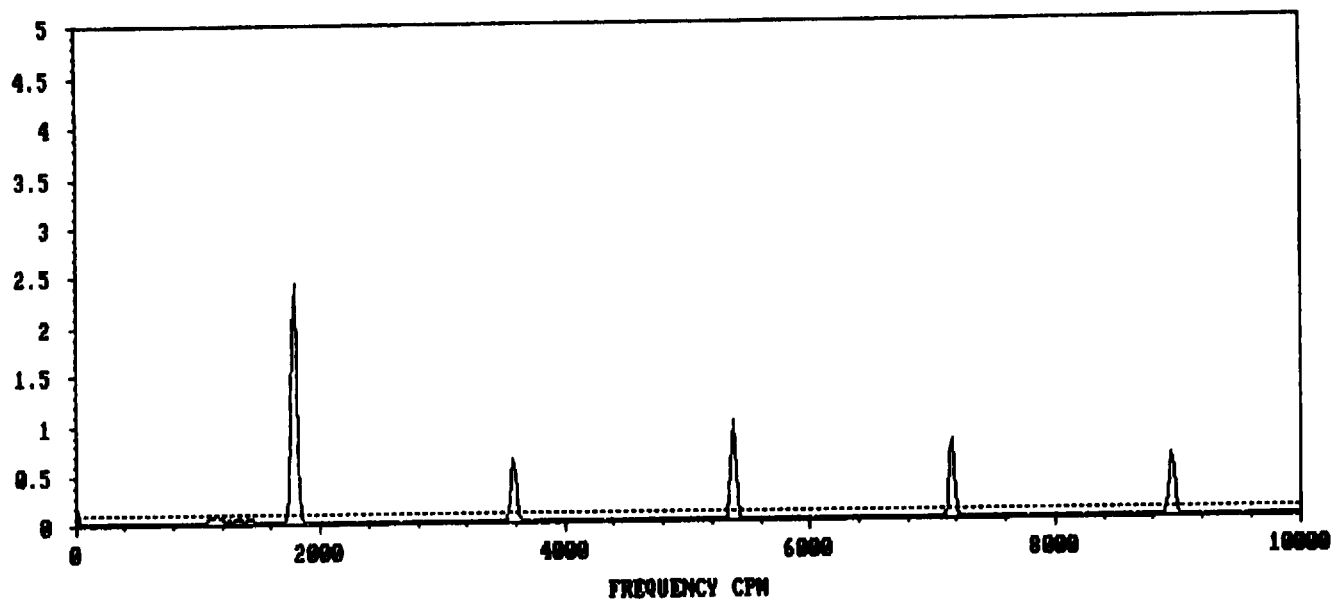
09-NOV-90 Palomar Technology

SINGLE SPECTRUM PLOT

SET: POWER GENERATION TYPE: FFT DATE: 08-NOV-90 13:01:32
POINT ID: TEST DESC:
WINDOW: HANNING LINES: 400 AVER: 1 FREQ: 0 - 10000 CPM
DETECT: PEAK TO PEAK RPM: 1800 THRESHOLD: 0.1000 UNITS: mils

FREQ: 0.00 AMP: 0 ORDER: 0.000 DEG: ---



IDENTIFICATION OF SPECTRAL PEAKS ABOVE THRESHOLD

NO.	AMP.	FREQ.	ORDER	NO.	AMP.	FREQ.	ORDER
1.	0.1349	25.0	0.014				
2.	2.3978	1800.0	1.000				
3.	0.6228	3575.0	1.986				
4.	0.9849	5375.0	2.986				
5.	0.7759	7175.0	3.986				
6.	0.6270	8950.0	4.972				

SPECTRAL ENERGY SUMMARY

OVERALL	SYNC	SUBSYNC	NONSYNC
3.049	2.908	0.2776	0.8761

Figure 15

system, someone must be available to analyze the data. This analysis is not necessarily complicated, but it will take some time; and if maintenance personnel are already stretched thin, the vibration analysis may get neglected.

8. Lubrication

The primary purpose of a lubricant is to reduce friction and wear between two moving surfaces, but a lubricant also acts as a coolant, prevents corrosion, and seals out dirt and other contaminants. In order for a lubricant to perform as intended, careful attention must be given to its selection and application as well as its condition while in use. FIST, Vol. 2-4, "Lubrication of Powerplant Equipment," provides more information on lubricants and their use. The equipment manufacturer should provide specific information on the type lubricant and periodic maintenance recommended for a particular application.

Oil.-Oil lubrication can take many forms, from a simple squirt oil can to a complex circulating system. Regardless of the method by which the oil is applied, the intent is the same, and that is to keep a lubricant film between moving surfaces. For successful lubrication, it is critical that the proper oil be chosen, properly applied, and kept clean and uncontaminated.

While it is beneficial to have as few types of oil in stock as possible, there is no one all-purpose oil that can be used in all applications. Various additives, such as emulsifiers, rust and corrosion preventers, detergent and dispersants, are added to oils to enhance their performance for a given application. Characteristics that may be desirable in one case, may be very undesirable in another. For example, emulsifiers added to motor oil allow the oil to hold any water in an emulsion until the engine's heat can boil it away. In bearing lubrication, where there is not sufficient heat to evaporate the water, the oil must be capable of readily separating from water. Work with a local lubricant distributor to determine what oil is right for a particular application.

Cleanliness is also extremely important. All seals should be installed and in good condition. Dirt, water, or other contaminants not only can cause premature wear of the bearings, they also can cause the depletion of some of the oil's additives. Samples of the oil from large bearings should be periodically tested for viscosity, acidity, water content, and the presence and identity of any foreign material. There may be local laboratories that can perform the tests; but, if possible, the oil's manufacturer should perform the tests. The manufacturer can usually perform the tests mentioned and also determine whether any of the additives have been depleted. The oil from large bearings should be periodically drained and filtered, and the oil reservoir thoroughly cleaned. The oil from small bearings should be periodically drained, the reservoir or case cleaned, and new oil installed. Care should be taken not to under or over fill a bearing oil reservoir. In some cases, an overfilled oil reservoir can cause as much damage as an underfilled bearing.

Another possible source of contamination is the mixing of incompatible oils. Different type oil or even similar oil from different manufacturers should never be mixed. Additives in different oils may not be compatible and when mixed, may have an adverse reaction, rendering the additives, and possibly the oil itself useless.

Grease.-Grease is a lubricant consisting of a lubricating oil combined with a thickening agent. The base oil makes up, depending on the grease, 85 to 95 percent of the grease and performs the actual lubrication; so it can be seen that a high-quality grease requires a high-quality oil. The thickening agent, usually some type of soap, determines many of the characteristics of a grease such as, heat resistance, water resistance, and cold weather pumpability. Various additives may also be added to improve performance.

Overheating and subsequent failure of grease lubricated bearings caused by over lubrication is a common problem. The idea that "more is better" coupled with the fact that it is usually difficult to determine the actual amount of grease in a bearing housing, causes many bearings to be "over greased."

Ideally a grease-lubricated bearing should be "packed" by hand so that the bearing housing is approximately one-third full of grease. When grease is applied using a grease gun, the relief plug, if so equipped, should be removed so that as the new grease is applied, all of the old grease is purged from the bearing housing. The unit should be operated approximately 30 minutes before the plug is replaced to allow excess grease to escape. If the bearing housing does not have a relief plug, grease should be added very infrequently to prevent over lubrication.

Many of the soap bases used in making grease are incompatible. Mixing two different types of grease will many times result in a mixture inferior to both of the component greases. As a general rule, different greases should not be mixed. If it becomes necessary to change the type of grease being used on a piece of equipment, the bearing housing should be completely disassembled and thoroughly cleaned to remove all the old grease. If this is not possible, as much of the old grease as possible should be flushed out by the new grease during the initial application and the greasing frequency should be increased until it is determined that all of the old grease has been purged from the system.

9. Pump Efficiency

Periodic efficiency testing can be helpful in scheduling major pump maintenance, especially with vertical turbine pumps where the inspection of the impellers is not possible. Through periodic testing, a gradual decline in efficiency may be noted, allowing maintenance personnel to predict when a major overhaul will be required. A true efficiency test can be a rather complicated and time-consuming process that requires determining the pumps discharge pressure, the amount of lift, the waterflow rate, and the energy use rate.

A simple and quick method of obtaining a relative measure of the output of an electric motor driven pump, is to measure the current draw or amperage of the motor. While this is not a measure of the pump's actual efficiency, when compared to previous readings, it does provide an indication of the relative condition of the pump. Amperage readings should be taken several times a year with the pump operating under the uniform conditions; that is, water levels and valve openings should be the same during each test. A decrease in amperage indicates a decrease in pump output, which suggests some maintenance is required.

10. Inspection Checklist

Items of inspection		
Pumps		
a. Impeller and casing	A	NS
b. Wearing rings		A
c. Packing		W
d. Mechanical seals		W
e. Fluid film bearings	D	A
f. Antifriction bearings		W
g. Shaft couplings	W	A
h. Pump inspection report		A

D – Daily inspection.
W – Weekly inspection.
A – Annual inspection.
NS – Not scheduled, frequency as required.

a. *Impeller and casing.*–

Annual inspection.–If inspection ports or mandoors are available, the pump impeller should be inspected annually. If disassembly is required to inspect the impeller, and disassembly may damage the pump, wait until there is a reduction in capacity or pressure; an increase in vibration; or other indication that a problem exists; or at intervals determined by past maintenance experience. If the pump can be disassembled without damage, it should be inspected annually. The interior pump casing and suction inlet coating should be inspected and repaired as required. Concrete encased pumps should be checked for voids between the suction tube liner and the concrete and grouted if necessary. Any leaks between the concrete and the pump casing or suction tube should be monitored and if excessive or if an increase is noted, the source of the leak should be found and repaired.

Not scheduled.–The bowl assembly of a vertical turbine pump or other vertical wet-pit pumps should not normally be disassembled for inspection unless there is evidence a problem exists. On small pumps such as these, the impellers and other components are usually too small to be easily repaired and replacement is usually more economical.

b. *Wearing rings.*–

Annual inspection.–If possible, the wearing ring clearance should be checked annually. Many pumps, such as vertical turbine pumps, are constructed so that wearing rings are inaccessible. In such cases, the clearances should be taken as part of the impeller inspection if and when disassembly of the pump is required.

c. *Packing.*–

Weekly inspection.–Check for excessive heat and for proper leakage past the packing. The required inspection and maintenance schedule for stuffing boxes can vary greatly from pump to pump. Periodic maintenance will normally involve tightening the packing gland as leakage becomes excessive and greasing the stuffing box if and when required.

d. *Mechanical seals.*–

Weekly inspection.–Check for excessive leakage. Properly installed mechanical seals should require very little attention. When excessive leakage does occur it normally means new seals are required.

e. *Fluid film bearings.*–

Daily inspection.–Check the bearing temperature and lubricant level.

Annual inspection.–Usually a fluid film bearing should require very little maintenance. Bearings should not normally be removed for inspection unless there is evidence a problem exists, such as overheating or excessive vibration. If accessible, bearing clearances should be checked annually.

Light scoring and minor damage from wiping can be removed by scraping on babbitt bearings and polishing with emery cloth on bronze bearings. If there is evidence that the babbitt lining has separated from the bearing shell, or if there is severe damage to the babbitt surface, the bearing should be rebabbitted. A severely damaged or worn bronze bushing should be replaced.

If a bearing is found to be damaged, the cause of the damage should be found and corrected. Insufficient lubrication or misalignment can lead to bearing failure. Even wear on the shaft and wear on one side of the bearing indicates misalignment of the bearings while wear on one side of the shaft and even wear on the bearing indicates a bent or misaligned shaft.

f. *Antifriction bearings.*–

Weekly inspection.–Check for vibration and for adequate lubrication. Unlike fluid film bearings, antifriction bearings have a finite life. Prior to complete failure, vibration will increase and the bearing will usually become extremely noisy. As it is sometimes difficult to detect an increase in noise or vibration, some sort of vibration monitoring system can be helpful. These systems are discussed in this chapter in paragraph 7, "Vibration Monitoring and Analysis." If a bearing fails prematurely, find the cause and correct it before restarting the pump. Insufficient or excessive lubrication, contamination of the lubricant, or misalignment of the shaft or bearings are some possible causes of premature bearing failure. If there is no apparent reason for the early failure, consult a bearing manufacturer's representative to determine if the right bearing is being used. The phrase, "If the shoe fits, wear it," doesn't apply to bearings. Bearings with the same physical dimensions can vary greatly in load carrying capability.

g. *Shaft couplings.*–

Weekly inspection.–Check shaft and coupling visually for excessive runout or vibration. Look for loose coupling bolts or other damaged coupling components.

Annual inspection.–Check shaft runout with dial indicator or with proximity probes and a strip chart recorder. Check shaft alignment as discussed in this chapter in paragraph 6, if runout is excessive.

h. *Pump inspection report.*–

Annual inspection.–A suggested form for reporting the condition of a pump and repairs is shown in figure 16. This form is primarily for large pumps but can be adapted for smaller pumps.

O & M 154
(10-56)
Bureau of Reclamation

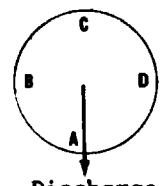
PUMP INSPECTION REPORT

PROJECT: Colo-Big Thompson PUMPING PLANT: Granby UNIT NO. 1 DATE: 3-12-56
MANUFACTURER: N.N. Shipbuilding & Dry Dock Co. MODEL NO.: None
TYPE: Centrifugal Vertical Pump SERIAL NO.: 10
CAPACITY: 200 cfs HEAD: 186 feet

CLEARANCES				
	POSITION**			
PART	A	B	C	D
WEARING RING, MOTOR END	.015	.014	.014	.015
WEARING RING, PUMP END	.014	.015	.015	.014
PUMP GUIDE BEARING, MOTOR END	.016	.017	.015	.017
PUMP GUIDE BEARING, INTERMEDIATE	.018	.016	.017	.016
PUMP GUIDE BEARING, PUMP END	.014	.016	.015	.015
*IMPELLER				
*OTHER CLEARANCES				

*EXPLAIN AND GIVE REFERENCE POINTS IN REMARKS IF NECESSARY.

**SHOW SKETCH



CONDITION OF:

PAINT AND KIND, OR IF BARE, METAL SURFACES OF, INCLUDING LOCATION OF PITTING AND EROSION AREAS AND SIZE AND DEPTH OF DAMAGED AREAS:

CASING: CA50 paint condition good except for small chipped areas covering approximately 5 square feet in area.

DISCHARGE PIPE: Short metal section good - Concrete section good.

IMPELLER, DIFFUSER: Bronze impeller not painted. Some cavitation on shrowd band. Cracks occurring in previous welded vanes. (See impeller report 4-5-56.)

SUCTION PIPE: Did not check.

SEAL AND WEARING RINGS: Slight scoring of wearing ring motor end considered satisfactory for further operation. Wearing ring pump end OK.

Figure 16 (front)

CONDITION OF:

OIL PUMP: D.C. Pump OK - A.C. Pump noisy bearing.

GAGES: OK Checked and calibrated 2-5-56.

INTAKE GATE:

LEAKAGE, 20 GPM, DESCRIPTION OF LEAKAGE: Leakage right hand bottom side

DISCHARGE GATE:

LEAKAGE, 25 GPM, DESCRIPTION OF LEAKAGE: Leakage along center at top

SHAFT PACKING:

LEAKAGE, 0 GPM, TYPE Garlock G44 NEED REPACKING? No

GLANDS AND LANTERN RING Condition good

SHAFT SLEEVE: Slight scoring serviceable after filing.

PUMP BEARINGS:

MOTOR END: Surface OK

INTERMEDIATE: Surface OK

PUMP END: Slight wiping in center of bearing. Bearing OK after scraping.

JOURNALS: OK

OTHER ITEMS:

NAME, MANUFACTURER AND VISCOSITY OF OIL USED: Standard Oil Stan - Oil 31

NAME, MANUFACTURER AND GRADE OF GREASES USED: Texaco No. 1

DATE LAST OVERHAUL: 2-5-55

REPAIRS MADE: Impeller removed and reconditioned. See Unit 1 overhaul report 3-6-55.

REMARKS AND RECOMMENDATIONS:

Repair damage paint area in pump casing.
Investigate repair of cracked runner vanes by chain lock method.
Replace A.C. oil pump bearing.

INSPECTION MADE BY: John Rose

Form O&M 154 12-1-51 (Back

Figure 16 (back)

CHAPTER 4 - DISCHARGE LINES, PIPING, GATES, AND VALVES

1. General

Pumping plants, depending on their size, can have a wide variety of piping. While the piping of a small pumping plant may consist of only the discharge and suction lines with some type of shutoff valves, a large pumping plant can have a great deal of auxiliary piping as well. Cooling, fire protection, and domestic water, as well as various hydraulic and pneumatic systems, are common in large plants. Since visual inspection of the interior of large-diameter pipes and valves is possible, protective coatings can be periodically repaired or replaced to keep them in good condition.

The auxiliary piping systems, except for the painting of their exterior surfaces, many times are ignored until leaks or other problems occur. Although a leak may be just an isolated event, frequently it can be an indication of the entire system's condition. By monitoring a system's condition, repair or replacement can be scheduled, preventing an unscheduled outage. Determining the condition of a piping system can be difficult. Partial disassembly can provide a good indication of the condition of the system but may damage the piping or valves. Radiographs or X-rays are nondestructive, easy to interpret, and provide a permanent record of the pipe wall thickness and the amount of mineral deposits or corrosion products built up in the pipe. Other nondestructive tests such as ultrasonic and eddy-current tests can also determine pipe wall thickness.

If a piping system fails prematurely because of a corrosion problem, it may be beneficial to replace the piping with a nonmetallic material. Pipe constructed of fiberglass and PVC (polyvinyl chloride) as well as other plastics have been used successfully in corrosive environments. Before switching to one of these materials, give careful consideration to its temperature and pressure limitations.

Large pumping plants may use various types of valves or gates, such as fixed wheel gates or butterfly valves, for the discharge and suction lines. These large gates or valves are usually specially designed for that application so the specific maintenance instructions, if available, should be followed when working on this equipment.

Small pumping plants and auxiliary piping systems most commonly use gate valves as shutoff valves. These valves should require little maintenance unless the water is corrosive or the valve is used for throttling flow, in which case, cavitation erosion may occur. If flow throttling is necessary and there is severe cavitation damage, consideration should be given to replacing the gate valve with a valve designed for throttling, such as a globe valve.

Check valves are also used in pumping plants in various applications. The most common type is the swing-check valve. This valve, depending on its service, should require very little attention outside of regrinding the seat if excessive leakage occurs.

Choosing the right paint for a particular application is critical for the long life of a piping system. Reclamation's Paint Manual, Painting Tabulation C-1000 and Instructions and Technical Requirements for Preparing the Painting Tabulation C-1001 provide general recommendations for types of paint and methods of application for various applications. For more specific recommendations, contact Reclamation's research laboratory in Denver.

2. Inspection Checklist

Items of inspection			
Discharge lines			
a. Foundation		Q	A
b. Sliding supports		Q	A
c. Expansion joints		Q	A
d. Welds, rivets, and bolts			A
e. Exterior paint and surface			A
f. Interior paint and surface			A
Auxiliary piping systems			
g. Pipe and fittings–exterior surface			A
h. Pipe and fittings–interior surface			NS
i. Gate valves, globe valves, plug valves, etc.	NS	W	A
j. Check valves			A
Large gates and valves			
k. General inspection–interior and exterior surfaces			A
l. Seals and guides			NS
m. Stems			A
n. Lubrication		NS	A
o. Journals, bearings, and bushings			NS
p. Wheels, pins, and rollers			NS
q. Operating cylinder or gear mechanism			NS
r. Control piping			A
s. Packing glands			W
t. Operation check			A

A – Annual inspection.
Q – Quarterly inspection.
W – Weekly inspection.
NS – Not scheduled, frequency as required.

Discharge lines.–

a. *Foundation.*–

Quarterly inspection.–Visual inspection for cracks, settling, and spalling.

Annual inspection.–Check alignment of pipe and foundation. Look for settlement or breakage of foundation.

b. *Sliding supports.*–

Quarterly inspection.–Visual inspection for adequate lubrication and obstructions of sliding members.

Annual inspection.–Check for adequate lubrication and obstructions of sliding members. Clean all exposed bearing surfaces of rust, scale, paint, or other material.

c. *Expansion joints.*–

Quarterly inspection.–Visual inspection for leaks and corrosion. Tighten adjusting bolts as necessary and clean sliding surface.

Annual inspection.–Repack as necessary. Clean and lubricate sliding surface. See that pipe sections are free to move at expansion joint.

d. *Welds, rivets, and bolts.*–

Annual inspection.–Visual inspection of all welds, rivets, and bolted flanges and joints for leaks and corrosion. Caulk rivets or replace where necessary, weld repair leaking weld joints with pipe drained. Tighten or replace bolts and studs where necessary.

e. *Exterior paint and surface.*–

Annual inspection.–Examine paint for cracking, chalking, or other deterioration. Examine surface for corrosion, paying particular attention to welded joints, rivet heads, and bolts and nuts at flanged joints. Prepare corroded or deteriorated surfaces with sandblasting or other recommended methods and repaint with suitable paint.

f. *Interior paint and surface.*–

Annual inspection.–Inspect for deterioration of the paint in the form of looseness, tubercles, dissolution, cracks, etc. Pay particular attention to rivet heads and welded and flanged joints. Prepare corroded or deteriorated surfaces with sandblasting or other recommended methods and repaint with suitable paint.

Auxiliary piping systems.–

g. *Pipe and fittings — exterior surface.*–

Annual inspection.–Visually inspect all threaded, welded, and flanged fittings checking for any leaks or corrosion. Replace or tighten fittings or pipe as required. Check pipe hangers and supports to make sure they are carrying their share of the load and that anchors are tight. Examine paint for cracking, chalking, or other deterioration. Remove corrosion by wire brushing, sandblasting, or other approved method and repaint.

h. *Pipe and fittings — interior surface.*–

Not scheduled.–Partially disassemble piping or utilize a nondestructive test method to determine condition of interior surfaces. Measure pipe wall thickness and thickness of any deposits.

i. *Gate valves, globe valves, plug valves, etc.*–

Weekly inspection.–Check valve stem packing for leaks and tighten packing gland as required.

Annual inspection.–Operate valve through its full range of movement several times. With valve closed under pressure, listen for leakage past valve and correct as required. Lubricate valve stems, plug valve seats, and other components as required with appropriate lubricant.

Not scheduled.–Disassemble valve and inspect condition of valve body, stem, and sealing surfaces and repair as required. Completely remove old valve stem packing and install new packing.

j. *Check valves.*–

Annual inspection.–Check for leakage past valve while under full operating pressure. Disassemble and replace or regrind valve seats as required.

Large gates and valves.–

k. *General inspection — interior and exterior surface.*–

Annual inspection.–Inspect exposed metal parts of valves and gates for corrosion, cracking, deterioration of paint, and other damage. Check rivets, bolts, and welds and repair as necessary. Clean corroded surfaces by sandblasting or other approved means and repaint as necessary.

l. *Seals and guides.*–

Not scheduled.–Check seals and guides for wear and deterioration. Renew seals and build up guides where scored, as necessary. Remove accumulated mineral deposit. Check alignment. Check slot heaters if installed.

m. *Stems.*–

Annual inspection.–Clean off all grease and dirt, and inspect for wear and breakage of the threads, scoring, and wear of the sliding surface. Renew or repair as necessary by building up scored surfaces and broken threads. Apply appropriate lubricant as required.

n. *Lubrication.*–

Not scheduled.–Lubricate all underwater fittings with suitable water resistant grease. Lubricate all fittings exposed to atmosphere. Flush out fittings on such items as rollers on coaster gates, and wheels on fixed-wheel gates. Check that rolling components are free and turn easily.

Annual inspection.–Inspect all grease grooves to see that they are not obstructed with hardened grease. Remove any hard deposit. See that all grease supply lines are clear. Flush all old grease from fittings and refill with fresh lubricant.

o. *Journals, bearings, and bushings.*–

Not scheduled.–Disassemble and check clearances. Examine bearing surfaces and journals for scoring wear. Replace bronze bushings and antifriction bearings, rebabbitt and re-bore babbitt bearing, build up journals by welding or metalizing and machine to proper dimensions as necessary.

p. *Wheels, pins, and rollers.*–

Not scheduled.–Check to see that all moving parts are free to move. Check for corrosion damage and wear. Look for signs of misalignment of rollers and wheels, such as uneven wear. Check pins for bending and scoring. Check bearing surfaces under linkage. Check linkage for cracks, bending, or other damage.

q. *Operating cylinder or gear mechanism.*–

Not scheduled.–Check hydraulic operating cylinders, pistons, rods, guides, bellcrank bearings, etc., for wear or other damage. Check hydraulic oil for water or dirt contamination and filter or replace as required. Check motor driven reduction gears for wear. Flush and re-lubricate gear boxes. Check torque limit devices on motor operators, limit switches on hydraulic cylinders, and any other protective devices for proper operation.

r. *Control piping.*–

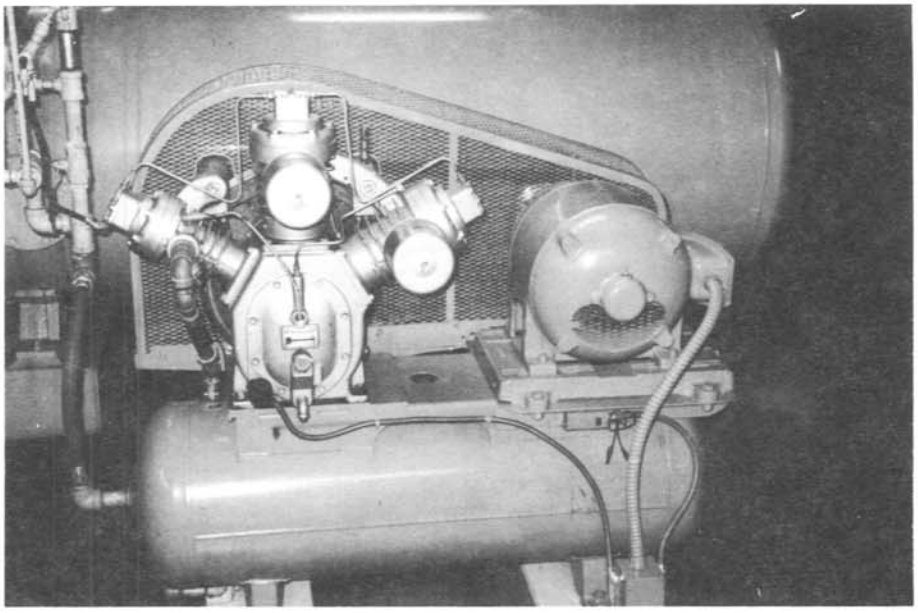
Annual Inspection.–Check for leaks and repair as necessary. Check relief valves to ensure they are in working order and set at the proper pressure. Clean and paint as required.

s. *Packing glands.*–

Weekly inspection.–Inspect for leaks and adjust gland as necessary. Remove gland, clean stuffing box, and replace packing when packing can no longer be compressed.

t. *Operation check.*–

Annual inspection.– Make an annual operation check under balanced conditions of gates having emergency closing facilities and which are depended upon for closing in case of a power outage or similar failure, to insure the equipment will operate when called upon. Other gates and valves should be given an annual operation check if conditions permit.



Tank-mounted reciprocating air compressor.

1. General

Air compressors are a common piece of equipment found in most pumping plants or maintenance shops. A compressor can be part of an elaborate air system serving the whole plant or shop, or it may be simply mounted on a small receiver tank. Regardless of the application, some maintenance is required on all compressors to provide trouble-free operation. There are a great number of different types of compressors available, but the two most common types are the reciprocating and the rotary screw compressors.

2. Reciprocating Air Compressors

Reciprocating compressors have been available for many years in a wide variety of sizes and configurations and make up the majority of air compressors found in plants and maintenance shops. Reciprocating compressors are efficient and relatively simple to operate and maintain. Most reciprocating compressors can be completely overhauled with a minimum of tools and parts.

A reciprocating compressor compresses air in a cylinder, against a cylinder head, by a reciprocating piston. While all reciprocating compressors operate in basically the same manner, there are a great many variations in the way they are constructed. For example, a reciprocating compressor can be single or multi-cylinder; single or double acting; single or multi-stage; air or water cooled; and can have a horizontal, vertical, or angled cylinder arrangement. Other variations are possible depending on the application.

Defining some of the above terms, a single-acting compressor compresses air only on one end of the cylinder while a double-acting compressor compresses on both ends

of the cylinder. In a single-stage compressor, all cylinders discharge air into a common line. In a multi-stage compressor, air compressed in the first stage or first cylinder passes through an intercooler into the second stage and is compressed to a higher pressure. Where high pressure is not required, most small compressors are single acting, single stage.

3. Rotary Screw Air Compressors

A rotary screw air compressor utilizes two meshing helical shaped rotors to compress the air. As the rotors turn, air is compressed by the advancing helix. The rotor may either be oil flooded or dry. Dry rotor compressors require the use of timing gears to maintain the proper clearance between the rotors. The oil in the oil-flooded-type compressor lubricates and seals the rotors and acts as a coolant to remove the heat of compression. The oil-flooded type does not require timing gears as the oil film prevents contact of the rotors, but an air-oil separator is required to remove the oil suspended in the compressed air as it leaves the compressor.

Rotary screw compressors have fewer moving parts than reciprocating compressors, but the construction is such that little maintenance can be accomplished in the field by plant personnel. The air end (i.e., the rotors and their housing) of the rotary screw compressor has no sacrificial components such as the piston rings of the reciprocating type. Since the air end is constructed with such high precision and tight tolerances, in most cases, the entire air end must be replaced as a unit. This is usually not complicated, but it can be expensive.

4. Pressure Relief Valves

As a safety precaution, a pressure relief valve is required in every compressed air system ahead of the first point that could conceivably act as an airflow restriction. This includes shutoff valves, check valves, and even in-line filters as they could clog. Receiver tanks should also have a relief valve installed on the tank with no restrictions between the tank and the valve. If there are no restrictions in the discharge line between the compressor and the receiver tank, the relief valve mounted on the receiver tank is sufficient to protect the system. The relief valve should be set to open at no higher than 10 percent above the maximum working pressure and periodically checked for proper operation. It should be noted that pressure regulators are not acceptable for protection against excessive system pressure as they do not vent air, but regulate pressure by restricting airflow.

5. Inspection Checklist

Items of inspection		
General		
a. Foundation		A
b. Frame		A
c. Compressor drive	W	A
d. Lubrication	W	A
e. Cooling system	W	A
f. Air intake and filter	W	M
g. Piping and valves		A
h. Receiver tanks	W	A
i. Gauges	W	A
j. Pressure and temperature switches	M	A
k. Unloader	M	A
l. Bearings	NS	W
Reciprocating compressors		
m. Packing gland	W	A
n. Crosshead	W	A
o. Cylinder		NS
p. Piston		NS
q. Connecting rod		NS
r. Intake and discharge valves		NS
Rotary screw compressors		
s. Air end		NS

A – Annual inspection.
M – Monthly inspection.
W – Weekly inspection.
NS – Not scheduled, frequency as required.

General.–

a. *Foundation.*–

Annual inspection.–Check foundation with level for settling. Examine concrete for cracks and spalling.

b. *Frame.*–

Annual inspection.–Examine metal for corrosion and cracks. Clean and paint as required.

c. *Compressor drive.*–

Weekly inspection.–Check V-belts for slippage, chains for looseness, and shaft couplings for excessive runout or vibration. Dress or tighten V-belts as required.

Tighten and lubricate chains as required. Tighten coupling bolts and lubricate coupling as required.

Annual inspection.–Check V-belts for signs of wear or aging and replace as needed. Check chain and sprocket for wear or distortion and replace as needed. Check shaft runout of direct coupled machines with dial indicator and check shaft alignment as discussed in Chapter 3, paragraph 6, if runout is excessive.

d. *Lubrication.*–

Weekly inspection.–Check that oil or grease cups are full and that crank case oil is at proper level. Replace or add the correct lubricant to bring to proper levels. Check forced oil systems for proper operation. Note any leaks and repair if excessive.

Annual inspection.–Clean oil or grease cups and piping. Check condition of lubricant and change if required. Repair any leaks.

e. *Cooling system.*–

Weekly inspection.–Check flow of water or coolant through compressor and aftercooler. Check for accumulation of dirt and lint on cooling fins of air-cooled compressors.

Annual inspection.–Flush and clean all water lines and repair any leaks. Thoroughly clean cooling fins of air-cooled compressors.

f. *Air intake.*–

Weekly inspection.–Check that intake is unobstructed.

Monthly inspection.–Remove intake filter and clean or replace. Filter may require cleaning more or less frequently depending on location of the intake.

g. *Piping and valves.*–

Annual inspection.–Clean and repaint piping as required. Repack and reseat valves as required.

h. *Receiver tanks.*–

Weekly inspection.–Open the receiver drain valve and blow down until water is removed from tank. Check for leaks.

Annual inspection.–If equipped with inspection door, open and clean all rust and sludge from interior of tank. Inspect interior of tank for corrosion or other damage and repaint as required. Make thorough inspection of exterior of tank paying close attention to joints, seams, and fittings. If tank has been visibly damaged or if the tank has been moved, a hydrostatic test at 1.5 times the maximum allowable working pressure should be performed.

i. *Gauges.*–

Weekly inspection.–Check operation of gauge. Look for loose or stuck pointer. If there is any doubt about the accuracy of gauge remove and check calibration or replace with new gauge.

Annual inspection.–Remove gauge and calibrate. Make any necessary repairs or replace with new gauge if gauge is not repairable.

j. *Pressure and temperature switches.*–

Monthly inspection.–See that pressure switches cut in and out at proper pressures. Check setting of temperature switches.

Annual inspection.–Check and clean switch contacts. Check calibration of temperature switches. Clean and adjust moving parts.

k. *Unloader.*–

Monthly inspection.–Check that compressor is not being loaded until operating speed is reached in starting and is unloaded when the pressure switch breaks the circuit to the motor and unloads at the proper pressure.

Annual inspection.–Inspect valves and air lines for leaks and valves for proper seating. Lap valves if required. Examine solenoid for deteriorated insulation or loose connections.

l. *Bearings.*–

Weekly inspection.–Check antifriction bearing for excessive vibration or noise and schedule replacement as required. Check for adequate lubrication.

Not scheduled.–Disassemble compressor and inspect condition of all bushings and babbitt-lined bearings. Repair or replace as required.

Reciprocating compressors.–

m. *Packing gland.*–

Weekly inspection.–Check for excessive leakage and for scoring on rod. Adjust packing as necessary.

Annual inspection.–Replace packing as necessary.

n. *Crosshead.*–

Weekly inspection.–If visible, check fit and lubrication.

Annual inspection.–Check bearing shoes for scoring and wear, and fit to crosshead. Shim shoes if necessary to obtain proper fit. Check pin and bushing for wear and replace or refit as required.

o. *Cylinder.*–

Not scheduled.–Check cylinder walls for wear and scoring. Measure inside diameters at top, bottom, and middle in two directions, 90° apart. If out of round or oversize, re-bore cylinder.

p. *Piston.*–

Not scheduled.–Check piston for wear. Check clearance with micrometer. Examine rings for tightness and fit. Replace if necessary. Check piston rod for trueness and scoring or wear. Renew or replace as required.

q. *Connecting rod.*–

Not scheduled.–Check for distortion or bending. Check bearing bolts and nuts for damage and replace as required.

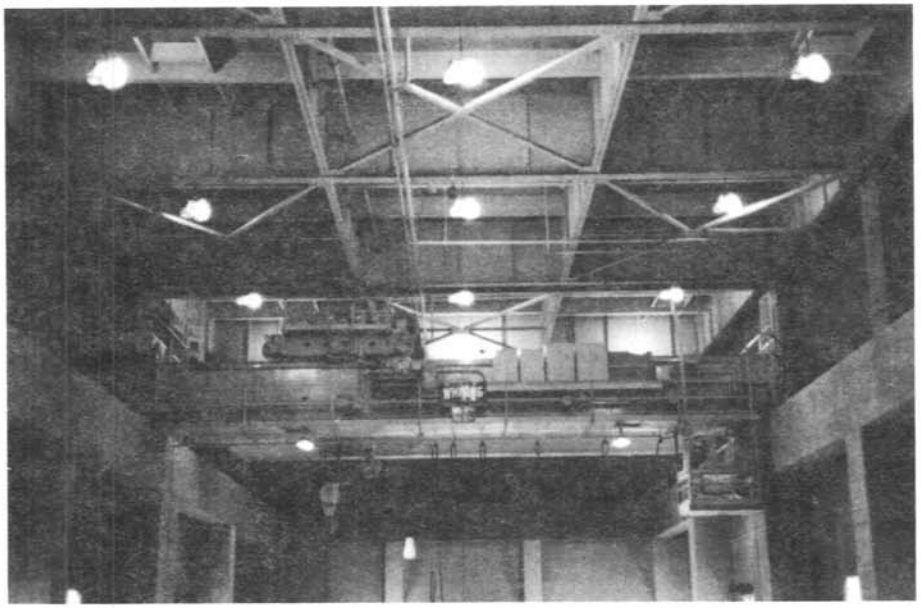
r. *Intake and discharge valves.*–

Not scheduled.–Inspect valves and seats for scoring and proper seating. Lap valves if needed. See that stems and guides are not bent or cocked. Check springs for proper tension. Check feather valves for proper operation.

Rotary screw compressors.–

s. *Air end.*–

Not scheduled.–Check condition of rotors and bearings. Replace if worn or if compressor efficiency has decreased noticeably.



Traveling overhead crane.

1. General

Due to the potential for injury to personnel and damage to equipment, periodic inspection and maintenance of cranes and hoists is very important. A preventive maintenance and inspection program based on the manufacturer's recommendations should be established for all cranes, hoists, or other lifting devices. This program should be well documented with detailed records of the inspections and maintenance performed on the equipment.

The American National Standards Institute (ANSI) publishes the following standards that may be useful in setting up an inspection and maintenance program for cranes and hoists: B30.2, "Safety Standard for Overhead and Gantry Cranes"; B30.5, "Safety Code for Crawler, Locomotive, and Truck Cranes"; B30.10, "Hooks"; B30.11, "Monorails and Underhung Cranes"; and B30.16, "Overhead Hoists (Underhung)."

2. Ropes, Slings, Chains, and Rigging Hardware

The *Rigging Manual* (published by the Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Canada, M5C 2A5) has been designated as the Bureau Rigging Manual. This publication provides information on safe rigging, load capacities of slings and other rigging equipment, and the inspection of wire rope and slings. The Bureau's *Construction Safety Standards* and ANSI Standard B30.9, "Safety Standard for Slings," may be helpful in the use and inspection of slings.

Prior to any lift, all of the rigging should be checked to ensure that it is safe to use. Defective equipment should immediately be marked as unsafe and removed from service. Capacity charts should be consulted, and all variables, such as sling angle, should be

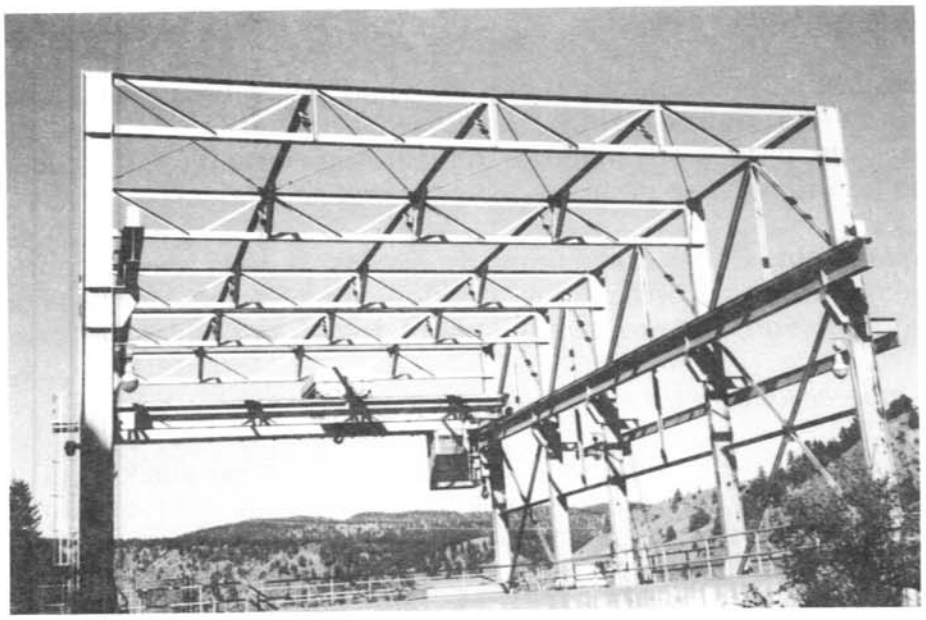
considered, to assure that the rigging hardware's rated capacity is not exceeded by the load being lifted.

3. Inspection Checklist

The Items of Inspection that are listed as daily inspections, should be done prior to use, each day a crane or hoist is used. Regardless of whether or not a crane or hoist has been used, all of the monthly and daily inspections should be performed at least semiannually; and if the crane or hoist has been idle for more than 6 months, the daily, monthly, and the annual inspections should be performed before the equipment is used. For a more complete description of inspection techniques and equipment requirements, refer to the above-mentioned ANSI standards, the *Rigging Manual*, the Bureau's *Construction Safety Standards*, and manufacturers' recommendations.

Items of inspection		
Cranes and hoists		
a. Operating mechanisms	D	A
b. Limit switches	D	A
c. Hooks	D	A
d. Braking systems	D	A
e. Wire rope or load chain	D	A
f. Crane rails, supports, and stops		A
g. Hoist, trolley, and bridge framework		A
h. Bumpers		A
i. Bridge and trolley conductors and collectors		A
j. Gears, shafts, bearings, and wheels	M	A
k. Catwalks, access ladders, and handrails		A
l. Cab		A
m. Hoist drums and sheaves		M
n. Hydraulic systems	M	NS
Slings and rigging hardware		
o. Slings (wire rope, chain, synthetic web, etc.)	D	A
p. Rigging hardware (eyebolts, shackles, etc.)	D	A
q. Lifting beams and specialized lifting devices	D	A

A – Annual inspection.
M – Monthly inspection.
D – Daily inspection (prior to use, each day equipment used).
NS – Not scheduled.



Gantry crane.

Cranes and hoists.-

a. *Operating mechanisms.*-

Daily inspection.-Check control levers and pushbuttons for free movement and for any obstruction that could interfere with proper operation.

Annual inspection.-Check controller contacts for signs of pitting or any other deterioration. Check for excessive wear or looseness of control levers.

b. *Limit switches.*-

Daily inspection.-Check operation of limit switches, without load, by carefully inching into limit switch.

Annual inspection.-Check electrical contacts for signs of pitting or any other deterioration. Check levers and cams for adequate lubrication and excessive wear.

c. *Hooks.*-

Daily inspection.-Visually inspect hook for cracks or deformation. Hooks with cracks or with a throat opening of more than 15 percent in excess of normal or with a twist of more than 10° shall be replaced. Refer to ANSI Standard B30.10 for more complete specifications for lifting hooks.

Annual inspection.-Perform magnetic particle, die penetrant, or other nondestructive crack detecting test in addition to visual inspection.

d. *Braking systems.*–

Daily inspection.–Check operation of bridge and trolley brakes and look for leaks in hydraulic lines. Before going ahead with a lift, lift load a few inches and check that hoist brakes are holding. Refer to the Bureau's Construction Safety Standards for information on brake tests for mobile cranes.

Annual inspection.–Check brake lining for excessive wear and oil contamination. Check brake drums for scoring. Check operating mechanisms for wear or damage, adequate lubrication, and proper adjustment. Repair or replace parts as required.

e. *Wire rope or load chain.*–

Daily inspection.–Check wire rope to assure there is no slack in drum or load block and that reeving is proper. Check load chains for worn or damaged links. Check that chain feeds into and away from sprockets smoothly.

Annual inspection.–Check wire rope for reduction of diameter, broken wires, wear, corrosion, kinking, crushing, unstranding, and other damage. Pay close attention to end connections and sections normally hidden. Refer to the Rigging Manual or the rope's manufacturer for recommendations for replacement of the wire rope. Apply lubrication, if required, according to manufacturer's recommendations.

Examine chain for gouges, nicks, weld splatter, corrosion, wear, and distorted links. Refer to the Rigging Manual or the chain's manufacturer for guidelines on the replacement of the chain.

f. *Crane rails, supports, and stops.*–

Annual inspection.–Check rails for alignment and level. Check concrete rail supports for cracking or spalling and steel supports for corrosion and loose bolts or rivets. Repair concrete as required. Tighten loose bolts and rivets. Check that rail stops are securely fastened.

g. *Hoist, trolley, and bridge framework.*–

Annual inspection.–Check bolts and rivets for tightness. Check all framework for deformation, cracks, and corrosion, paying close attention to load bearing members and welded joints. Clean and repaint as required.

h. *Bumpers.*–

Annual inspection.–Check for looseness and proper positioning. Check for leaking of hydraulic bumpers and fill to proper level. Check rubber or plastic bumpers for cracks or other damage. Replace or repair as required.

i. *Bridge and trolley conductors and collectors.*–

Annual inspection.–Check the contact surfaces of open conductors and collectors for signs of arcing damage, pitting and corrosion. Check condition of insulators. Clean as required. Check that festoon-type conductor cable moves freely with bridge and trolley movement. Check the condition of insulation and for kinking in cable.

j. *Gears, shafts, bearings, and wheels.*–

Monthly inspection.–Check lubrication and look for excessive wear.

Annual inspection.–Listen for excessive noise or vibration from bearings. If possible check clearances of journal bearings. Replace or refit as required. Examine gears for signs of abnormal or excessive wear. Check lubricant levels and check the oil of enclosed gear cases for metal filings. Check drive shafts and couplings for signs of misalignment. Check wheels for excessive wear or other damage. Repair or replace as required.

k. *Catwalks, access ladders, and handrails.*–

Annual inspection.–See that handrails and ladders are firmly secured and rigid. Check catwalks for obstructions, damaged floorway, or other safety hazards. Walking surfaces of catwalks and ladder landings should be an anti-skid type. Check all steel members for corrosion. Clean and paint as required.

l. *Cab.*–

Annual inspection.–Check cab for loose articles which would interfere with operation and for general housekeeping. Check for broken windows or doors. Check guard rails and doors. Check bolts and rivets for tightness. Check welded joints for cracks. Look for corrosion of steel member. Clean and paint as required.

m. *Hoist drums and sheaves.*–

Monthly inspection.–Visually inspect drums and sheaves for cracks or other damage. Check bearings for wear and proper lubrication. Check grooves of drums and sheaves for wear with sheave gauge. Repair or replace as required.

n. *Hydraulic systems.*–

Monthly inspection.–Check that pump delivers full pressure. Check piping and cylinder packing for leaks. Check condition of oil filters. Clean or replace as required.

Not scheduled.–Inspect cylinder walls and piston for scoring and wear. Check condition of pump. Inspect valve seats for wear. Repair or replace as required.

Slings and rigging hardware.–

o. *Slings (wire rope, chain, synthetic web, etc.).–*

Daily.–Check all slings for any damage or defects prior to use. Immediately remove any damaged slings from service and mark them as unsafe.

Annual inspection.–Check wire rope slings for broken wires, wear or scraping, kinking, crushing, bird caging, corrosion, signs of heat damage, and damaged end attachments. Chain slings should be checked for wear, nicks, gouges, and deformed links. Synthetic web slings should be checked for wear, broken or worn stitches, snags, punctures, tears, or cuts, and melting, charring, or other signs of heat damage. Refer to the Rigging Manual and the Bureau's Construction Safety Standards for more information on removal from service requirements.

p. *Rigging hardware (eyebolts, shackles, etc.).–*

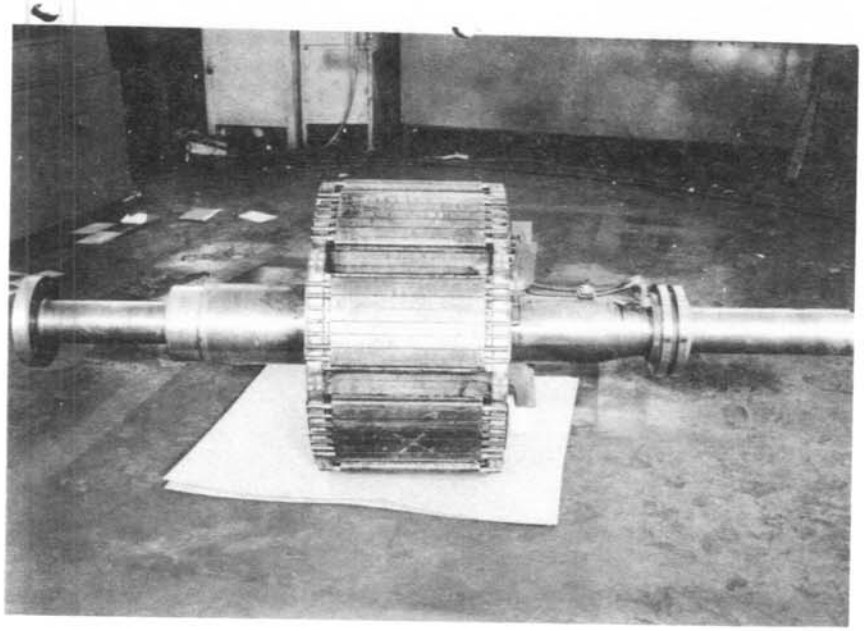
Daily inspection.–Check all rigging hardware for damage or defects prior to use. Immediately remove any damaged equipment from service and mark it as unsafe.

Annual inspection.–Inspect rigging hardware thoroughly for any damage such as nicks, gouges, or deformation. Refer to the Rigging Manual and the Bureau's Construction Safety Standards for more information on removal from service requirements.

q. *Lifting beams and specialized lifting devices*.–

Daily inspection.–Check for any sign of deformation or other damage. All specialized devices should be designed and certified for use by a engineer competent in the field. Lifting devices designed for a specific operation should not be used for any other operation unless approved by a competent engineer.

Annual inspection.–Check for deformation, lubricate bearings and bushings. Check that all pivot points and level indicators are free. For rarely used lifting devices, apply a protective coating to areas prone to corrosion. Clean and paint as required.

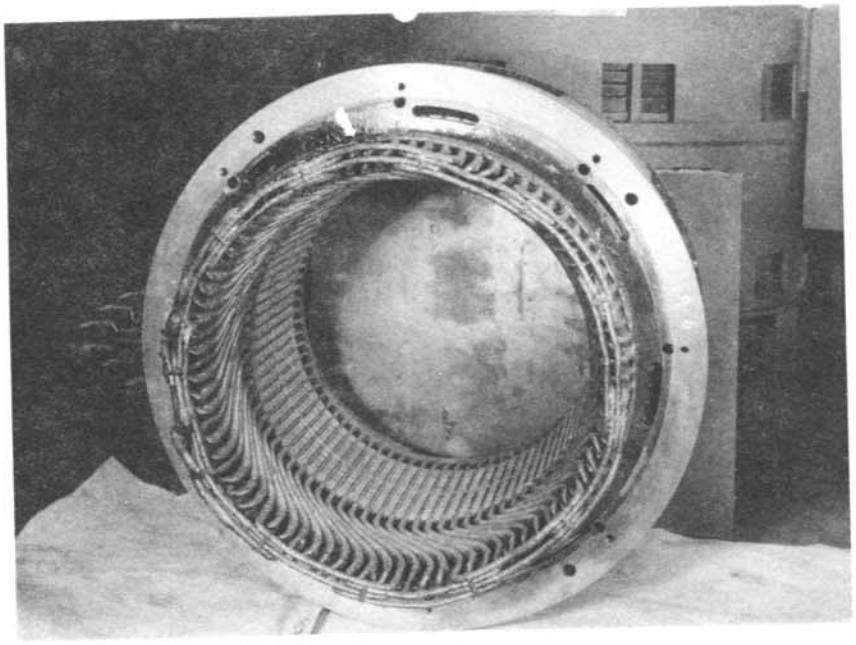


Electric motor rotor.

1. Inspection Checklist

Items of inspection		
a. Foundation, base, or support	M	A
b. Frame		A
c. Laminations and pole pieces		A
d. Armature or rotor		A
e. Airgap		A
f. Air fans		A
g. Windings	M	A
h. Banding and lashing		A
i. Slot wedges		A
j. Commutator or collector rings		W
k. Brushes		A
l. Temperature indicators and relay		A

A - Annual inspection.
M - Monthly inspection.
W - Weekly inspection.



Electric motor stator windings.

a. *Foundation, base, or support.*–

Monthly inspection.–Visual inspection to see that machine foundation, base or support is in good condition.

Annual inspection.–Check concrete foundation for cracks. Check base or support for broken, loose, or weakened parts. Check and tighten anchor bolts. Check condition of vibration isolation mounting.

b. *Frame.*–

Annual inspection.–Check for cracks, loose, or broken parts. Clean and repaint as necessary. Check frame ground connection.

c. *Laminations and pole pieces.*–

Annual inspection.–Check for loose laminations and tighten clamping bolts. If laminations vibrate and cannot be stopped by tightening clamping bolts, force some quick-drying varnish or shellac between the loose laminations while the machine is out of service. Check for damaged laminations at airgap due to rubbing or objects caught in airgap. Check and tighten field pole piece clamping bolts.

d. *Armature or rotor.*–

Annual inspection.–Check induction motor squirrel-cage rotor bars or synchronous motor amortisseur windings for loose or broken bars or end connections. Check synchronous motor field circuit connections and tighten if necessary. Check voltage drop across each synchronous motor field pole by

O & M - 150
(9-56)
Bureau of Reclamation

MOTOR OR GENERATOR INSPECTION REPORT

LOCATION Black Canyon Pr. Pl. DATE OF INSPECTION 5-18-67
PURPOSE OF UNIT Main Unit UNIT No. 3
MFR. OF UNIT

RATING:

VOLTS 6600 AMPS. 436 PHASE 3 FREQ. 60
H.P. KW. 4000 KVA. P.F. %
R.P.M. 225 TYPE
FRAME SIZE SERIAL No.
FIELD ~~OR SEC.~~ AMPS. 96 VOLTS 250
KIND OF BEARINGS

MAIN EXCITER: KW. 35 VOLTS 250 AMPS. 140
TYPE SERIAL No. 119500
PILOT EXCITER: None KW. VOLTS AMPS.
TYPE SERIAL No.

CONDITION OF UNIT AND AUXILIARY DEVICES:

COIL INSULATION Clean OK
FIELD COIL RESISTANCE 1.90 OHMS AT 21 °C.
MAIN EXCITER FIELD COIL RESISTANCE 25.0 OHMS AT 21 °C.
PILOT EXCITER FIELD COIL RESISTANCE OHMS AT °C.
FRAME AND ROTOR Good
STATOR AND ROTOR LAMINATIONS Good
SHAFT "
COUPLING "
BEARINGS "
ANY OIL LEAKS? No
BEARING OIL OK
COLLECTOR RINGS OK
COMMUTATOR Exciter commutator slightly grooved
BRUSHES OK
COLLECTOR RING OPERATION OK
COMMUTATION OK

IF TROUBLE IS EXPERIENCED GIVE:

BRUSH GRADE SIZE NUMBER
COLLECTOR-RING MATERIAL MAX. AMPS.
SPRING PRESSURE LBS. RING OR COM. DIA. IN.

MISALINEMENT OR VIBRATION? Slight
DOES END PLAY FLOAT FREELY?
BEARING THERMOMETERS OR ~~XXXXXXXXXX~~ OK
BEARING OIL GAGE ~~XXXXXXXX~~ OK
BEARING COOLING-WATER PRESSURE GAGE OR SWITCH None
STATOR TEMP. INDICATOR OR THERMOSTAT RTDs on swbd indicator OK
FIRE PROTECTIVE EQUIPMENT None

Figure 17 (front)

AIR GAP CLEARANCE (INCH)	NORTH	EAST	SOUTH	WEST
MAIN UNIT	.42	.44	.46	.45
MAIN EXCITER	.15	.18	.16	.14
PILOT EXCITER				

(MEASURE OPPOSITE SAME SPOT ON ROTOR FOR EACH POSITION IF PRACTICAL)

WAS INSULATION RESISTANCE MEASURED? See Form O&M-109

(REPORT DATA ON FORM O&M 109)

MAXIMUM LOADING AND TEMPERATURES OF UNIT (FROM LOG SHEETS OR TEST)

DATE	5/18		5/18		5/18
HOUR	3P		11P		1A
A.C. AMPS.	410		272		80
A.C. KV.	6600		6600		6600
KW.	4900		3510		1600
KVAR. P.F.	99/aq		95/aq		95/aq
FIELD AMPS.	70		55		40
FIELD VOLTS	133		120		100
PILOT EXCITER AMPS.					
PILOT EXCITER VOLTS					
TURBINE GATE OPENING	.8		.6		.3
TURBINE NET HEAD	92		92		92
STATOR TEMP. °C.	78.5 by RTD		71 by RTD		65 by RTD
INLET AIR TEMP. °C.	30		22		20
THRUST BRG. TEMP. °C.	56		50		50
UPPER GUIDE BRG. TEMP. °C.	50		45		45
LOWER GUIDE BRG. TEMP. °C.	49		45		45
TURBINE GUIDE BRG. TEMP. °C.	44		40		40
COOLING WATER TEMP. °C.					
AMBIENT TEMP. °C.	30		22		20

REPAIRS OR CHANGES MADE AT TIME OF THIS INSPECTION

None

OTHER REPAIRS OR CHANGES RECOMMENDED

Respace exiter brushes and stone commutator.

INSPECTION MADE BY: John Jones

NOTE: CROSS OUT ALL ITEMS WHICH DO NOT APPLY TO THE UNIT COVERED BY THIS INSPECTION.

Figure 17 (back)

applying alternating current at the collector rings and then measuring the voltage across each pole with a voltmeter. This will show up a turn-to-turn short better than direct current. After this test it may be necessary to "flash the field" to restore the proper residual field polarity. Flashing the field may be performed by momentarily connecting a 6- or 12-volt battery, with the proper polarity, across the slip rings. Check pole keys for tightness. Re-balance armature or rotor if vibration is excessive.

e. *Airgap.*–

Annual inspection.–Check airgap at four positions, 90° apart and re-center rotor if necessary. On horizontal machines, the bearings may need to be replaced if bottom airgap is appreciably smaller than the top.

f. *Air fans.*–

Annual inspection.–Check rotor fans for fatigue cracks. Check and tighten holding bolts or screws.

g. *Windings.*–

Monthly inspection.–Visual inspection for damaged insulation and dirt, oil, or moisture on winding.

Annual inspection.–Blow out dust with clean dry air at pressure not exceeding 40 lbs/in^2. Clean exposed parts of windings thoroughly with a nonflammable solvent, using suitable brushes for inaccessible places. Check for insulation deterioration such as tape separation, cracking, brittleness, or evidences of corona. Check insulation with Meggar or high-voltage direct-current method.

h. *Banding and lashing.*–

Annual inspection.–Check wire and string banding on direct-current armature windings. Check end turn lashing of alternating-current stator coils. Apply lashing if end turns vibrate excessively.

i. *Slot wedges.*–

Annual inspection.–Check slot wedges and replace loose ones. Tighten coils in slots by re-wedging if necessary.

j. *Commutator or collector rings.*–

Weekly inspection.–Check commutation or collector ring and brush operation. Wipe commutator or rings if needed. Have brushes replaced if worn too short.

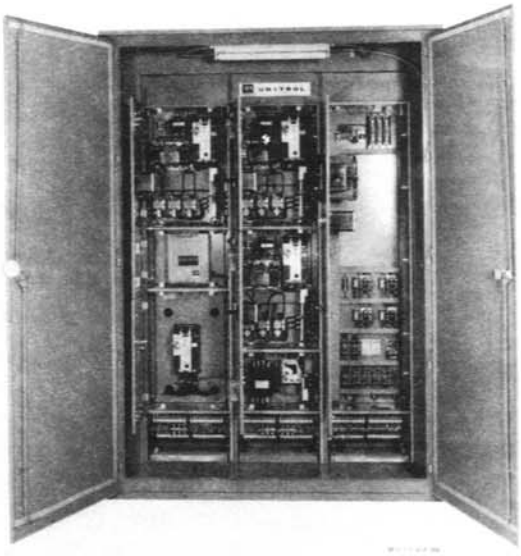
k. *Brushes.*–

Annual inspection.–Turn down, stone, or polish commutator or collector rings if grooved, rough, or eccentric. Undercut mica if high. If commutator or rings

have a good polish, they should not be disturbed. Check brush spring tension and brush fit. Tighten bolts, screws, and connections. Reset brush holders if not properly spaced. Check brush neutral position. Replace and sand in new brushes if needed. Clean up carbon or metallic dust.

l. *Temperature indicators and relays.*–

Annual inspection.–Check bearing and stator temperature indicators and relays for sticking, dirty contacts, etc. Check calibration if in doubt. Check water and oil flow or pressure gauges and relays for proper operation.



Motor controls.

1. Inspection Checklist

Items of inspection		
a. Knife switches		A
b. Fuses and circuit breakers		A
c. Contacts and shunts		A
d. Blowout coils and arc chutes		A
e. Solenoids		A
f. Operating shaft		A
g. Mechanical and electrical interlocks		A
h. Latches and trip devices		A
i. Auxiliary switches		A
j. Overload trip		A
k. Step starter timers		A
l. Compensator or autotransformer	*(see Chapter 15)*	
m. Miscellaneous control devices		A
n. Power supplies and wiring	W	A

W - Routine weekly inspection when in service.
A - Annual inspection.

a. *Knife switches.*–

Annual inspection.–Check hinges and clips for good contact. Tighten connections. Check door interlocks of safety switches if provided. Clean insulating base if dirty.

b. *Fuses and circuit breakers.*–

Annual inspection.–Check to see that fuse ratings agree with the ratings shown on the drawings. See that fuses are tight in the clips and contact surfaces are clean. See that renewable links are tight in holders. See that spare fuses are on hand. Where small enclosed circuit breakers are used for circuit protection instead of fuses, check mechanical operation of breaker and tighten connections.

c. *Contacts and shunts.*–

Annual inspection.–Dress contacts, if rough, with a fine file. It is necessary to remove only the projecting beads. Pits in a flat, smooth surface are not objectionable. Check for alignment and adjustment. Check rolling or wiping action and spring pressure. Check flexible shunts and replace if frayed. Tighten connections.

d. *Blowout coils and arc chutes.*–

Annual inspection.–See turns of blowout coils are not short circuited and that coil is properly assembled to blow arc outward, not inward. See that arc chutes are in good conditions.

e. *Solenoids.*–

Annual inspection.–See if coil is operating too hot and, if so, check resistance for possible short-circuited turns. Check alignment of matching faces of magnet frame. Check shading ring for open circuit. A noisy alternating-current solenoid generally indicates poor alignment or a broken shading ring, either of which will cause heating of the solenoid.

f. *Operating shaft.*–

Annual inspection.–See that shaft is free to move in its bearings, or rods are free in the guides.

g. *Mechanical and electrical interlocks.*–

Annual inspection.–See that interlocks are properly adjusted to prevent closing of both contactors, such as on a reversing starter, at the same time. Check enclosure door interlocks. Tighten operating arm supports.

h. *Latches and trip devices.*–

Annual inspection.–Check latches on latched-in contactors or manually operated starters for wear and insecure holding. (Check trip solenoid as in subparagraph e. above on solenoids.

i. *Auxiliary switches.*–

Annual inspection.–Clean and refinish contacts if corroded or pitted. Check spring pressure. Tighten connections. Check operating levers or linkage. Check closing and opening adjustment with respect to main contacts.

j. *Overload trip.*–

Annual inspection.–Check operating current and time delay of thermal or magnetic overload trip and see that it is correct for the motor or other equipment controlled. See that trip device functions reliably. Check time-delay dashpots for binding; leaking valves; and low, dirty, or incorrect oil.

k. *Step starter timers.*–

Annual inspection.–Dress contacts if rough with fine file. Pits in contact surfaces are not objectionable, but projections should be removed. Replace contacts if repairing is impractical. Check time-delay device used for controlling steps on multi-step starters to see that proper time delay is obtained and operation is reliable.

l. *Compensator or autotransformer.*–(*See Chapter 15.*)

m. *Miscellaneous control devices.*–

Annual inspection.–Check and clean contacts of control devices such as pushbuttons, time switches, pressure, vacuum or float switches, etc., and see that these devices are in proper operating condition.

n. *Power supplies and wiring.*–

Weekly inspection.–See that all power and control supply circuit switches are closed and fuses in place.

Annual inspection.–Check and tighten wiring connections at terminal points. Inspect wiring for open circuits, short circuits, and damaged insulation. Check insulation resistance of wiring with devices connected.

1. Inspection Checklist

Items of inspection		
Switchboards and control panels		
a. Panels and cabinets		A
b. Panel wiring and terminal blocks		A
c. Auxiliary and control relays	W	A
d. Control switches and pushbuttons	W	A
e. Indicating lamps	W	A
f. Meters and instruments	W	A
g. Position indicators	W	A
h. Protective relays	W	A
i. Test switches		A
j. Rheostats and resistors		A

W – Routine weekly inspection when in service.
A – Annual inspection.

a. *Panels and cabinets.*–

Annual inspection.–Repair finish and hardware, and clean up as necessary. Tighten bolts and screws. Check boxes and cabinets in damp locations for corrosion and rust. Clean and refinish as necessary.

b. *Panel wiring and terminal blocks.*–

Annual inspection.–Check for general housekeeping. Blow out wiring and equipment on back of panels with clean, dry, compressed air or use an industrial-type vacuum cleaner with nonmetallic hose fittings if available. Inspect wiring for open circuits, short circuits, and damaged insulation. Check insulation resistance of wiring or equipment on which the insulation appears to be questionable. Re-mark conductor tags or designations before they become obscure. Replace lost conductor tags. Tighten connections at terminal points.

c. *Auxiliary and control relays.*–

Weekly inspection.–Check condition of contacts wherever possible. Note whether coil temperature is excessive. Check noise and vibration of alternating-current contactor magnet frame and armature.

Annual inspection.–Dress contacts if rough with fine file. Pits in the contact surfaces are not objectionable, but projections should be removed. Replace contacts if repairing is impractical. Blow out dust, check arc chutes, blow out coils, and barriers. Tighten connections. Check contact shunts. Check contact spring pressure and contact wiping action. Check insulation between circuits or phases. Note whether operating coil temperature is excessive. Check alignment and vibration of alternating-current magnet frame and armature and examine shading ring.

d. *Control switches and pushbuttons.*–

Weekly inspection.–Try out operation of control switches or pushbuttons wherever possible to see if operation is correct.

Annual inspection.–Examine contacts and refinish with fine file if burned or corroded. Check contact operating cams, levers, or drums. Check contact spring pressure. Tighten connections. Examine insulation.

e. *Indicating lamps.*–

Weekly inspection.–Check lamps to see that they are not burned out, and replace as necessary.

Annual inspection.–Inspect indicating lamps, series resistors, and color caps. Check to see that each lamp gives correct intended indication. Tighten connections.

f. *Meters and instruments.*–

Weekly inspection.–Note sticking of moving element of indicating and recording instruments and watt-hour meters, unsatisfactory inking of record on recorders, and incorrect timing of recorder charts. Have these faults corrected at first opportunity.

Annual inspection.–Check calibration of important instruments and recorders or others suspected of being incorrect. Check watt-hour meters against rotating standard and adjust as necessary. Check to see that movement is free and unobstructed. Check pivots and bearings and repair or replace as necessary. See that cover gaskets are tight so as to exclude dust, dirt, moisture, and insects. Clean cover glasses using a damp cloth so as to avoid placing a static charge on the glass which affects the indication of some instruments. Check external resistors, reactors, and potential fuses. Tighten connections. Check wiring connections if any changes have been made in associated circuits or equipment.

g. *Position indicators.*–

Weekly inspection.–Note sticking pointers.

Annual inspection.–Check for correct positioning between transmitter and receiver. Check for friction and vibration of moving element and excessive heating.

h. *Protective relays.*–

Weekly inspection.–Visual inspection for anything unusual about contacts, coils, or moving elements. Check targets and reset them.

Annual inspection.–Dress contacts if rough with fine file. Pits in the contact surfaces are not objectionable, but projections should be removed. Replace contacts if repairing is impractical. Blow out dust, check arc chutes, blow out coils, and barriers. Tighten connections. Check contact shunts. Check contact spring pressure and contact wiping action. Check insulation between circuits or phases. Note whether operating coil temperature is excessive. Check alignment and vibration of alternating-current magnet frame and armature and examine shading ring.

i. *Test switches.*–

Annual inspection.–Check taps, resistor settings, or other adjustments against relay data sheets. Check setting for correct operation and adjustment as necessary. Examine moving parts and see that they are free and unobstructed. Examine relay and test switch contacts and refinish with fine file if burned or corroded. See that cover gaskets are tight so as to exclude dust, dirt, moisture, and insects. Note excessive heating of coils and resistors. Tighten connections. Check wiring connections if any changes have been made in associated circuits or equipment. Try out trip circuit, if possible, to see that relay trips all devices as intended.

j. *Rheostats and resistors.*–

Annual inspection.–Clean contact buttons and brush; check to see if corroded, burned, or cutting. Check brush and hub contact spring pressure. Check resistor elements for burned-out or corroded sections. Test insulation from line to grounded parts.