Boiler Machinery
A Guide to Preventative Maintenance

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INTRODUCTION

COULD THIS HAPPEN TO YOU?

An extruder operates three shifts a day, seven days a week. The unit had not experienced any major problems. Suddenly, a tie rod broke and rendered the unit immediately inoperative. As a result, the extruder was out of operation for approximately one week. Since the plant was operating at full capacity, production had to be reduced approximately 25%.

What causes a loss of this type? An investigation showed that the rod had extensive metal fatigue, and improper tightening of other tie rods led to overstress of this rod. This loss could have been extensively reduced or eliminated had a preventive maintenance program been in effect. Strain gauges could have been installed on the tie rods to detect undesirable movement and stress. Frequent checks of the tie rods for proper tightness and adjustment could have been made.

WHAT IS PREVENTIVE MAINTENANCE?

Preventive maintenance is the practice of conducting routine inspections, tests, and servicing of equipment on a program basis to detect and eliminate impending problems which could cause breakdowns. The program should consist of concise instructions, measurements and operating parameters. The results of the inspection, tests and servicing should be recorded for review to establish maintenance and operating trends.

WHY BOTHER?

A preventive maintenance program is essential to the efficient operation of any machinery and equipment. Its proper use and implementation can prevent untimely breakdown of equipment and, in the long run, lower maintenance costs. Since maintenance will be optimized, greater efficiency of plant equipment will result with decreased down-time and extended equipment life. All these factors will contribute to an increase in the profitability of the operations.

IMPLEMENTATION

Implementing a preventive maintenance program is no easy task. As with all important corporate programs, full support of local management by top corporate management is essential. Corporate management must issue a policy statement which clearly defines the company's attitude and position on preventive maintenance. This support and attention by top management must be continued through follow-up, and clear lines of responsibility and communications must be developed for the program to be effective. The corporate policy statement should be clearly written so that personnel at all levels can work within the intents of the program in conjunction with the corporate policy, each individual plant must form a preventive maintenance program tailored to that plant. The program should be formally written and clearly expressed so that all personnel involved will fully understand the program.

When a policy is originally formulated, maintenance managers must be consulted to insure that the program is realistic for their respective plants and complete for all essential machinery and equipment.

FACTORS for SUCCESS

The success of a preventive maintenance program depends on several factors:

1. The program must be well organized with clearly defined responsibilities.

2. The planning and scheduling of maintenance must be realistic. If a major production machine is to be down for preventive maintenance, scheduling should be coordinated for a normal plant shutdown, etc. Proper feedback from the maintenance personnel is essential for the continued efficiency of the program.

3. Detailed records of all maintenance must be kept; and, based upon the records and feedback, adjustments should be made to develop a program that is suited to the needs of the plant. This will be an ongoing process due to changing production needs, equipment needs and personnel.

4. Constant evaluation of the preventive maintenance program will be needed to insure that it properly suits the needs of the plant.

KEY PEOPLE ARE ESSENTIAL

The key to the effectiveness of the preventive maintenance program will be, as always, the people involved. Personnel must be reliable and capable of performing the assigned tasks. They must be properly trained for performing the maintenance and must know the intent of the preventive maintenance program. As with the program itself, this training of personnel will be an ongoing process.

EVERY PLANT IS UNIQUE

Realistically, no one preventive maintenance program can apply to all types of industry, nor to all types of plants within an industry. The preventive maintenance program must be tailored to the individual plant. The needs of each plant must be recognized and the plan molded to meet those needs. The pant should be inspected for all important equipment and services. Once the equipment and services are recognized, they should be listed, identified and cataloged. Documentation can consist of cards, sheets, logs, or a combination of these. The documentation should include specific information about the object, as well as its maintenance. Manufacturers' instructions for maintenance, as well as breakdown experience, should be recorded on these documents.

THE THREE ESSENTIALS

There are three main areas of maintenance that should be emphasized in the preventive maintenance program. These are inspection, testing and servicing. Inspections include visual inspections of equipment for any signs of improper operation, such as overheating, excessive vibration, etc. Testing includes non-destructive testing, such as hydrostatic tests for boilers, etc. Certain tests and inspections may require assistance of outside contractors, who should be engaged prior to any performed maintenance. Servicing includes replacement and/or repair of equipment as needed to prevent untimely breakdown or malfunction. Consultation with the manufacturer of the various types of equipment will assist the formulation of the preventive maintenance program.

CONSIDER THIS CASE

A machine utilizes a cable tray for distribution of power to the various drives of the unit. Copper cable is used for main power distribution with aluminum cables for the individual feeders. The wire connectors, at the junction of the copper and aluminum wiring, had not been checked in over eight years of operation. A loose aluminum wire

connection arced against the cable tray shorting out the wiring of the unit. The resulting down-time cost over $500,000 in business interruption.

Had the need for a preventive maintenance program been recognized, simple periodic inspections of the electrical connections could have been made and reduced the probability of this loss ever or occurring. A preventive maintenance program will be effective only when the expertise of the maintenance personnel is fully utilized, with full top management support and follow-up.

As previously stated, no one program can apply to all types of industry or plants. The following guidelines, however, will be of some assistance to start you on the road to safe, efficient operation of your plant.

ELECTRICAL

The scheduled frequency of maintenance and inspection depends on the importance and environment of the equipment. The maintenance procedures as outlined are recommended for the average installation. Equipment in damp, hot, dusty or oily occupancies may require more frequent application.

Whenever possible, follow manufacturers suggested maintenance procedures.

CABLES AND WIRING

A. General

1. Set up an adequate testing program. Frequency depends on the importance of the circuit, its condition and the severity of service.

2. Testing Methods (see pages 39 thru 43)

   a. D-C high potential.
   b. Dielectric absorption (insulation resistance vs. time).
   c. Megger testing (insulation resistance).
   d. Infrared (thermal-vision).
   e. Power factor.

B. Semi-Annually

1. Examine wiring subject to vibration, and tighten any loose connections, supports, etc.

2. Inspect aluminum conductors for heating at terminals and splices.

C. Annually

1. Make a complete inspection of all wiring.

2. Check ampere load on all circuits.

3. Note amount and condition of temporary wiring. Remove as promptly as possible.

4. Clean and paint corroded conduit boxes, etc.

5. Support any loose wires.

6. Protect wires subject to physical damage or oily conditions.

7. Check necessary ground connections.

8. Check accessibility of wiring.

9. Check adequacy of flame proofing where necessary.

10. Check and record insulation resistance of wiring and be aware of changes over a period of time.

11. Inspect manholes of underground cables. Examine for movement, abrasion, sharp bends, insulation swelling, water accumulation, cracked jackets, corroded and weakened supports.

12. Inspect aerial cable and supports for mechanical damage.

13. Check potheads on cable terminations for leaks. Check porcelain bushings for cracking and chips. Keep surfaces clean and connections tight.

ELECTRIC PANELS

A. Monthly

Industry or corrosive atmospheres, items 1 through 7 "Annually" should be completed monthly.

B. Annually

1. Inspect and clean dust or lint with dry compressed air.

2. Remove any foreign materials.

3. Clean corrosion from fuse contacts.

4. Cover all unused conduit openings.

5. Check condition of doors, covers, gaskets, etc.

6. Check necessary grounds.

7. Check ventilation where necessary.

8. Replace oversized fuses with those having the proper ampacity. Remove all shunts.

9. Check the ampere rating of all fuses and the trip setting of all circuit breakers.

10. Be sure that panels are not exposed to rain, snow or other liquids.

11. Operate each switch a few times by hand with no load.

12. Examine all devices for missing or broken parts, excessive wear and proper spring tension.

13. Clean all copper contact surfaces.
14. Lubricate the operating parts of all switch mechanisms where necessary.
15. Tighten all bolted bus connections in accordance with manufacturer's torque specifications.

C. Semi-Annually

1. Check cartridge fuses for signs of overheating and replace when necessary.
2. Check fuse clips for spring tension and clean contact areas.
3. Check conduit connections to insure proper grounding.

SWITCHGEAR

A. General

1. Annual maintenance inspections are minimal.
2. Environmental or operational conditions may warrant more frequent inspections.
3. Infrared scanning is recommended to detect hot spots, loose connections, overloaded circuits etc.
4. After each fault interruption check unit and replace damaged parts.

B. Daily

1. Listen for unusual noises.
2. Check for overheating.

C. Weekly

Examine indoor enclosures for signs of moisture or water.

D. Annually

1. Keep interior clean and free of any dust or accumulation of foreign materials.
2. Check interior surfaces for moisture.
3. Check ventilation.
4. Check all insulating members for evidence of cracking.
5. Check high voltage switchgear for corona (white or gray powdery residue).
6. Check for thermal damage caused by exposure to excessive temperatures.
7. Check and tighten loose connections.

MOTOR CONTROL EQUIPMENT

A. General

The proper cleaning frequency depends upon the operation and surrounding conditions.

B. Weekly

Inspect and clean if equipment operates many times a day.

C. Monthly

1. Inspect copper arcing tips. Dress as necessary.
2. Clean and tighten all connections and lubricate bearings.
3. Check level and condition of oil (If used—could be dry).
4. Keep covers closed and latched and enclosures tight.

D. Annually

1. Clean copper contacts and renew when proper contour cannot be maintained.
2. Remove deposits from arc chutes and barriers.
3. Remove and replace barriers before they are burned through.
4. Check contact pressure and alignment.
5. Check controls for undesirable grounds.
6. Replace frayed or worn shunts.
7. Check fluid in oil dashpots.
8. Check bus-bar support insulators and keep clean.

E. Every Two Years

Check settings and test all automatic tripping units. Test for operation including tripping mechanisms.

CIRCUIT BREAKERS

A. General

1. After every automatic operation during fault conditions inspect breaker and test condition of oil and contacts of important breakers.
2. Inspection frequency may vary according to number of operations and condition of oil.

3. Check adequacy of interrupting capacity whenever changes are made that would increase the available short circuit current.

OIL CIRCUIT BREAKERS

A. Annually

1. Perform complete inspection and overhaul.
2. Test oil.
3. Thoroughly clean all parts inside and out. Lubricate those parts requiring it. Give particular attention to operating and tripping mechanisms and bushings.
4. Check contact alignment and adjustment.
5. Dress slightly rough places on contacts with sandpaper or a fine file.
6. See that lift rods are not warped or cracked.
7. See that latches and triggers are properly adjusted and not badly worn or corroded.
8. Inspect flexible shunts, if any.
9. Examine main current paths for evidence of overheating.
10. Check pins, bolts, nuts, and general hardware. Tighten and replace if necessary.
11. See that auxiliary switches are tightly mounted and contacts are in good condition.
12. Check control wiring for loose connections.
13. Check settings for auto tripping units and test their operation.
14. Check reliability and adequacy of circuit breaker, tripping current source.
15. Lubricate bearings, gears, etc.

AIR CIRCUIT BREAKERS

A. Annually

1. Clean the arc quenching or de-ionizing mechanisms.
2. See that arc chambers are properly aligned and securely fastened.
3. Perform complete inspection and overhaul.
4. Thoroughly clean all parts inside and out. Lubricate those parts requiring it. Give particular attention to operating and tripping mechanisms and bushings.

5. Check contact alignment and adjustment.

6. Dress slightly rough places on contacts with sandpaper or a fine file.

7. See that lift rods are not warped or cracked.

8. See that latches and triggers are properly adjusted and not badly worn or corroded.

9. Inspect flexible shunts, if any.

10. Examine main current paths for evidence of overheating.

11. Check pins, bolts, nuts, and general hardware. Tighten and replace if necessary.

12. See that auxiliary switches are tightly mounted and contacts are in good condition.

13. Check control wiring for loose connections.

14. Check settings for auto tripping units, and test their operation.

15. Check reliability and adequacy of circuit breaker, tripping current source.

16. Lubricate bearings, gears, etc.

ELECTRIC MOTORS

A. Weekly

1. Open-frame motors in dusty or linty locations should be cleaned with vacuum equipment unless designed for cleaning with low pressure compressed air. Air should be clean, dry and less than 30 psi.

2. Check oil level sleeve bearings and condition, of oil rings.

3. Check the bearing temperature.

4. Inspect motor surroundings for water, oil, steam, dirt, dust and any loose objects.

5. Observe motor for vibration and noise.

6. Motors with commutators or slip rings should be checked for excessive sparking. Also check commutator for high or loose bars or roughness. Examine brushes for excessive wear and condition of holders. Collector rings should be clean and smooth with no scoring or pitting.

7. See that lift rods are not warped or cracked.

8. See that latches and triggers are properly adjusted and not badly worn or corroded.

9. Inspect flexible shunts, if any.

Examine main current paths for evidence of overheating.

B. Semi-Annually

1. Drain, wash out and renew oil in sleeve bearings.

2. Check grease in ball and roller bearings. Bearings sealed for life require no additional lubrication.

3. Check motor amperes.

4. Check motor hold-down bolts, end-shield bolts, pulleys, couplings, gears, journal keys, set screws and alignment.

C. Annually

The following pertains to open-type motors larger than 500 HP.

1. Dismantle, clean and overhaul unless operating in a very clean environment.

2. Clean foreign accumulations on windings and air passages.

3. Check all electrical connections for tightness.

4. Check the condition of coil insulation and examine all windings.

5. Check bearing wear and rotor clearances.

6. Clean out and renew grease in all ball and roller bearing housings.

7. Measure insulation resistance by the dielectric absorption or high potential test method.

8. If varnish has deteriorated, windings should be re-varnished in accordance with manufacturer's recommendations.

D. Every Three Years

Totally enclosed motors over 500 HP should be dismantled, cleaned and overhauled as recommended (Items 1 through 8) for open motors.

E. Every Five Years

Totally enclosed motors over 500 HP may have overhaul inspections extended if the environment is clean and dry, the motor properly used, and bearings maintained.

STORAGE BATTERIES

A. General

1. Adequate ventilation should be provided for all battery storage areas to prevent hydrogen accumulation.

2. Inspect battery terminals to make sure that they are clean, tight, and free of corrosion .
3. Remove any dust or dirt accumulations on top of cells and keep them clean and dry.

4. Check level of electrolyte.

C. Monthly

Check and record specific gravity and voltage of the pilot cell on each battery or group of cells.

D. Quarterly

Give the battery an equalizing charge to ensure that it is fully charged.

E. Semi-Annually

1. Check specific gravity and voltage of each individual cell. Uneven cell voltages and specific gravity indicate trouble or approaching failure.

2. Check ventilation in the area where the battery is located.

AC GENERATORS

A. General

1. Peaking units may require more frequent inspections than base-load machines.

2. Qualified personnel or a manufacturer's representative should conduct internal examinations.

3. A complete dismantle inspection, supervised by the manufacturer, and should be completed after the first year for units 2500 KVA and above.

B. Daily

Visually inspect collector rings and brushes for sparking, dust accumulations, or vibration.

C. Weekly

1. Blow off excessive dust from collector ring insulation and brush rigging.

2. Check brushes for freedom of movement, excessive wear, pressure and alignment.

3. Check collector ring for smoothness of operation.

4. Inspect the lube oil system for possible leaks, excessive vibration and temperature.

D. Annually

Measure insulation resistance by the dielectric absorption or high potential test method.

E. Every Three Years (Totally Enclosed Recirculating)

1. Dismantle the generator for a careful inspection.

2. Clean the stator and field windings. Re-varnish stator coils where required.

3. Check stator and field windings for looseness in slots, tightness of slot wedges. Inspect condition and tightness of blocks and spacers and twine lashings. Check for tape separation and evidence of damage to the insulation due to corona discharge.

4. Examine rotor-retaining rings and slot wedges for signs of movement, overheating and cracking.

5. Check the bearings.

6. Check collector rings, brushes and brush holders.

7. Check vibration of machine before and after each overhaul.

8. Service the exciter.

9. Test the insulation resistance of the rotor and stator windings.

10. Following a satisfactory insulation-resistance test, make a dielectric absorption, over potential or insulation power factor test.

11. Carefully inspect the oil lines, steam lines, valves, fittings, and other hot surfaces of the turbine.

12. Inspect all oil lines for the generator and eliminate all leaks and vibration. Inspect connections for gauges and similar accessories.

F. Unscheduled Shutdown Inspections (All Types)

Steps 1 to 8 below should be performed at each major shutdown. If a dismantle inspection has not been made within twenty-four months, follow all steps.

1. Clean collector insulation thoroughly.

2. Check insulation resistance of the collector ring and the rotor winding.

3. Determine if collector rings are cylindrical and running true.

4. Clean inside of brush holder boxes.

5. Inspect air filters and clean or replace.

6. Check gas or air coolers for effectiveness. Keep outer heat-transfer surfaces of cooler tubes clean, and check drains for signs of leaks.

7. Check hydrogen-cooled machines for leakage by observing the ability of the system to maintain the gas pressure or by an approved combustible gas indicator.

8. Remove end shields and rotor and check stator winding for oily deposits and corona. Clean winding if necessary and inspect insulation and connections. Check bracing and cording for looseness.

9. Check gas passages and remove any obstructions.

10. In liquid conductor-cooled machines, check all connections, hose, and piping for leaks.

11. Inspect armature core, finger plate, and structural parts for hot spots.

12. Examine rotor for movement or distortion of field coils, blocking of end turns, dirt in ventilating ducts, loose wedges, and local hot spots on rotor surfaces between the retaining ring wedges and rotor body.

13. Examine stator lead bushings for cracks, loose parts and oil leakage; clean thoroughly.

14. Inspect fan blades for cracks.

15. Test retaining ring for cracks by means of ultrasonic detection, liquid penetrant, or by the magnetic particle method.

16. At each major overhaul, dismantle the hydrogen seals and clean seal oil grooves and holes. Check the wearing surfaces of the seal ring and shaft for alignment and wear. The seal oil and vacuum pumps should be dismantled and carefully inspected at this time.

17. Check the bearing assembly for tightness and correct alignment.

18. Test all gas-control equipment and the alarm system.

19. Remove all loose dust with a vacuum cleaner. Remaining oil or dirt should be removed by wiping exposed surfaces with clean cloths.

20. Inspect windings for evidence of deterioration.

DC GENERATORS (ROTARY CONVERTERS)

A. Weekly

Inspect bearings, commutators, brushes and brush holders.

B. Check insulation resistance.

C. Every Two Years

1. Check bearings and air gaps on sleeve-bearing units.

2. Recondition brushes, commutator, brush rigging and slip rings.

3. Clean windings and re-insulate or re-varnish if conditions require.

4. Examine rotor-band wires for corrosion or looseness.

5. Check rotor coils, washers, and coil braces for looseness or mechanical defects.

INDUCTION VOLTAGE REGULATORS

A. Annually

1. Service the external operating mechanism.

2. Measure the insulation resistance of the windings.

3. Test the dielectric strength of the oils (If lower than 22 KV recondition or replace).

B. Every Five Years

Conduct a careful internal inspection.

RELAYS

A. Daily

Observe indicating targets.

B. Semi-Annually

Inspect relays and condition of contact.

C. Annually

1. Check contacts and replace if necessary.
2. Inspect bearings for wear.
3. Check calibration and operate to determine if relays will function as needed under fault conditions by setting up artificial conditions under simulated loads.

LIGHTNING AND SURGE PROTECTIVE EQUIPMENT

A. Annually

1. Inspect and clean all exposed insulation surfaces on lightning arresters and capacitors.
2. Check line and ground leads for damage. Clean and tighten connections.
3. Test resistance of the ground connection. Resistance should be five ohms or less.

TRANSFORMERS

A. General

1. A D-C high potential test should be scheduled whenever internal trouble is suspected.
2. If a transformer has handled severe overloads or there is indication of internal trouble, it should be inspected as soon as possible.
3. The need for spares depends on importance of the process or production served repair time and replacement lead time.

B. Daily

Listen for unusual noises.

C. Weekly

1. Readings of load and voltage should be recorded unless continuous chart readings are taken.
2. Check liquid level on liquid-immersed units.
3. Check ambient temperature.
4. Check inlet and discharge cooling-water temperature for water-cooled units.
5. Check temperature of ingoing and outgoing cooling air for dry-type.
6. Check temperature of oil entering and leaving the heat exchanger for a forced oil-cooled unit.
7. Check pressure-vacuum gauge on sealed type units.
8. Check any pumps and fans for proper operation.
9. Investigate the cause of unusual noise.

D. Monthly

1. Check the ampere load on important transformers if changes have been made in power consumption.
2. Clean dirt and dust from exterior.
3. Check breather for any restrictions.
4. Check protective alarms such as temperature indicators.

E. Quarterly

1. Check relief devices and relays for leaks at gasket joints and cracks in diaphragms. Look for rust in pipes and evidence of moisture.
2. Check ground connections.
3. Test insulating liquid if unit is water-cooled.
4. Complete an external inspection on self-cooled and air-cooled units:

   a. external damage
   b. deterioration
   c. leakage
   d. accumulation of foreign deposits
   e. corrosion
   f. clean and test bushings
   g. check ground connection

F. Semi-Annually

1. Complete an external inspection on liquid-immersed and gas-cooled dry-type units:

   a. external damage
   e. corrosion

b. deterioration

c. leakage

d. accumulation of foreign deposits

f. clean and test bushings

g. check ground connection

2. Check water pressure and flow for water-cooled units.

3. Check tap changers and load ratio control apparatus when provided.

4. Make an internal inspection on self-cooled and air-cooled dry-type units larger than 50 KVA and more than 600 volts.

   a. Check top and bottom ends of windings.

   b. Check bus bars.

   c. Check bushings.

   d. Inspect and clean insulators and terminal boards.

G. Annually

1. Analyze water for scale, corrosive properties, etc. for water-cooled units.

2. Service any pumps and fans by cleaning and overhauling.

3. Check ground connection resistance. Resistance of ground should be five ohms or less.

4. Check and clean lightning arrestors.

5. Clean, test and recalibrate relays.

6. Fuses

   a. Clean all insulators and inspect for damage.

   b. Replace badly pitted or burned contacts. Check pressure and alignment.

   c. Check expulsion fuses for mufflers to restrict gas discharge.

   d. Check latch to be sure fuse assembly is firmly locked in when closed.

   e. Check size of fuses and adequacy of interruption capacity.

7. Test insulation liquid for acid, moisture, color, gas and dielectric strength.

8. Insulation Test

   a. Insulation Resistance

   b. Dielectric Absorption

H. Five Years

1. Make an internal inspection on liquid-immersed units.

   a. Check internal connections and check for evidence of moisture and heating.

   b. Check surfaces of coils for dirt and sludge. If necessary, lift core and clean core coils and inside of the case.

I. Ten Years

Make an internal inspection on gas-cooled dry-type units.

MECHANICAL

The scheduled frequency of maintenance and inspection depends on the importance and operating procedures of the equipment. The maintenance procedures as outlined, are based on equipment operating within manufacturer's specifications and in a clean environment.

ENGINES:

A. Daily Program:

1. Observe the water temperatures, exhaust temperatures, load condition, lubricating oil temperatures, and pressures, fuel oil pressure and fuel gas pressure, starting air and control air pressure, and air inlet manifold temperature and pressure.

2. Check the engine oil level, governor oil level, water level in standpipe, and fuel oil supply.

3. Lubricate all linkage and exhaust valves every 48 hours or as necessary to prevent sticking. Do not over lubricate!

4. Turn handles on lubricating and fuel oil strainers (if cleanable type).

5. Drain moisture from air tanks

B. Monthly or every 600 Hours:

1. Clean the air filters (as indicated necessary by amount of dirt in air), lubricating oil strainer, and lubricating oil filter(as indicated necessary by amount of dirt in air).

2. Check the overspeed shutdown device, condition of zinc plates (if any) in heat exchanger and oil cooler, valve tappet clearance, fuel injection nozzle opening pressure and spray pattern, and crankcase (inspect bottoms of piston skirts for sludge or evidence of blow-by, feel cylinder walls for scoring, and check all bolts for tightness)

3. Remove cover plates and inspect the conditions of cams and rollers.

4. Obtain complete analysis of the lubricating oil and change if condition is below requirements .

C. Semi-Annual or every 3600 Hours:

1. Adjust chain tightness.

2. Check the main valve and fuel injection tips.

3. Measure and record compression pressure.

D. Annual or Every 8000 Hours:

1. Main Valves - check condition of the main valves on one or two cylinders. If the condition warrants, check remainder of valves and recondition if necessary.

2. Crankshaft - check the shaft alignment by the crankshaft web deflection readings.

3. Turbocharger - clean and inspect per manual instructions.

4. Turbo coolers or After coolers - clean and inspect per manual instructions.

5. Breathers - clean all cylinder heads and crankcase breathers. Clean element in fuel oil or kerosene. Blow dry before assembly.

6. Inspect the main and connecting rod bearings. Remove and inspect the shells and shims of the second main bearing from the flywheel end after an initial 8000 hours of operation. This should be done even though interim investigations listed below indicates no cause for concern. When the shells are removed from any bearing, it is recommended that the journals be examined for cracks by the "dye-check" method. The areas around the holes and the fillets at the ends of the journal should be examined very closely. The manufacturer representative should be consulted if there are any doubts regard bearing conditions. Interim inspections, as noted below, should be made to detect possible failures and to avoid non-scheduled maintenance and downtime.

    a. An examination of the lube oil strainers and filters for metal particles should be made. If metal particles are found, proceed as per step B below;

    b. A laboratory analysis of used lube oil samples should be made to determine metallic content quantitative and qualitative.

    c. If connection rod bearings are deteriorating, a periodic examination of the inner side crankcase doors and of interior ledges where oil, thrown off by the cranks, may deposit metal particles should be completed.

        1.) The examination should also include an inspection of the surfaces of the main bearing area, at the cap sides and below the bearing saddle.

        2.) Any metal particles, migrating from a main bearing, may also wash down the wall under the saddle. If shell conditions are very bad the flakes and granules will be found at the base of the wall.

        3.) When the oil is changed the entire crankcase floor should be examined for metal particles.

        4.) When the sump is full and a check below the saddles is desired, a rod fitted with a soft cloth or small swab can be used to examine the deep areas.

d. Any departures from normal good crankshaft alignment within the engine, which is really a check of bearing attitudes and relative elevations, is another indication of probable bearing trouble. But, bearing surfaces may be well on the way toward critical condition without a noticeable change in alignment.

e. Sometimes, in the absence of metal particle findings, the "jack" method of checking bearing clearances will disclose bad bearing conditions. Simple removal of shims to reduce clearance is not always the correction. An examination of both upper and lower shells and of the shims, plus measuring the "side" fit of the cap in its saddle should be included. The base may have spread because of poor foundation support or loose tie-rods. Thus, the "oil" clearance horizontally will be wide and the vertical clearance will be lessened, perhaps to or near interference.

STEAM TURBINES

A. General

1. A complete warranty dismantle inspection by the manufacturer within the first year of operation.

2. A complete dismantle inspection should be made as follows:

a. Every 25,000 operating hours or five years for units operating less than 8,000 hours per year and more than eight starts per year.

b. Every 40,000 operating hours for units operating at least 8,000 hours per year and less than eight starts per year.

c. Every 12,000 operating hours or three years for all other units.

3. The frequency of any tests should be increased if operating experience indicates more frequent tests are required.

4. Records should be kept and include operating hours, all repairs, tests, and other important data.

5. Manufacturer's suggested operating procedures should be followed for oil systems, temperatures, vibration, etc.

B. Weekly

Test units equipped with throttle valve stem, reheat stop valve, and interceptor valve stem exerciser.

C. Monthly

Check:

a. Overspeed trip.

b. Low bearing oil pressure trip.

c. Low vacuum trip.

d. Thrust bearing oil trip.

e. Test lubricating oil for contamination.

Semi-Annually

1. Test overspeed trip mechanism by overspeeding. If continuous operation test annually.

2. Test solenoid trip initial pressure regulator thrust bearing trip and auxiliary governor while unit is out of service for overspeed tests.

3. Turbines not equipped with exercisers for simulating should be tripped by actual overspeeding test every ninety days to check the installed independent overspeed trip devices.

E. Annually

1. Inspect speed governor system and replace any worn parts. Clean and lubricate.

2. Annual inspection should include stop valve assembly, bearings, oil system, and access openings should be visually examined.

F. Dismantle Inspection

1. Bearings—Examine for heating, cracks, scoring, wear between oil ways.

2. Blading — Examine for rubbing, cracking, corrosion and erosion, cleanliness and secure, general condition. Check and record axial and radial blade clearance.

3. Shrouds—check for tightness, wear, corrosion, cracking, and erosion.

4. Coupling—Examine for secureness and condition of fit, lubrication, gear wear and alignment if applicable and make dye penetrant test of bolts.

5. Diaphragms—Examine for cracks, check carbon and labyrinth packing.

6. Drains—Examine drains for all stages.

7. Foundation—Examine for deterioration, cracks, settling, penetration of oil, loose foundation bolts.

8. Governor—Note wear of latches, triggers, plungers, springs, etc. Check for cleanliness, examine operating cylinder walls, piston and piston packing

9. Nozzles—Examine for wear, rubbing, corrosion, erosion, cracking and cleanliness.

10. Lubricating System—Examine casing, gears, nuts, examine piping for loose fits, cleanliness of complete system, cooling coil, screens and baffles.

11. Piping—Examine inlet and exhaust for flexibility, excessive strains and security, proper over-pressure protection.

12. Valves—Examine valve seats; check to see that stems turn freely; check packing, etc.

13. During Dismantle:

    a. Visually examine all parts.
    b. Pressure-containing parts-check by magnetic particle or dye penetrant.
    c. Welded Joints—Check by ultrasonic.

d. Bolts—Subject to vibration or high heat—check by magnetic particle or ultrasonic.
e. Rotors—Check ultrasonically.

WATER TURBINES

A. General

1. Annually check wicket gate and runners.

2. Conduct Dismantle inspections every two to three years. Items such as the blades and bearings should be thoroughly inspected.

3. Corrosion and build-up of the blades should be checked, also, any other adverse conditions.

4. Records should be kept of all maintenance including inspection and testing, replacement of parts, etc.

HYDRULIC PRESSES

A. General

1. Hydraulic presses are subject to wear, shock, cyclic loading, thermal stresses and breakage. In general, they should be thoroughly checked from two to six times a year, depending on the amount and type of service. This should include a check of alignment, with no deviation from installation tolerance. Rod stretch should be even and platens should be parallel to the surface of the rams. For these checks, trammels, inside micrometers, leads, and ultrasonic techniques are used.

2. Flange bolts or connections to flanged fittings on accessories should be tightened with a torque wrench to insure tightness without overstressing.

3. Pressure relief devices and safety shut off valves should be carefully inspected and their reliability ascertained.

4. The press frame should be inspected for cracks and broken pieces. Hold-down bolts should be checked for looseness and fracture.

5. All column or tie rod anchor nuts should be frequently checked for tightness and platens examined tor cracks and defects.

6. Ram adjusting screws and bolts which are more subject to fatigue than other parts of the press should be examined for fatigue cracks. Check magnetically, ultrasonically, or by the dye penetrant method.

7. To prevent damage to either the main tie rods or to the press structure on heavy-tonnage presses, i.e. 500,000 tons, an automatic bonded filament type strain gauge protective system should be used.

8. Check oil frequently, change and clean sump in accordance with manufacturer's specifications.

9. Limit switch accuracy should be determined.

B. Annually

1. Check main cylinders and tie rods for cracks, using the ultrasonic or dye penetrant method.

C. Every Two Years

1. Overhaul all oil pumps.

RECIPROCATING COMPRESSOR

A. General

1. It is recommended that the follower plate bolts, crank counter-weight connecting-rod bolts be replaced about every five years or so necessary.

2. Establish a regular inspection and cleaning program to prevent formation of excessive deposits in the compressor system. Include cylinders, discharge valves, air piping, water jackets, intercooling and aftercooling, receivers and air filters.

3. Blow out receivers, aftercoolers and piping low points regularly to remove oil residues and sludge.

4. Manufacturer's specifications should be followed with regard to lubrication, vibration, etc.

B. Annual

1. Open and inspect cylinders annually or every 8,000 operating hours.

2. Check all items subject to wear and tear such as suction and discharge valves, controls, etc.

C. Three Years

1. Provide a complete dismantle inspection.

a. Remove piston from cylinders.

b. Remove bearings for examination.

c. Check for fatigue cracks. Attention should be given to those parts where there is a likelihood of fatigue cracking. Where there is any doubt, parts should be examined by dye penetrant or magnetic particle and if the need for further examination is indicated, radiographic or ultrasonic may be necessary.

d. Piston rod fractures are a problem and the threads where the rod is screwed into the piston or cross head should be checked using the above-mentioned methods as necessary.

CENTRIFUGAL COMPRESSOR

A. General

1. Establish a regular inspection and cleaning program to prevent formation of excessive deposits in the compressor system. Include cylinders. discharge valves, air piping, water jackets, intercooling and aftercooling, receivers and air filters.

2. Blow out receivers, aftercoolers and piping low points regularly to remove oil residues and sludge.

3. Dismantle inspections should follow the manufacturer's recommendations. If not available, a complete dismantle should be conducted every 3 years. Inspection should include items such as those mentioned under Steam Turbines.

   a. Lubrication Systems

   b. Turbine Blades

   c. Alignment

   d. Thrust Bearings

4. During dismantle inspections non-destructive testing should be conducted as mentioned under Steam Turbines.

5. Start-UP and Shut-down procedures should be adhered to.

B. Annual

1. Inspect bearings for wear, lubrication system, shafts, couplings, etc.

CLUTCHES AND COUPLINGS

A. General

1. Spare parts should be stocked for components with lengthy replacement time.

2. Manufacturer's instructions for maintenance and lubrication should be followed when available.

B. Weekly

1. Where feasible, the inlet and outlet cooling water temperature and pressure should be checked and recorded for electric couplings and magnetic clutches.

C. Annually

1. Check for wear, alignment of unit, and tightness of components.

2. Flush and clean cooling passages.

3. Remove inspection covers and examine gears for wear and alignment.

DIER ROLLS ON PAPER MACHINES

A. General

1. Check regularly to assure the condensate is being removed from all diers.

2. Operator should check the machine at regular intervals for the following: leakage of drier rolls, noisy gears, lack of bearing lubrication, any movement of machine frame, water logged or noisy driers,

pressure and temperature charts are recording properly, maximum allowable working pressure is not exceeded .

3. When taken out of service, the driers should be rotated for a cooling off period without the emission of steam for approximately the equivalent time of the warming-up period.

4. All drains on the steam supply header, branch lines and secondary headers supplying the driers should be opened to permit the removal of water during shutdown.

B. Weekly

1. Make a close check of each dryer for audible evidence of loose internal parts and carefully inspect for cracks, leaks, and excess bearing wear.

2. Check drive gears for proper mesh and alignment.

C. During Scheduled Shut-downs

1. Inspect condensate siphons, making sure they are intact and in proper position.

D. Quarterly

1. Test and record safety valve operation.

E. Two Years

1. Inspect all condensate siphons.

FLY WHEELS AND PULLEYS

A. Annually

1. All parts of a wheel should be hammer tested and closely inspected with the aid of a good light giving particular attention to characteristic weak spots. Use one of the nondestructive test methods to check for cracks (see page 31).

2. If looseness of the wheel on its shaft or movement of any part is suspected, apply a hard quick drying varnish or enamel along the area where the two surfaces join. After the coating is dry and the wheel is operated. any movement will usually be indicated by cracking of the coating.

3. Use a strobe light to help check for flaws, cracks, at rotational speed.

4. If over-speed devices are used, perform necessary maintenance and check periodically for proper functioning.

5. The maximum allowable rim speeds of all wheels and large pulleys in a system of line shafting should be calculated and recorded. A check should be made to make sure that pulleys in use are operating at safe speeds.

VACUUM PUMPS

A. General

1. Completely dismantle every three years.

a. Check bearing clearances.

b. Check lobe clearances.

c. Check proper gear mesh.

d. Check shaft, gears, etc. for cracks. Suggest dye penetrant.

e. Check lubrication. Follow manufacturer's specifications.

PUMPS

A. General

1. A principle used in scheduling complete overhauls is that pumps need not be opened for internal inspection unless factual or circumstantial evidence indicates it is necessary. This does not hold true it there are corrosion or erosion problems or reduced pump capacity.

B. Daily

a. Check bearing temperature.

b. Check packing for sufficient leakage to cool and lubricate packing; excessive leakage is unnecessary and wasteful.

c. Check pressure gauges and flow meters (if installed) for proper operation conditions.

d. Promptly investigate unusual noises or sudden change in pump's running sound.

C. Semi-Annual

a. Inspect packing box.

b. Clean and oil gland nuts and bolts.

c. Verify alignment of pump and driver.

d. Bearings

1. Oil lubricated bearings — drain and refill with new oil.

2. Grease lubricated bearings — check grease for correct consistency, amount and cleanliness.

D. Annual

a. Bearings should be opened and inspected after they are thoroughly cleared.

b. Packing should be removed and shafts, or shaft sleeves, should be checked for wear.

c. Disconnect coupling and check vertical shaft movement and bearing end play.

d. After pump is reassembled, install new packing in accordance with the manufacturer's recommended procedures.

GEAR SETS

A. General

1. Service lubricated couplings according to manufacturer's instructions.

2. Do not disturb anti-friction bearings unless they are giving trouble.

B. Daily

1. Monitor for lubrication, noise and temperature.

C. Semi-Annually

1. Take vibration readings at least two times a year. Units that are expensive or important to production, without spares, should be tested at least three to four times a year. Tests should also include driver and driven object.

2. Oil in large gear sets (driven by units 500 hp or over) should be spectrographically tested.

D. Annually

1. Dismantle to examine ^for bearing wear, gear wear, gear mesh and alignment, cleaning of lube oil system and filter replacement.

2. Check shaft alignment.

E . Two Years

1. Examine sleeve bearings every two years unless conditions warrant more frequent inspections.

AIR CONDITIONING SYSTEMS

A. During Winter Shut-down

1. Carefully inspect compressor bearings. Measure the seal gap in thrust bearings when unit is new and re-measure each year to check for excessive wear. Excessive wear (greater than 0.005 inches per year) should be promptly investigated.

2. Check the oil carefully and renew before spring start-up. Drain oil from the seal oil reservoir, atmospheric float chamber and main oil sump and replace it with new oil after service operations have been completed.

3. Make a thorough check for leaks and repair if necessary. The most likely places are around the cooler ruptured disc or relief valve, the cooler condenser expansion joint, suction damper seal, low refrigerant cut-out bulb in the cooler, and valves, flare and gauge connections in the purge.

4. Inspect the purge thoroughly for tightness of all connections. Make a leak test and an operational test.

5. Inspect electric dryers. Check starter contacts for burning and replace if necessary. Check for loose connections and starter operation.

6. Clean motors of foreign material. On variable speed motors, inspect the drum controller for smooth operation. Check the resistance element for loose connections.

7. Check shaft journal bearings and thrust bearings for wear and proper clearance. Examine starter motor winding insulation.

8. Check operation and setting of all safety controls. This includes condenser high pressure cut-out, low refrigerant temperature cut-out, purge high pressure cut-out, low chilled water temperature cut-out, low oil pressure switch. Inspect operating controls such as the chilled water controller. Inspect and clean all thermostats, hydrostats and relays. Check for proper calibration. Examine sequence of operation of control instruments and operators such as damper motors and chilled-water valves.

B. On a Regular Basis as Necessary.

1. Clean or replace filters.

2. Perform shut-down and start-up inspections on condensers and cooling towers and check frequently for excess noise on vibration.

3. Obtain specific water-treatment advice from a water-treatment specialist since the major part of preventive maintenance on cooling towers and evaporative condensers is a good water-treatment program.

FANS AND BLOWERS

A. General

1. The scheduled frequency of maintenance and inspection depends on the importance of the fan and the environment it operates in. The manufacturer's suggested maintenance procedures and schedule should be followed if available.

B. Weekly

1. Check cleanliness of filters and general area.

2. Check dampers for proper operation.

3. Monitor bearing vibration.

4. Test safety and/or alarm devices if so equipped.

C. Monthly

1. Check gear box oil level if applicable.

D. Quarterly

1. Check v-belts for condition and tension.

2. Check and tighten all bolts, nuts, and fasteners.

E. Semi-Annually

1. Conduct lubricating oil trend analysis and change if necessary.

2. Inspect for abrasive erosion, corrosion and deposit buildup.

3. Grease anti-friction bearings. If oil bath type, change oil if operating under adverse conditions.

4. Check axial, horizontal and vertical vibration.

5. Check coupling, shaft alignment and clearance between stationary and moving parts.

F. Annual

1. Conduct complete dismantle inspection on large important units.

2. Change anti-friction bearing oil, when operating in a clean environment.

3. Inspect and thoroughly clean unit.

4. Check:

   a. All bearings and seals.

   b. Coupling wear.

   c. Instrumentation.

   d. Lubrication systems.

   e. Gears.

5. Using one of the non-destructive testing methods, check blading, face plate junction areas and all welds.

PRESSURE VESSELS

PRESSURE VESSEL

A. General

1. Pressure vessels are generally designed and fabricated for a specific service and should be so used, following the manufacturer's suggested operating and maintenance procedures. Pressure, temperature, corrosion and cracking should be strictly controlled and monitored.

2. This section includes air receivers, heat exchangers, etc.

3. Repair and clean as needed, based on previous records and inspection.

4. Periodic thickness checks should be conducted where there is a possibility of corrosion or erosion.

B. Weekly

1. Observe physical conditions.

2. Where applicable, drain condensate.

3. Where applicable, inspect and record operating valves and controls.

C. Monthly

1. Test safety devices.

D. Annually

1. Test and calibrate all controls.

E. Every Two Years

1. Conduct an internal examination. Pressure vessels containing corrosive materials or involving erosion problems should be examined more frequently.

BOILERS

A. General

1. Provide a thorough water-side and fire-side inspection at least annually.

2. Inspection frequencies are most generally established by the legal jurisdiction.

3. Unattended boilers should have two low-water fuel cutoffs. One should be of the manual reset type and should be the lower unit.

4. A daily log as well as records of all inspections maintenance, and testing should be maintained.

5. Follow manufacturer's instructions for start-up and operation.

6. If water level is noted below safe level on steam boilers, shut down immediately and cool slowly. Apply a hydrostatic test and inspect for leaks and overheating.

7. Following the operation of a safety device, always determine the cause and correct the deficiency before resuming operation.

8. On steam boilers, blow down water-wall headers and economizers in accordance with manufacturer's instructions.

9. Keep blow down valve in good repair and free of leaks.

10. If necessary water treatment should be controlled to retard corrosion and/or scale formation. This should be conducted by a reputable water treatment specialist

11. All boiler repairs which may affect the integrity of the pressure parts should be done by ASME certified welders.

12. Perform a slow drain test on low water fuel cutoff on hot water boilers whenever boiler is drained.

B. Daily

1. Continually monitor water level.

   a. Check water gauge glass for proper water level on steam heating boilers.

   b. Check pressure on attitude gauge on hot water heating boilers.

   c. Blow down water gauge glass each shift on steam boilers.

2. Observe combustion conditions and check for leaks

3. Make sure all drain valves and cocks are tightly closed after daily tests.

4. Steam heating boilers:

   a. Operate each gauge cock.

   b. Open blow off valve for a few seconds to drain off sediment .

5. Hot water boilers:

   a. Check expansion tank glass to ascertain proper air cushion.

   b. Check water temperature. It should never exceed 250 ° F (120 ° C).

6. On high pressure steam boilers, test feed water regulators, low water fuel cut-offs by a quick drain test and alarms.

7. Check boiler for water leaks. If leaks are serious, they should be repaired immediately.

C. Weekly

1. Blow down float (or electrode) chambers of each low water fuel cut-off, low water alarm, and feed water regulator to keep chambers free of sediment and to keep them operable. Testing of low water fuel cut-offs should be done with the burner in operation; if the burner fails to shut off, service immediately.

D. Monthly

1. Perform prescribed inspections and tests of combustion safeguards at intervals recommended by manufacturers, or at least once a month for gas or oil fired equipment. Include tests for tightness of safety shut-off valves, response to flame failure and proper action of fuel air interlocks.

E. Quarterly

1. Test each low water fuel cut-off on high pressure steam boilers in an actual test by slowly lowering the boiler water level until the burners shut off. When making this test, water level should never be permitted to fall out of sight in the gauge glass.

F. Annually

1. At least annually the boiler water should be lowered to simulate a low water condition. Do not let water level fall out of sight in gauge glass.

2. At least annually the low water cut-offs should be dismantled, inspected and cleaned as necessary to determine proper operation.

G. End of Heating Season

1. Steam boiler

a. Drain boiler and remove closure plate and/or plugs from all access openings.

b. Remove all fuses from burner circuits.

c. Remove all soot and ash from furnace, tubes, and flue surfaces.

d. Flush boilers thoroughly to remove all sludge and loose scale particles from internal surfaces.

e. Repair or replace leaking tubes, nipples, stay bolts, packing and insulation.

f. Clean and overhaul automatic controls.

g. Check the condensate return system for tightness and integrity components.

h. Leave steel boilers open and dry.

i. Attach a conspicuous sign warning that boiler is empty and not to be fired.

j. If wet lay-up is preferred, boiler should be completely filled with properly treated water to prevent corrosive action. A boiler-water treatment specialist should be consulted.

k. After draining and flushing cast iron boilers, refill with clean water to normal operating level.

2. Drain hot water boilers from bottom while boiler is still hot until the water runs clear, then refill. If water treatment is used, sufficient treatment compound should be added to condition the replacement water.

H. Beginning of Heating Season

1. After firing, test all automatic controls including feed water regulator, low water fuel cut-off, alarm, and combustion safeguards. Also "pop test" safety valves to assure they will work under boiler pressure within allowable tolerances. At all times maintain a permanent boiler log book to record maintenance work, inspections, tests, and other pertinent data.

COIL-TYPE WATER TUBE BOILERS

A. Annual

1. To prevent burn-outs of the coils by scale formation, it is recommended that the units be cleaned by acid on an annual basis under the direction of a reputable concern.

2. Excess temperature controls and low-water cut-offs should be provided and properly maintained (see Boilers for testing and maintenance).

PRESSURE RELIEF VALVES

A. General

1. The testing interval should not exceed what is necessary to keep the safety valves in satisfactory condition, based on operating experience. Any safety valve testing requirements established by regulatory bodies, including government agencies, must take precedence over other conditions.

B. Testing

1. Low pressure heating and process boilers up to and including those operating at 15 psi:

   a. Manually test once a week.

   b. Pressure test once a year.

2. Steam boilers operating at 16 psi to 900 psi:

   a. Manually test once a month.

   b. Pressure test once a year.

NON-DESTRUCTIVE EXAMINATION METHODS

ULTRASONIC

Used on metal, ceramics, plastic, etc. to detect surface and subsurface discontinuities, measure thickness of a material, and detect weld flaws.

Advantage: Only one side of a surface of an object need be accessible.

Principle: High frequency vibration or sound waves are reflected as echoes from both the discontinuity and the front and back surfaces of the piece being tested. Echoes are converted to electric signals for amplification and display on an oscilloscope.

RADIOGRAPHY

Used to search for imperfections beneath the surface of fabricated metal in fire and unfired pressure vessels. Also used to reveal internal discontinuities in welded joints. Will pick up gas pockets or voids, slag inclusions, incomplete fusion and inadequate joint penetration.

Advantage: Gives a permanent record and in most instances will detect a small discontinuity.

Principle: Short wave-length electromagnetic radiation, specifically X-Ray or Gamma-Ray, is used to penetrate objects opaque to longer wave length visible light.

LIQUID PENETRANT

Used to locate surface discontinuities in various products, such as fine surface cracks.

Advantage: Can provide indication of discontinuities in metals and other nonporous materials.

Principle: Liquid flows evenly over the object and into the tiny cavities of the specimen. Excess material is removed leaving behind that which seeped into the discontinuity. A developer draws the material that seeped into the discontinuity by capillary action. After drying, examination is performed under a white light or black light condition depending on whether visible dye or fluorescent penetrants were used.

MAGNETIC PARTICLE

Used to detect discontinuities such as surface or slightly subsurface cracks in ferro-magnetic materials.

Advantage: The sensitivity of the magnetic particle test is higher than that of the dye penetrant process.

Principle: Either dry powder or liquid fluorescent magnetic particles are used. The method consists of magnetizing an area to be examined and then applying magnetic particles of different colors to the

surface. The particles are retained on the surface at cracks and discontinuities due to leakage in the magnetic field.

EDDY CURRENT

Used to check pipe and tubing for defects such as seams as shallow as .002 of an inch in such material as automotive valve spring wire. It can check over 150 ft. of resistance per minute.

Advantage: Can detect flaws in materials not easily accessible.

Principle: A circulating electrical current is induced in an object being checked. This electrical whirlpool is known as an eddy current. Flaws in the test material disrupt the current and consequently reveal themselves.

THERMAL OR INFRARED

Used to test the amount of heat or the heat flow through a piece of equipment and measure its quality for evaluation. Will pick up hot spots in electrical equipment such as switchboards, cables, etc.

Advantage: An entire plant can have its electrical equipment checked in a short period of time. Will point out hot spots and the degree of heat being admitted over normal temperatures. Equipment can take a picture of the material showing the seriousness of the condition.

Principle: Infrared, known as thermo vision, is equipment which detects admitted infrared radiation, converts it to a video signal and reproduces the thermal image in black and white on a monitor screen. It allows you to see heat images.

OVERPOTENTIAL

Determines that insulation on electrical equipment can withstand the normal or abnormal stresses to which it is subjected.

Advantage: Equipment for D.C. over potential testing is relatively small, lightweight, portable and less expensive than the equivalent A.C. equipment. D.C. voltages are less damaging to insulation than A.C. and time is not critical.

Principle: The D.C. over potential test is a controlled overvoltage test, sometimes referred to as a direct current leakage test or step voltage test. The current is measured at each step increase of applied direct current potential and is constantly observed for any abnormalities since, in most cases, the test can be stopped before breakdown occurs.

INSULATION-RESISTANCE

Used to detect grounds, damp windings, carbonized or damaged insulation, foreign deposits, current leakage to ground and other conditions that cause or contribute to electrical breakdown.

Advantage: Test equipment is generally lightweight and portable. Testing can also be completed in a short time.

Principle: A 500-volt D.C. megger is standard test instrument. Electrical equipment should be disconnected from all sources of power. Insulation resistance varies with changes in temperature, humidity, test voltage, and duration of test voltage application. Consequently, for a comparison of one set of readings with another, the conditions should be the same. Ideally, the insulation-resistant test should be administered by applying 500 volts D.C. for one minute at a temperature of 40°C.

DIELECTRIC ABSORPTION

This test furnishes data concerning the relative condition of the insulation with respect to moisture and other contaminants.

Advantage: Test equipment is generally lightweight and portable. Access to only one surface is needed.

Principle: Insulation-resistance test equipment can be used for this test. A test voltage of 500 volts direct current is commonly used and applied for 10 minutes, with readings of the insulation resistance taken at definite intervals. For high voltage apparatus, a 2,500 volt test voltage is preferred. A graph of the insulation resistance in megohms as a function of time should be plotted. Readings are taken at 1/4 minute intervals for the first minute and every minute for the next 9 minutes. A steady increase in insulation resistance during the time that the voltage is applied is an indication of clean, dry windings. A moist or dirty winding will not have a steady increase and the curve will flatten out. This is the result of current leaking through, or over, the surface of the winding insulation.

POWER FACTOR

Sometimes known as the doble test, it is used for determining the quality of the insulation in cables, circuit breakers, insulating liquids, regulators, rotating machines and transformers. Also, insulating qualities of bushings and insulators.

Advantage: Equipment is generally lightweight and portable.

Principle: Power factor is a measure of the energy component of the charging current and watts loss of insulation. The power factor of the insulation is principally affected by the type of insulation, test voltage and the moisture and voids in the insulation. An increase in the power factor over a period of time indicates deterioration. Results are recorded and compared with previous tests. A low power factor is an indication of a safe condition.

VIBRATION ANALYSIS

Used to measure vibrations over and above normal operating limits which may indicate abnormal conditions.

Advantage: Can provide advanced warning of impending equipment failures while the equipment is in service.

Principle: The technique is based on the fact that all machines vibrate and a change in vibration is an indication of a change in mechanical condition. Periodic or constant readings are compared to a

base figure. The difference between the two readings can provide valuable insight into the operating condition of any given machine.

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