particularly drums and kegs
  - Waste generation – use the least product necessary to complete task
- 6 Knowledge Development
  - Develop an attitude of chin up value
  - Find motivated, no-nonsense change agent
  - Develop plant wide / company wide objectives
  - Empower and reward

Lubrication

Sector	Particle Induced Failure			Non-Particle Induced			Total
	Abrasion	Erosion	Fatigue	Adhesion	Fretting	Other	
Transportation	799	-	202	240	17	68	1326
Agriculture	735	54	45	104	2		940
Mining	551	117	25	15	1	17	726
Pulp & Paper	217	93	13	36	4	19	382
Forestry	101		14	25			
Power Gen	69	30		31	26	34	190
Total	2472	294	299	451	62	144	3722
Percentage by Category	82%			18%			

Lubrication

- One of the most important things an operator can do for his machinery is to make sure it is properly lubricated
- Many people believe that a lubricant is simply used to make things “slippery.”
- friction reduction, it also reduces the amount of wear that occurs during operation, reduces operating temperatures, minimizes corrosion of metal surfaces, and assists in keeping contaminants out of the system

Lubrication

- Friction is the force that resists relative motion between two bodies in contact. If friction didn't exist, nothing would ever stop moving
- If the lubricant in your equipment has not been appropriately selected with standard operating temperatures, load, speed, etc., in mind, catastrophic failure may result.
- we lubricate our machinery to minimize the resistance to movement, and as a result, minimize the amount of heat produced

Lubrication

- All lubricants start as a base oil
  - Mineral
  - Synthetic
  - Vegetable
- Mineral and synthetics are the main products used in industrial settings

Lubricants

- Mineral based
  - Developed from crude oil and different applications require different oil quality
  - Made up of four different types of molecules
    - Paraffin
      - Long, straight chain structure
    - Branched paraffin
      - Long, straight chain structure with a branch
    - Naphthene
      - Saturated ring structure and used most common for moderate temperature applications
    - Aromatic
      - Non-saturated ring structure, used for manufacturing seal compounds and adhesives

Lubricants

- Synthetics
  - Man-made fluids
    - Identical straight chained structures, similar to branced paraffin
  - Molecular size and weight are constant, where as mineral oils vary greatly
    - Provided predictable properties
- Advantage and disadvantages
  - High quality mineral based oil is made of paraffinic based oils, similar to synthetics
    - May be just as good as synthetic due to high cost of synthetic, toxicity, solubility, incompatibility, and disposal.
  - In extreme applications with high flash points, low pour points, fire resistance, thermal stability, high shear strength, or high viscosity index synthetics are preferred

Lubrication

- A lubricants viscosity is the most important characteristic to review when choosing a product
  - Viscosity is the oils ability to resist shear and flow
- Viscosity needed wil depend on the speed, operating temperature, and type of bearing, as well as type of component such as a gearbox versus a motor
- Additatives can improve the properties of viscosity
  - Rust inhibitors protect surfaces against rust by forming a thin water repelling film on the metals surface
  - Dispersants help protect components against abrasion from wear products by enveloping particles and suspending them in the oil so that they may be easily flushed and removed from the system
  - Antiwear and extreme pressure (EP) additives react with a component's surfaces to form a thin protective layer to prevent metal-to-metal contact
  - Detergents work to neutralize acids and clean surfaces where deposits may be detrimental
  - defoamants weaken the surface tension of bubbles so that they may break easily and minimize foaming

Lubrication

- Grease
  - For any given oil, the ingredients are the base oil and the additives. The only difference for grease is that it also has a thickener. This is most commonly described as "the sponge that holds the lubricant." Up to thirty percent of grease is made up of the thickener which is either a simple or complex soap. Simple soap is made up of long fibers and has a smooth, buttery texture. Examples of simple soaps are lithium, polyurea, calcium, and silica. Complex soap is made up of short and long fibers and has a more fibrous texture. Some examples are aluminum, sodium, and barium.
  - There are benefits of using a grease as opposed to oil in certain applications. Grease seals out contaminants, is better suited for insoluble solid additives like molybdenum disulfide and graphite, and has better stop-start performance because it doesn't drain away like oil, for a lower chance of a dry start. However, the thickness of grease limits bearing speed, reduces cooling of components, makes for difficult sampling and analysis, and makes it difficult to determine the proper amount of grease that needs adding. This is something that must be taken into consideration when deciding if oil or grease would be better suited for the application.

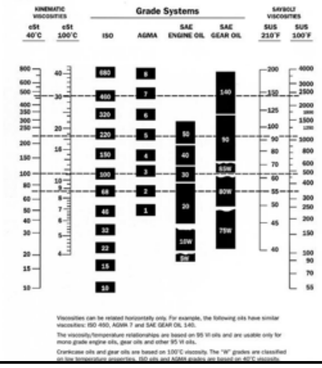


Table 6: NLGI Grease Consistency Ranges (6)	
Grade Number	**60-Stroke Penetration Range @ 25°C**
000	445 – 475
00	400 – 430
0	355 – 385
1	310 – 340
2	265 – 295
3	220 – 250
4	175 – 205
5	130 – 160
6	85 – 115

Lubrication

Ultrasound

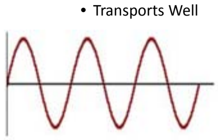
- Frequency of sound
  - Infrasound – Audible Sound- Ultrasound

Ultrasound

- Audibe Sound (Things we can hear)
  - 20Hz – 20,000Hz
  - 2,000Hz – 5,000Hz (optimal)
  - Below 17,000Hz (reality)
- Ultrasound (things we cant hear)
  - 20,000Hz and above

Ultrasound

- Ultrasound
  - High Frequency
  - Short Wavelength
  - Lower Amplitude
  - Directional
  - Quickly Attenuated
- Audible Sound
  - Low Frequency
  - Long Wavelength
  - Powerful Amplitude
  - Multi-directional
  - Transports Well



Ultrasound

- Generated by Many Things
  - Plant Machinery
  - Leaks (pressure and vacuum)
  - Electrical Faults
  - More…

Steam Traps | MCC Panels | Bearings | Couplings | Valve Leaks | Lubrication

Ultrasound

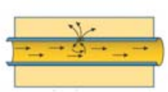
- Ultrasound moves through almost any medium
  - Gas, liquid, solid
- Two modes of detection

Airborne Detection

Structure Borne Detection

Ultrasound

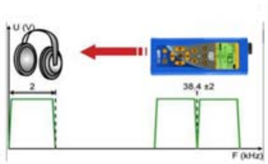
- Sources of Noises
  - Turbulence
    - Leaks in pressurized systems
    - Leaks in vacuum systems
    - Leaks in hydraulic systems
    - Leaks in steam systems
  - Friction and Impacts
    - Wear from mechanical arts
      - Couplings, gears, bearings
  - Electrical Arching
    - Faults in electric systems
      - Arching, tracking, corona discharge, rtv interference



Ultrasound

How Does It Work

- Convert ultrasound to audible sound
- Maintain characteristics of original sound
- Measure for trending
- Capture for analysis



Ultrasound

Uses in the plant

- Leak Detection
- Bearing Monitoring
- Lubrication
- Electrical Inspection
- Steam Systems
- Pump Cavitation
- Compressor Valves
- Heat Exchangers
- Hydraulic Systems
- Tightness Control

Ultrasound

- Leak Detection
- Turbulent flow at the leak site
- Produces ultrasound with pea
- Directional making it easy to p
- Oblivious to plant noise
- Is it a tenable defect?
- Is it CBM?

Ultrasound

Leak Detection Procedure

- Right, Left, Up, Down
- Leak sound increases sharply
- Adjust sensitivity and headset volume
- Use focusing tip and shielding techniques

Ultrasound

Ultrasound

- Ultrasound can be used to find electrical faults
  - Arching
  - Tracking
  - Corona
  - Special areas
    - Flow
    - Loose part monitoring

Ultrasound

- Electrical Inspection
  - Transformers
  - Switchgear
  - Relays
  - Bushings
  - Transmission Lines
  - Street Poles
  - Junction Boxes/ Circuit Breakers
  - Buss Bars
  - Capacitors
  - Insulators

Ultrasound

- Corona, Tracking and Arching
  - Corona and tracking do not generate heat
  - Corona produces a constant burbling sound
  - The ability to capture scalable data allows for comparison

Ultrasound

- Electrical Equipment Trending

Ultrasound

- Two Methods of Detection
  - Contact or airborne
  - Requires the use of correct sensor

Ultrasound

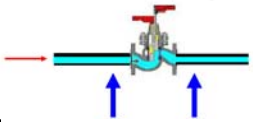
Ultrasound

Mechanical Condition Monitoring
- Rotating and Non-rotating Equipment
  - Bearings
  - Gearboxes
  - Pumps
  - Motors
  - Compressors




Ultrasound

- Valve Body Inspectio
  - Check valves for flov
    - Upstream and dowr
    - Works with any liquid or gas



Ultrasound

What make ultrasound an effective technology for condition based lubrication?

Ultrasound

Machine parts that are rubbing causes wear, temperature increase, and wasted energy

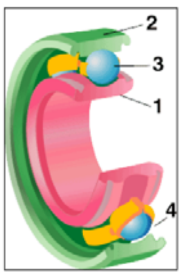
Ultrasound

How do you know when to stop greasing?

Ultrasound

Anatomy of a bearing

1. Inner Race
2. Outer Race
3. Rolling Element
4. Cage

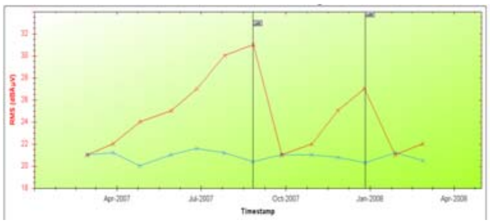


Ultrasound

Regardless of how a bearing is lubricated, friction within the bearing produces an ultrasound signature that can be detected and trended

Ultrasound

A bearing that is properly lubricated produces an ultrasonic signal that has lower intensity than a poorly lubricated bearing



Ultrasound

- Time Based
- Condition Based
- When to Grease
- How Much to grease
- Listen Only
- Digital Metering

Ultrasound

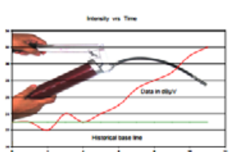
Ultrasound

Why are half shots of grease recommended as opposed to full shots?

Ultrasound

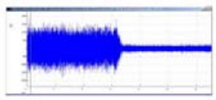
Ultrasound

When ultrasonic intensity is trended over time it is possible to predict when lubrication is needed, and how much is the optimum amount



Ultrasound

Acoustic lubrication requires a base line to be established. When intensity increases 8dBuV over the base line, small amounts of grease should be applied until the intensity returns to the historical level



Ultrasound

Ultrasound

Any point in the plant can be audited for lubrication performance manual or automatic application devices work using the same principles

Ultrasound


Picture courtesy Farval

Centralized Grease System

- Check before and after injection cycles to record difference in signal intensity
- Change means the injector is working


Monitoring auto lube injectors in a cement mill with SDT 170MD Lube Tech Kit

Ultrasound

Automatic Grease Lubricators

- After just a few minutes of installation take readings to determine a baseline. Every week recheck to trend the value a max 3dBuV change is permissible

Ultrasound

Automatic Spray System

- Air pressure is critical for performance
- Use leak detection to determine if there are leaks in the system

Thermographic Inspection

Thermographic Inspection

- Thermography is a non-destructive test method that may be used to detect poor connections, unbalanced loads, deteriorated insulation, or other potential problems in energized electrical components. These problems may lead to excess power use, increased maintenance costs, or catastrophic equipment failure resulting in unscheduled service interruptions, equipment damage, or other problems.

Thermographic Inspection

- Thermography, also called infrared inspection, is based upon the sensing of heat emitted from the surface of an object in the form of infrared radiation. Test instruments are used to detect and convert the infrared radiation into either a temperature value or a thermal image, which can be used to assess the thermal condition of the object at the time of measurement. An infrared camera is one common type of an infrared thermal imaging device.
- Energized electrical systems generate heat because of electrical resistance. The amount of heat generated is related to the amount of current flowing through the system and the resistance of the individual system components and connections within the system. As components deteriorate, their resistance increases, causing a localized increase in heat. Similarly, a poorly made connection will have higher resistance than a well-made connection, along with a higher temperature profile. Thermography may be used to detect these temperature differences.

Thermographic Inspection

- Benefits
  - The National Fire Protection Association (NFPA) estimates that ten percent of the fires occurring in manufacturing properties are related to electrical system failures, such as failure of electrical insulation, terminals, and related components.
  - failures can cause employees to be exposed to live electrical circuits, making them susceptible to serious injury or death from electrocution.
  - advantages to detecting and repairing these faults are the cost savings from energy conservation and lower outage and repair costs. High resistance in circuits causes an increase in current flow. When current flow is increased, the resulting power consumption will increase. Further, high current draw can cause critical electrical circuit components, such as fuses, circuit breakers, and transformers, to fail prematurely. These failures result in higher maintenance and repair costs, and resultant business interruptions.

Thermographic Inspection

- The Occupational Safety and Health Administration (OSHA) addresses work on live electrical components in Subpart S of the General Industry Standard. Specifically, 29CFR1910.335(a)(1)(v), requires that “Employees shall wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion.” Article 130 of NFPA 70E, Standard for Electrical Safety in the Workplace, provides details on the level of protection required based on the arc flash potential present
- A company may perform thermographic inspections in-house or hire a consultant. Because thermographic imaging equipment is complex, persons performing evaluations require special training
- The American Society for Non-Destructive Testing has developed a certification program for thermographers that can be used for training staff or evaluating consultants.

Thermographic Inspection

- Businesses with high electrical demands should have a thermographic scan performed at least annually on critical systems, such as circuit panels, switchgears, and transformers.
- NFPA 70B, Recommended Practice for Electrical Equipment Maintenance, published by the NFPA, provides a listing of maintenance and equipment testing intervals in Annex L. In addition to these recommended intervals, some conditions and circumstances may specifically warrant a thermographic scan

Thermographic Inspection

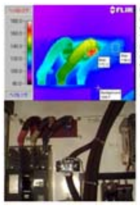
- Power Systems and Equipment
  - Power systems having electrical services greater than 120 volts.
  - Step-up or step-down power transformers onsite.
  - Power transfer circuits, such as switchgears and relays.
  - Modifications to electrical panels, power control boxes, and sub-panels.
  - Buildings with aluminum wiring.
  - Motor starter circuits.
  - High torque and heavy current draw motors.
  - Presence of high output lighting equipment, such as mercury vapor lamps.
  - Use of uninterruptible power supplies.
- Observations
  - An increase in power consumption without an increase in equipment use.
  - Reports of motors, computers, and other equipment "slowing down."
  - Dimming of lighting when other equipment is started.
  - Unexplained power surges noted in computer, processing, or building service equipment.
  - Unexplained odor of burning plastic or rubber in the area of electrical panels, wiring, or equipment.
  - Electrical equipment temperature changes.
- Property History
  - Previous occurrences of fluorescent lighting failures or frequent bulb changes.
  - Construction or repair activities that result in added electrical demand.
  - Damage to facilities from fire, flood, earthquake, or other similar disasters.
  - Previous occurrences of electrical system fires.

Thermographic Survey
Suggested Actions Based on Temperature Rise

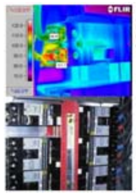
Temperature difference (ΔT) based on comparisons between similar components under similar loading.	Temperature difference (ΔT) based upon comparisons between component and ambient air temperatures.	Recommended Action
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency; warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency; repair as time permits
- - - - - -	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy; repair immediately

Thermographic Inspection

Thermographic Inspection

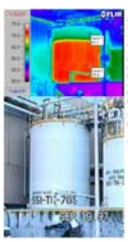


Cable to Busbar Connection
This cable to busbar connection feeding a pump is excessively hot and needs attention.



110 A Circuit Breaker
240V 110A breaker feeds LAN rooms.
Load Reading A=65 B=95 N=84
B phase exceeds 80% ampacity and temperature exceeds breaker rating.

Thermographic Inspection



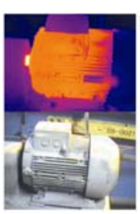
Acid Tank Levels
Infrared Thermography is a SAFE and effective way to verify, or check acid tank levels. Infrared can also be used on various other liquid, and solids tanks.

Currently the practice would be to have an operator manually go out and place a wooden stick in the tanks' to verify or check tank levels. The instrumentation department was also glad to see this capability to aid them in trouble-shooting problems with their level transmitters.

The time saving and safety aspects of doing thermography on just Acid tanks was estimated at 1000 man-hours a year and immeasurable safety gains.

Transformer
Cold cooling fins due to low oil level in a transformer.

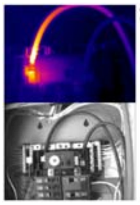
Thermographic Inspection



Motor
Internal winding problem.

Fuses
Hot fuse connection.

Thermographic Inspection



Circuit Breaker
Hot lug connection.

Liquid Storage tank
Determination of liquid level.

Thermographic Inspection

Selection of PPE by task is allowed in lieu of a flash hazard study. However, for tasks not listed in table 130.7(C)(9)(a) and for clearing times different then those listed there, a complete flash hazard analysis is required.

A selection from table 130.7(C)(9)(a):

600-volt class switchgear (with power circuit breakers or fused switches)

- CB or fused switch operation with enclosure doors closed 0
- Reading a panel meter while operating a meter switch 0
- CB or fused switch operation with enclosure doors open 1
- Work on energized parts, including voltage testing 2*
- Work on control circuits with energized parts 120 V or below, exposed 0
- Work on control circuits with energized parts >120 V, exposed 2*
- Insertion or removal (racking) of CBs from cubicles, doors open 3
- Insertion or removal (racking) of CBs from cubicles, doors closed 2
- Application of safety grounds, after voltage test 2*
- Removal of bolted covers (to expose bare, energized parts) 3
- Opening hinged covers (to expose bare, energized parts) 2

Note: Above 600 V, removal of bolted covers (to expose bare, energized parts) carries a Class 4 (scale 0 to 4, where 4 is determined the riskiest)

Thermographic Inspection

Using flash hazard analysis or task risk assessment the following table can be used to identify the correct PPE.

Class	Cal/Cm2	PPE
1	1.0 - 4.0	Cotton underwear, FR pants and LS shirt, hard hat, safety glasses
2	4.01 - 8.0	Cotton underwear, FR pants and LS shirt, hard hat, arc rated face shield or flash hood, leather gloves and shoes, hearing protection
3	8.01 - 25.0	Cotton underwear, FR pants and LS shirt plus FR coverall, hard hat, arc rated flash hood, leather gloves and shoes, hearing protection
4	25.01 - 40.0	Cotton underwear, FR pants and LS shirt plus multi-layer flash suit, hard hat, arc rated flash hood, leather gloves and shoes, hearing protection