

MAJOR FOUNDATION REPAIR OF A TWENTY TON CENTRIFUGAL COMPRESSOR

by

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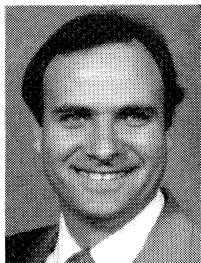
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Prior to joining Exxon, he spent 18 months in East Kalimantan, Indonesia (Borneo) with Roy M. Huffington, Incorporated, at the P. T. Badak LNG Plant as the Assistant Maintenance Manager and Logistics Manager.

Mr. Monroe has written several papers on turbomachinery subjects, pump installation, and grouting, and has contributed to books on the subjects of pump installation/commissioning and electric motors.

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ABSTRACT

In the course of purchasing, installation, and startup of turbomachinery, much attention has been given to process design, machine design, piping design, control systems, and economics. Oftentimes however, there is a lack of attention given to the intricate details of foundation grouting. In order for high speed turbomachinery to perform to its optimum design, the machines must stand on a firm and strong foundation. Grouting of heavy equipment is no small task and should not be taken lightly. Much research and development has been provided by the manufacturers of the epoxy systems, and many hours have been invested in perfecting the grout installation procedures.

The intent herein is to show the reader that the foundation grouting procedures of such machinery is a major step of a project and not a minor one. The presentation will define a step by step process of foundation grouting. It will also include the necessary steps of preplanning and scope development, writing of the specifications, and coordination of all craft disciplines performing the work. It is hoped the reader will understand the value and extreme importance of preplanning and scope development for a job of this nature and realize that one must pay particular attention to details.

Included is an APPENDIX entitled "Preparation and Specification for Epoxy Grouting." This specification was written specifically for this machine; however, one can alter it to meet the needs of a particular situation.

INTRODUCTION

To best illustrate proper grouting procedures, the reader will be taken through a foundation rebuild of a steam turbine driven four stage centrifugal air compressor. It is referenced as the South Process Air Compressor (PAC). The weight of the compressor itself is about 20 tons. The installation of the compressor and the turbine took place in 1974. The condition of the foundation in 1990 is shown in Figures 1 and 2. A small hammer was used to hit part of the grouting near the steam turbine foot (Figure 3), and it easily broke off. The jack hammering effort to remove this grout took approximately one day; the authors had planned three days to do the job. Upon removal of the grouting it was obvious that the

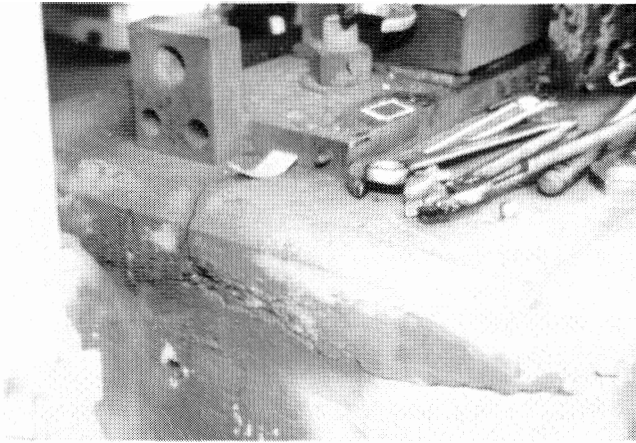


Figure 1. Cracking in the Grout After 15 Years of Service.

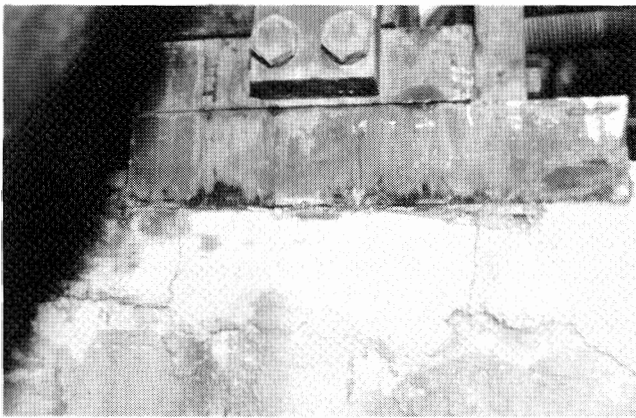


Figure 2. Soleplates with Squared Corners.

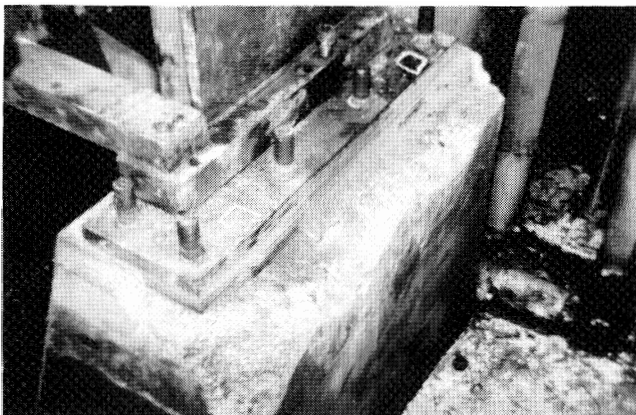


Figure 3. Grout Was Broken Easily with a Strike of a Hammer.

foundation had not been properly prepared, as well as the corners and bottom of the soleplates had not been rounded, forming stress risers.

One of the problems encountered with this machine was the vibration response. When the machine was ramping through the critical at around 3400 rpm during startup, the vibration levels on the turbine inboard would surpass three mils, causing it to trip. The trip switch for the turbine inboard horizontal proximity probe was jumpered in order to get the machine to start up. It was known that

the rotors were out of balance, and is obvious in the photographs, the condition of the foundation did not help matters. The compressor and turbine were removed and sent to outside shops for repair (i.e., balance, bearings replaced, clearances checked, etc.). The machinery repair is a different subject; this presentation will focus on the regrouting of the foundation.

PREPLANNING AND SPECIFICATION

The foundation repair of the South PAC was part of a major shutdown involving the catalyst changing of two reactors. When the job scope was developed for the foundation regrouting and turbine/compressor repair, its duration was determined to be approximately 25 days, which made it the critical path for the turnaround. The important thing to note is that the shutdown personnel had to understand the nature and scope of this job and what craft disciplines had to be coordinated. The disciplines included the millwrights, who removed and reinstalled the compressor and turbine and performed the foundation rework. It involved the instrument and electrical crafts, who disconnected the machinery before removal and hooked it up upon reinstallation. It included the contractor that did the rigging and lifting, which definitely had to be coordinated in that this particular contractor was a major player in the overall turnaround.

The writing of the grout specification for this particular job was somewhat difficult, yet easy. Difficulty came in that the writer did not have any experience on a job of this nature. Many people in the chemical industries find themselves responsible for major work of this caliber, yet do not have the hands on experience to take on such a job. What is important for one to remember when a job of this nature is at hand is to utilize the resources that are around them. The grout manufactures have a great deal of expertise concerning the installation of their product. Also, the more progressive grout manufactures most likely have a procedure already written. Other resources may include professional societies such as the Vibration Institute, ASME, or the Turbomachinery Laboratory (Texas A&M University) Symposiums. Other resources to utilize are turbomachinery consultants.

The specification that was written for this job was basically a combination of three procedures that were already in hand. One was written by coauthor Perry Monroe, the other two were provided by grout manufactures. Those procedures were altered to fit this particular job application. Before this procedure was issued for work, it was reviewed and refined by Monroe.

COORDINATION MEETING

The success of the South Process Air Compressor overhaul/regROUT job can be credited to the preplanning and coordination (among all crafts) that was conducted prior to and during the shutdown. Twelve days before the scheduled shutdown, a meeting was held that included the Area Maintenance Engineer Supervisor, the I&E Supervisor, the Shutdown Superintendent, the Rotating Equipment Engineer, the Mechanical Foreman, the Contract Millwright Supervisor, the Contract Grouting Consultant, and three representatives of the epoxy grout manufacturer. One thing to acknowledge is the Contract Grouting Consultant (Monroe) was to be onsite to oversee the foundation preparation and grouting. He was empowered by the client in the decision making process.

During the meeting, it was learned that the grout representative would be out of town during the scheduled time of the grout pour. Arrangements were made during the meeting to move the shutdown up four days, so key people could be present at the grout pour. All possible problems that might occur during the shutdown that would delay the startup were discussed and contingency plans made. For example, it might rain, so plans were made to construct a tent over the compressor foundation area after the steam turbine

and compressor were removed. During the meeting, it was agreed that an optical alignment crew would be brought in to establish an optical reference system, so the mounting rails could be regROUTED at the existing locations.

PRESHUTDOWN WORK

Four days before the revised shutdown date, the optical crew came into the plant and established a reference system that located the mounting rails to remote data points (Figures 4, 5, and 6). Once the reference system was established, "HOT" optical alignment data were taken as the compressor ran, in order to determine the amount and direction of thermal growth. These readings would be compared to "Cold" optical alignment readings taken after the compressor had been shut down and adequate time was allowed for cooling. Prior to taking the optical readings, a "PEG" test was conducted on the optical scope to determine the accuracy of the precision scope level. The scope was off 0.009 in in 50 ft, so it was recalibrated to 0.000 in per 50 ft. *Always request a "PEG" test at the job site prior to obtaining optical alignment readings.* Optical reference plates were attached to the bottom of the compressor concrete foundation using drop-in anchors (HDI) (Figures 7, 8, 9, and 10).

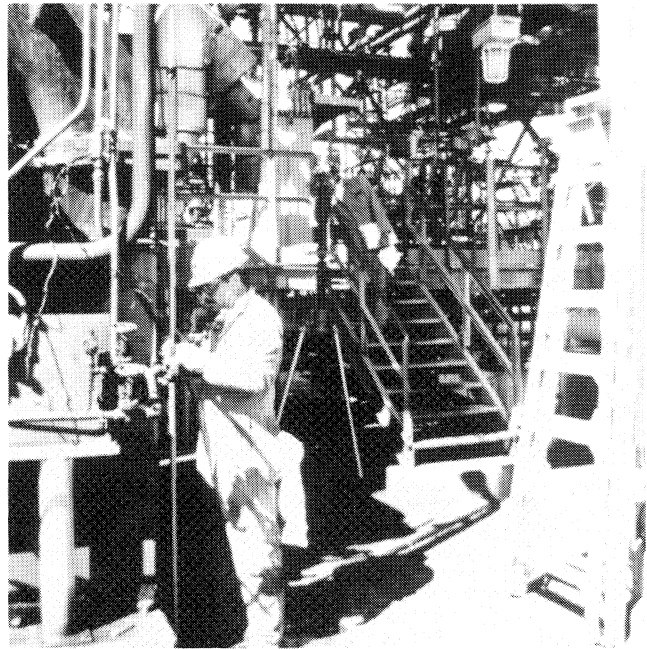


Figure 5. Optical Measurements Taken.



Figure 4. Benchmark Determined for Optical Alignment.

Optical Alignment Procedure [1]

For this project, two different telescopic instruments were used to obtain cold and hot readings on machinery. To obtain horizontal data, a telescopic transit square was used to plunge a vertical plane along the two sides of each unit. The transit was adjusted to read through two fit reference points. Optical scales were extended from each data point along the machine train to coincide with the

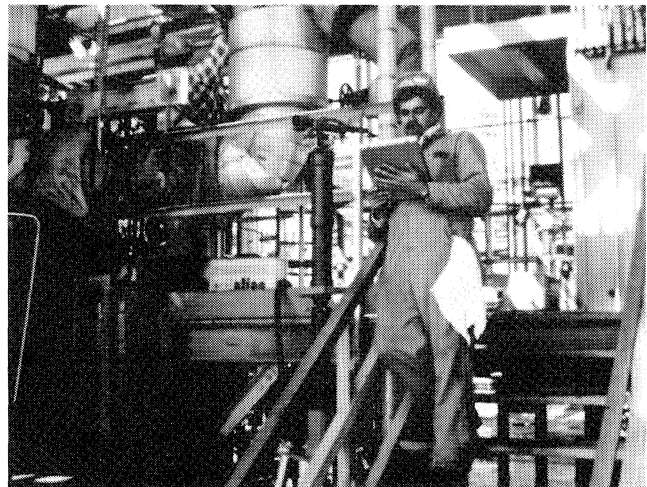


Figure 6. Optical Data Recorded.

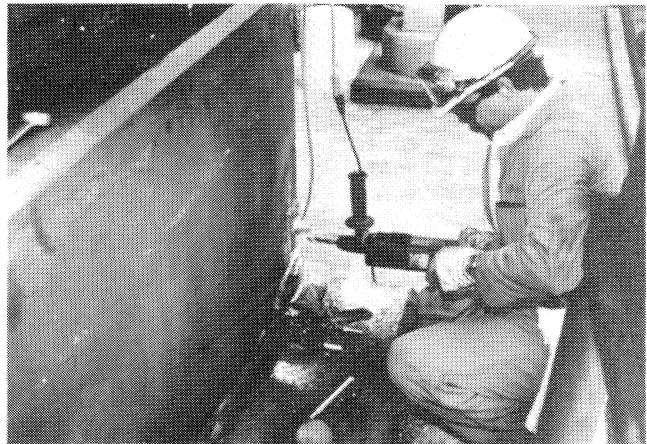


Figure 7. Foundation Drilled for Optical Reference Plates.

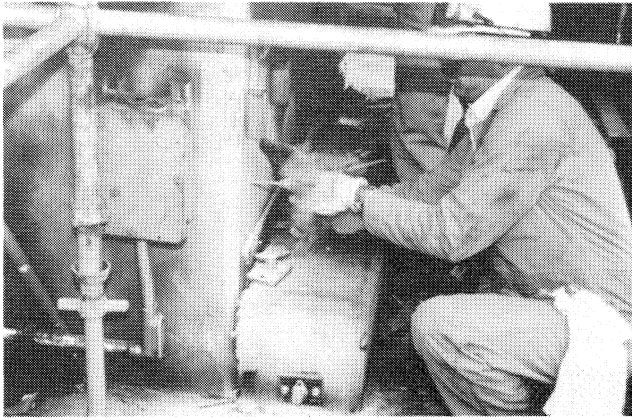


Figure 8. Hole Cleaned Before Anchor Is Inserted.



Figure 9. References Established on the Soleplates.



Figure 10. Reference Plate in Use.

line of site. The same line of site is repeated for the follow up set of data acquisition, be it hot or cold.

A precision site level was used to establish a horizontal plane from which a vertical data was taken. The level was set up at different location around the machine train and reference to a predetermined bench mark. Optical scales were extended vertically from each datum point to coincide with the line of site. Since the horizontal planes are reference to gravity, they are all parallel to each other and in the final data reduction are adjusted with one line of site.

A reference elevation was established in order to reset the turbine split line on the same horizontal plain it was on prior to its

removal. Two pieces of data were tied together to set the soleplates. The split line to the bottom of the support feet measurements and the amount hard shin desired under each support were determined. Reference bench marks were also set up in order to locate the soleplates, actually prior to grouting them..

Optical Instrumentation [1]

The instrumentation utilized to take these optical readings involved a telescopic transit square, a precision site level, optical tooling scales, and holder system.

A telescopic transit square was used to obtain the horizontal and actual data. The transit was an optical tooling instrument used to establish an align of site which can be reestablished time after time without variation and position. The transit's main barrel is set up to plunge a precise vertical plane measure displacement from the line of sight. A device called a reticle is used to provide a reference by means of which readings from scales or targets can be made. The physical position of the reticle is fixed by the construction of the telescope and the image of the target is caused to form in the plane of the reticle.

The level's construction is similar to that of the transit, with the exception that the barrel is set up to rotate on a precise horizontal plane. A coincidence vial is used in conjunction with a precision vertical tilting screw to accurately locate the line of sight perpendicular to gravity.

The scales are hardened tool steel and are comprised of a series of paired-line graduations at 1/10 in intervals. The scales are manufactured to be interchangeable.

The scale holder and extension system is used to get the optical scale to coincide with the telescopic line of sight. The holder system is usually comprised of a one inch stainless steel cylinder made to adapt to a dowel pin which is located on the machine surface. A one-half inch tooling ball is adapted to the holder to provide a measurement surface from which a vertical or horizontal reading can be obtained. These holders are interchangeable. The scale extension system is made up from a set of invar tubing in five, ten, and twenty inch increments. These rods are manufactured to meet length specifications traceable to the National Bureau of Standards. An adapter screws into the end of the tubing and forms a uniform fit on the tooling balls.

While the optical reference system was being established, the grout consultant designed a lifting cradle that would support the 20 ton compressor during the precision mechanical alignment operation after the regout job. Hand sketches were given to the welder who fabricated the cradle (Figure 11). A detailed check list was also written to cover the modifications required on the compressor and steam turbine mounting rails. Each rail needed all sharp edges removed which included radiusing all corners and cutting a 45 degree bevel on the bottom. Jack bolt holes ($\frac{1}{2}$ in NC) had to be

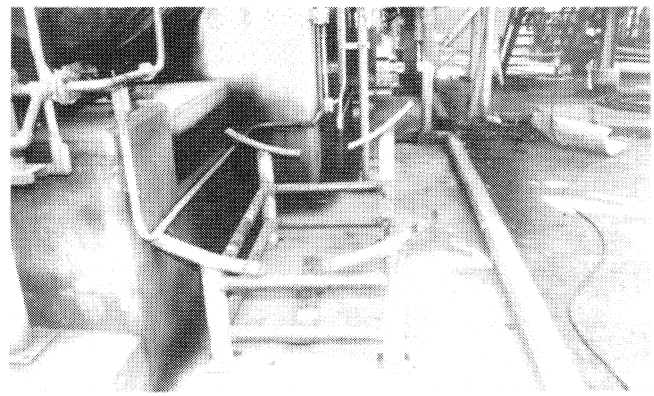


Figure 11. Cradle to Support the Compressor for Alignment.

drilled and tapped in each rail prior to machining the top surface to 0.0005 in flat. The last step was to sandblast to white metal and prime all the rail surfaces that would contact the epoxy grout with rust inhibitive primer. None of this work could be performed until the rails were chipped from the old grout. The plant machine shop was notified of the work scope and the estimated time of rail availability so the machine tools could be ready.

DISMANTLEMENT

Shutdown

Day 1: At 07:40 hours, the team learned that the steam turbine was still on slow roll; too hot to take cold optical readings. At the first crack out of the box, they had their first chance to use one of the contingency plans. Since the turbine was hot, the optical crew started to take vertical reference readings of the compressor mounting rails (the compressor was cold) (Figures 12 and 13). Late in the afternoon, vertical readings were taken on the turbine mounting rails, and the compressor/turbine mechanical alignment was taken with a laser alignment indicator.

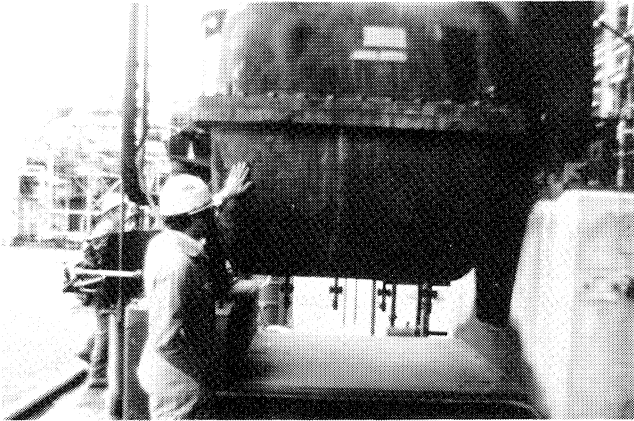


Figure 13. Technician Taking Vertical Readings.

The millwright crew started removing the inlet air filter (Figure 14), the upper decking, and inlet piping. None of the pipe removal affected the optical work, because of the rubber expansion joint on the inlet line. Instrument and electrical technicians started removing all wiring to facilitate the compressor/turbine removal. About two to three days of work had to be done to clear piping, conduit, and structural steel before the turbine or compressor could ever be lifted, therefore, no shutdown time was lost.

Day 2: The vertical readings on the turbine were checked first thing and revealed a 0.033 in parallel rise of the turbine instead of

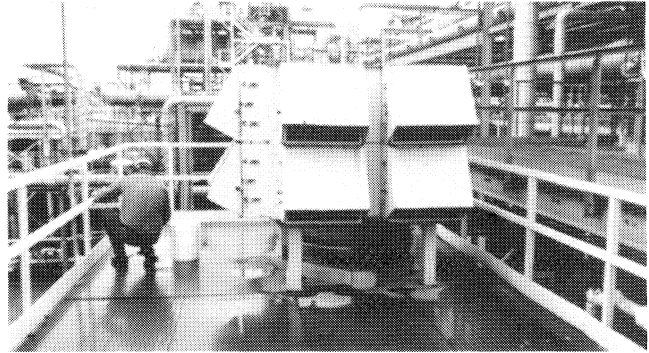


Figure 14. Inlet Air Filter to the Compressor Being Removed.

the 0.011 in rise measured the day before. It appeared that the grout cap (when hot) raised more than the legs of the turbine and explained the difference in thermal rise measured by the X ball method. The X reference balls were installed in the hot zone of the grout cap and measured relative growth of the turbine to the top of the grout. The optical reference system used measured both the turbine growth and the grout growth. *When taking thermal growth readings, be sure the reference data benchmarks are located in an area not affected by mechanical or thermal movement.* By the end of the day, all the mounting rails had been located vertically, horizontally, and axially to the optical benchmarks to a tolerance of 0.002 in (Figure 15).

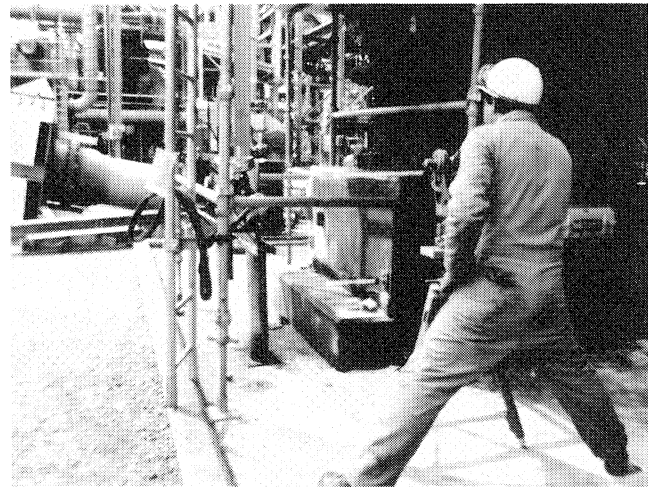


Figure 15. Final Readings Taken of the Soleplates.

Day 3: All the piping, decking, and wiring had been removed around the compressor, so a 65 ton hydraulic crane (Figure 16) was moved into position. The lifting crew rigged the compressor but the Grout Consultant did not like the setup, and stopped the lift. The Area Maintenance Engineer Supervisor, was notified and changes were made in the rigging. The compressor was lifted without any problem once correctly rigged (Figure 17). Because of the tight space, there was only one way the compressor and turbine could be removed. Pictures were taken of the entire operation to provide training for the crew who will perform the same work on the North PAC. A detailed sketch of the rigging/lifting requirements was later provided by the lifting crew and put in the planning package. The compressor was loaded onto a flatbed trailer and taken to a local shop for overhaul. A plant machinery engineer followed the shop repairs while the foundation work continued.

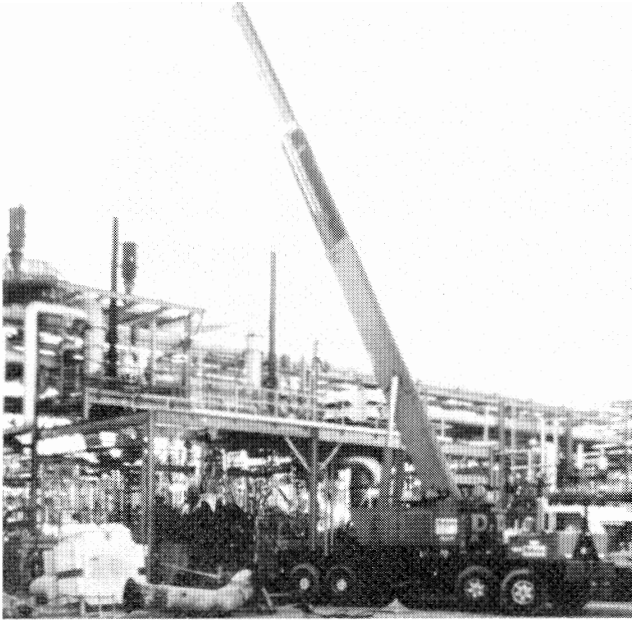


Figure 16. A 65 Ton Hydraulic Crane Was Used to Lift the Compressor.

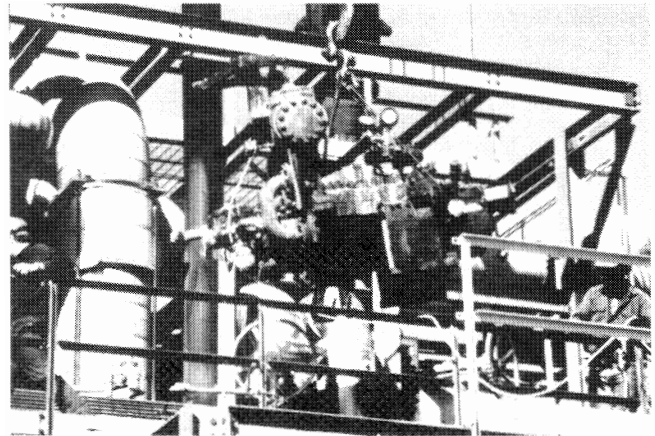


Figure 18. Rigging and Lifting of the Steam Turbine.

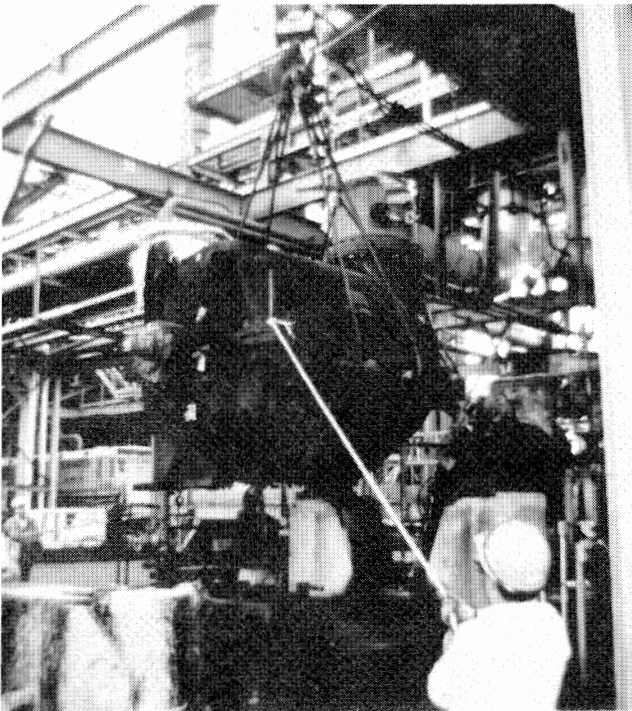


Figure 17. Correct Rigging of the Compressor.

FOUNDATION PREPARATION AND EPOXY GROUTING

Day 4: The turbine was rigged, lifted (Figure 18), and placed on a flatbed trailer for shipment to a local shop for repairs. A contract machinery engineer followed the repair of the turbine. After the removal of the compressor and turbine, the millwright crew started chipping out the old grout. Chock blocks (Figure 19) were used to level the soleplates which caused the soleplate to rest on the chock blocks and a good bond between the grout and the soleplate did not

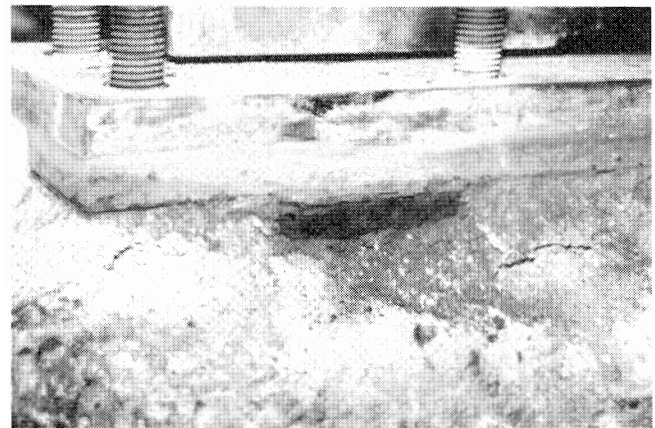


Figure 19. Soleplate Resting on the Chock Block, Not the Grout.

take place. Several days had been scheduled for grout removal because the old grout was epoxy, but the crew finished the job in one day. The best method to remove old epoxy grout is shown in Figure 20. Chip out the concrete under the grout to break the epoxy bond and then break off pieces of the grout (Figure 21).

Day 5: After the grout and mounting rails were removed, it was discovered that epoxy grout had filled the anchor bolt sleeves (Figure 22). This grout must be removed in order for the anchor



Figure 20. Chipping of Existing Grout Should Begin between the Concrete and the Grout.

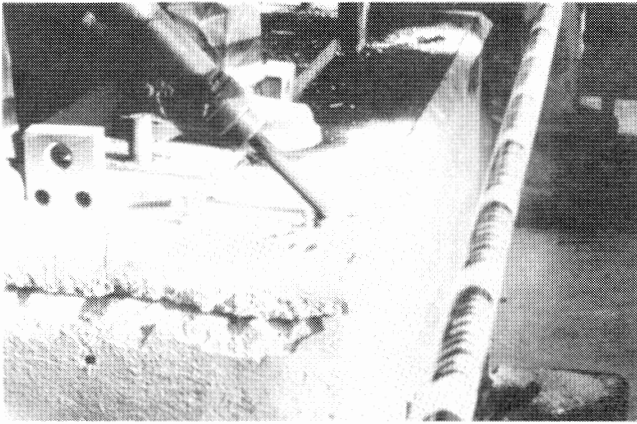


Figure 21. Chip Off Pieces of Grout after Breaking the Bond with the Concrete.



Figure 22. Anchor Bolt Sleeves Were Filled with Grout. Not a good practice.

bolts to have five to ten bolt diameters of free length to elongate when the bolt is torqued. The millwrights used a trepan tool powered by a electric drill to cut an annulus around the anchor bolts to a 10 bolt diameter depth (Figures 23, 24, 25). All the mounting rails were taken to the plant machine shop for modifications per the check list.

Day 6: While the anchor bolt trepanning operation continued, the Grouting Consultant and the Millwright Supervisor went by the machine shop to see how the mounting rail modification work was progressing. They also went by the warehouse to verify that the epoxy grout had been received and stored properly. Arrangements were made to rent, and have delivered, a mortar mixer for the epoxy grout. The scaffolding crew constructed a tent over the foundation area to protect the freshly chipped concrete from rain (Figure 26). The two enemies to a good bond between epoxy grout and concrete are moisture and oil. The tent would prevent moisture (rain) from contaminating the concrete and any oil stained concrete was chipped away. During the concrete inspection, oil stains were found on the high pressure end of the turbine and had to be chipped away (Figure 27). Once the concrete was clean, it was sealed with a coat of epoxy primer (Figure 28). A die-nut was used to chase the threads on all the anchor bolts (Figure 29).

A meeting was held at 14:00 hours to discuss the optical alignment readings and determine the mounting rail elevations. After reviewing the readings, it was decided to add a 0.250 in shim

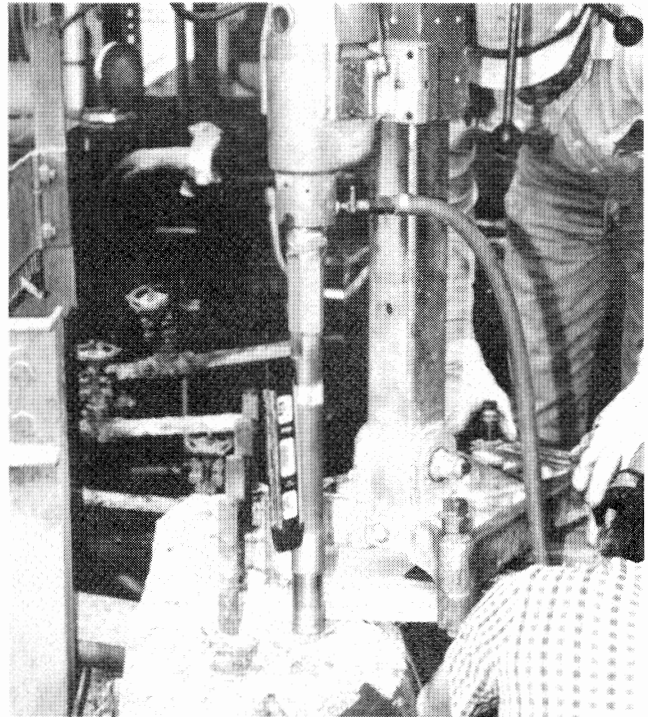


Figure 23. Electric Drill Used to Power the Trepan Tool.

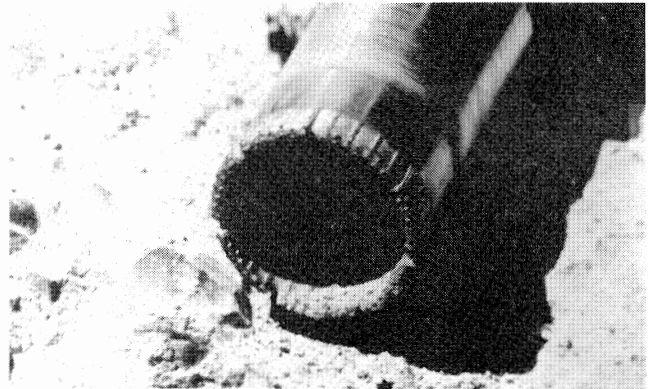


Figure 24. Trepan Tool Used to Cut the Annulus around the Anchor Bolt.

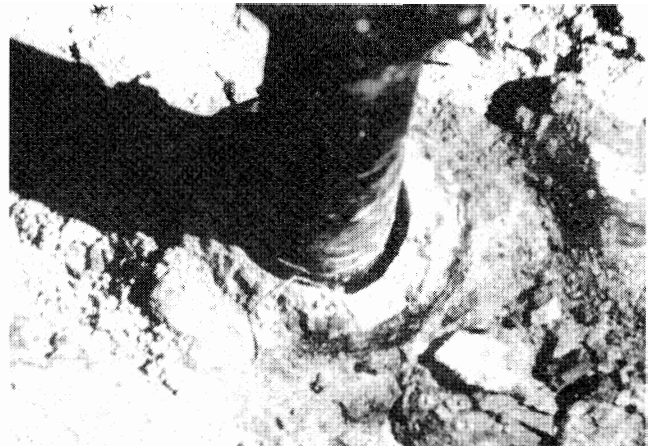


Figure 25. View of the Anchor Bolt after Cutting the Annulus.

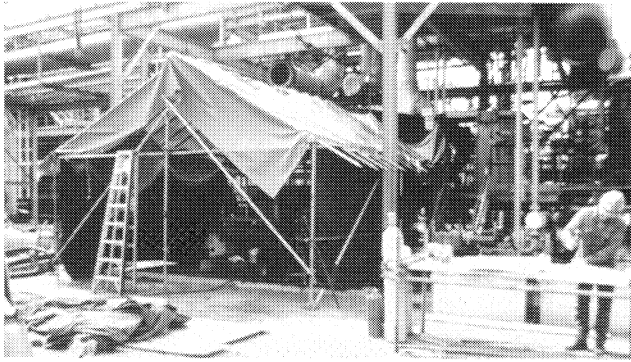


Figure 26. Tent Constructed to Protect the Foundation Area from Rain.



Figure 27. Chipping Away of the Oil Stained Concrete.



Figure 28. Epoxy Primer Coating Placed on the Clean Concrete.

under each foot of the compressor and a 0.125 in shim under each turbine foot to aid mechanical alignment. A typical alignment graph is shown in Figure 30—in this case, the final alignment of the turbine/compressor train.

Day 7: A carpenter crew began making the grout forms for the outboard end (OB) compressor mounting rail (Figure 31), while waiting for the mounting rail to be delivered from the machine shop. Rough measurements taken of the rail elevation prior to removal, enabled the carpenters to fabricate the grout forms without the compressor OB mounting rail being installed. The surfaces of the forms that would contact the epoxy grout were waxed three times with floor paste wax, allowing the wax to dry between each coat (Figure 32). If this procedure is not followed, the wooden forms will stick to the grout.



Figure 29. Die-Nut Used to Chase the Anchor Bolt Threads.

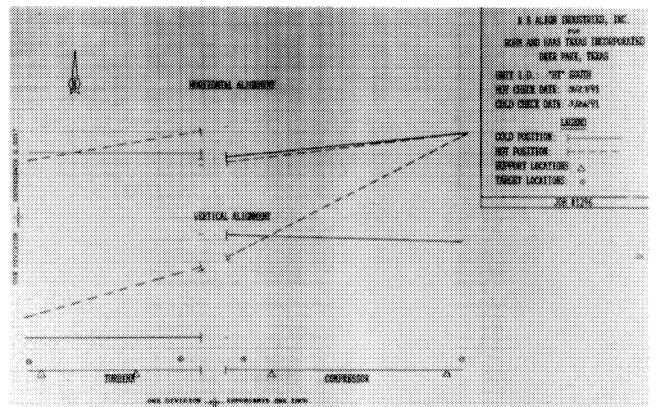


Figure 30. Typical Alignment Graph Showing the Final Alignment of the Turbine/Compressor.



Figure 31. Grout Forms Constructed around the Compressor Outboard Soleplate.

While the forms were being waxed, the millwrights installed the O.B. compressor rail and the 2.0 in dia. plates the jack screws would rest on (Figure 33). The jack screw plates were mounted on epoxy putty and leveled in two directions to 0.0005 in/ft. The epoxy putty hardened in two hours and helped to maintain the correct rail elevation while horizontal and axial adjustments were made. The optical crew is shown in Figures 34 and 35 locating the rail to the original position to a tolerance less than 0.002 in. It was possible, with the use of optics, to detect the wear of the cutting tool

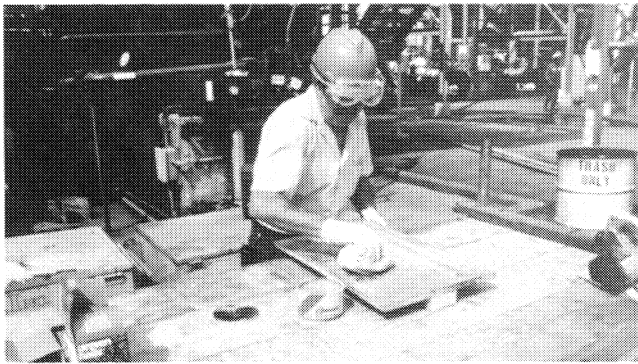


Figure 32. Three Coats of Paste Wax Placed on the Form That Will Contact the Grout.

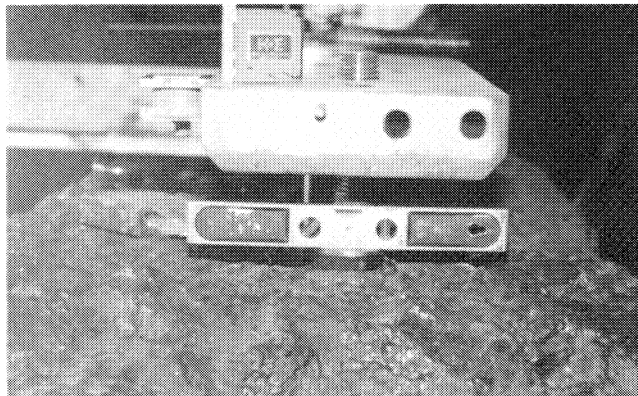


Figure 33. Jack Pads, 2.0 In Diameter, Where the Jack Bolts Will Rest Supporting the Soleplate.

during the machining operation because the south west corner of the rail was 0.004 in higher than the other three corners. This corner was left 0.004 in high, because the compressor foot area would be on the flat portion of the rail. The other three corners



Figure 34. Soleplate Being Positioned in the Horizontal Plane.



Figure 35. Soleplate Being Positioned in the Vertical Plane.

were set at zero. After the OB compressor rail was positioned and leveled, the carpenters finished forming the rail before leaving for the day.

Day 8: The Millwright Supervisor and the Grouting Consultant checked the mortar mixer that would be used in the afternoon to mix the epoxy grout. Arrangements were made to have a five gallon can of gasoline and a fire extinguisher at the mixing site during grout placement. A tour through the machine shop revealed the coupling end steam turbine rails were ready and the hot end steam turbine mounting plate was on the final cut. The finished rails were taken to the sandblast yard for the blasting of the surfaces coming in contact with the epoxy grout.

While waiting for the rails at the machine shop, the optical crew checked the elevation of the compressor north coupling end rail and found it to be 0.003 in lower than the readings taken the afternoon before. The temperature was much cooler than the day before so the rails were not changed. There were problems in leveling the south coupling end compressor rail, because the circular jack bolt plates were not level, so epoxy putty was applied and the plates were releveled.

At 10:00 hours, a minigrout seminar was conducted by the Grout Consultant for everyone participating in the mixing and placing of the epoxy grout (Figure 36). During the seminar, the problem of the concrete foundations supporting the coupling end compressor rails was discussed. The concrete was not wide enough to provide the 2.0 in embedment required on the east side, so it was decided that epoxy grout would be used to embed the rails. Details are shown in Figure 37. After the grout seminar and lunch, the crew installed and leveled the south coupling end compressor rail and the north coupling end steam turbine rail. Because of the lateness of the day, the grouting operation was postponed until the next day. The crew had problems positioning the turbine rails because the



Figure 36. Classroom Training Was Conducted Before the Actual Grout Pour.

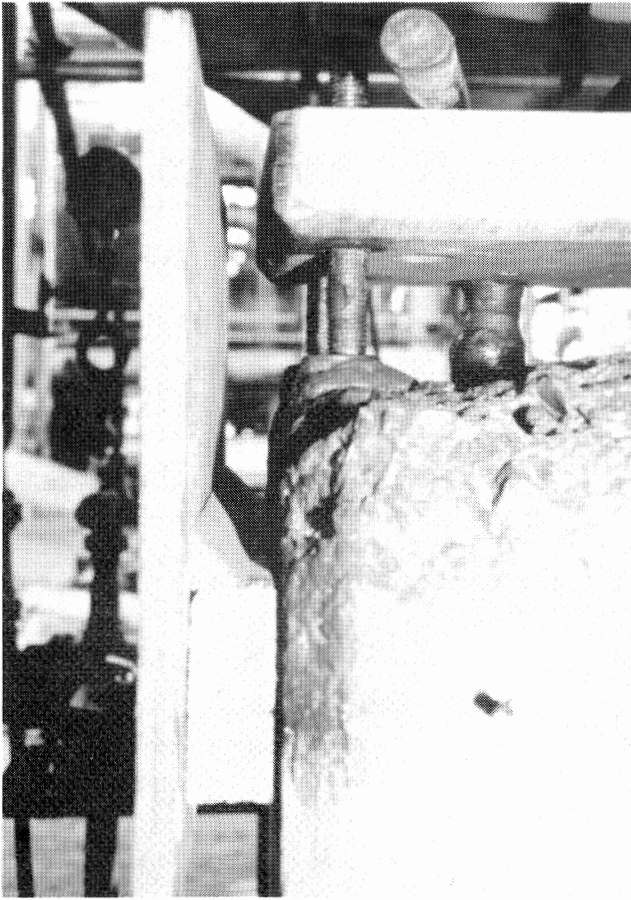


Figure 37. Forms Were Spaced to Provide 2.0 In Embedment of the Rail.

anchor bolts were bolt bound so a note was made to increase the anchor bolt holes 1/8 in on future jobs. The north coupling end turbine rail was leveled before the end of the day.

Day 9: As the carpenters formed the north IB turbine rail, the optical crew positioned and leveled the south IB turbine rail. The hot end turbine soleplate was last to be installed and leveled. All grouting forms were finished by 15:00 hours (Figure 38) and the crew was given a long break in preparation for the grout pour.

The epoxy grout had been stored inside the warehouse until the last minute and was then placed at the mixing site. Grouting material was placed in rows with the one can of epoxy resin, one can of epoxy hardener, and five bags of aggregate to the row

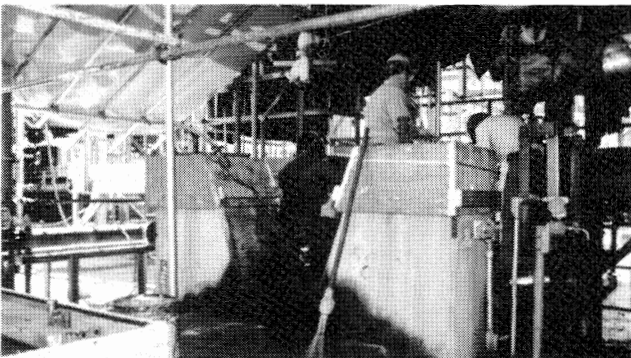


Figure 38. Forms Complete and Ready for Grout Pour.

(Figure 39). It is recommended that a “jiffy-mixer” (Figure 40) be used to blend the epoxy resin and hardener for three minutes. The last thing to be done before mixing the grout was to blow out the formed areas with oil-free air to remove any loose dirt and debris.



Figure 39. Grout Material Staged by Volumetric Unit.

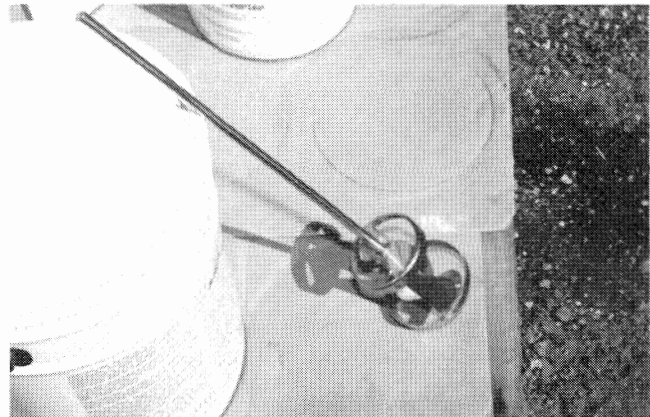


Figure 40. “Jiffy-Mixer” Used to Blend Resin and Hardener.

The grout mixing began with the placement of the epoxy hardener into the can of resin and blending with a jiffy-mixer for three minutes. Once the epoxy was mixed, the catalyzed mixture was poured into the hardener can (Figure 41) to catalyze the unreacted hydrocarbon, preventing an EPA disposal problem. Both cans of epoxy were emptied into the mortar mixer and the aggregate was added to the epoxy. Rotating speed of the mortar mixer blades should be between 15 to 30 rpm. A half bag of aggregate should be cut from the first unit of grout mixed in the mortar mixer, because some of the epoxy is lost wetting the mixer walls and blades. The aggregate should be poured into the mixer slowly to allow the air trapped in the bag to separate (Figure 42). This prevents air bubbles in the grout which reduces the load bearing area. The epoxy and aggregate were blended until all the aggregate was wetted and the mixture was dumped into a large wheelbarrow for placement. The epoxy cans were used to place the grout in the forms, pouring from one side and allowing the grout to flow under the rails until the forms were full (Figures 43, 44, 45, and 46). Six units of epoxy grout were mixed and placed in 1 hour and 27 minutes. High pressure water was used to clean the mortar mixer and tools immediately after placing the epoxy grout. After cleaning up, the remaining grout was placed inside the tent and the crew was secured for the day.

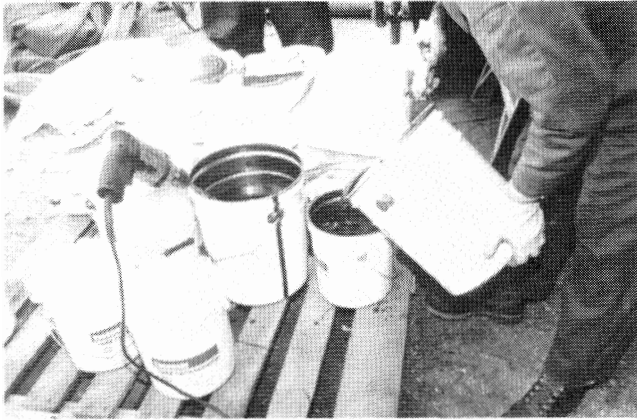


Figure 41. Catalyzed Mixture Poured Back Into Hardener Can to Prevent EPA Disposal Problem.

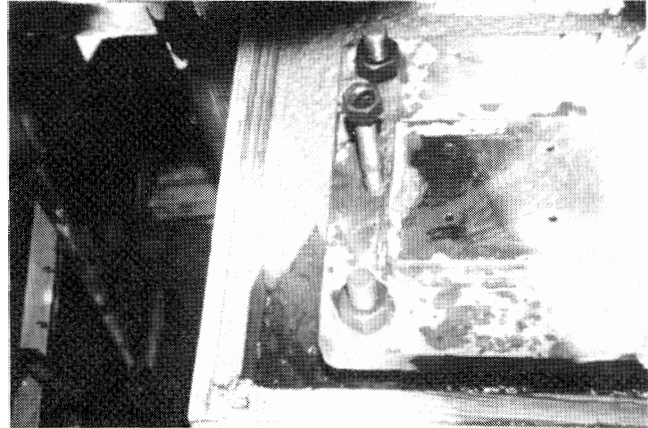


Figure 44. Time Allowed for the Grout to Flow under the Rails.

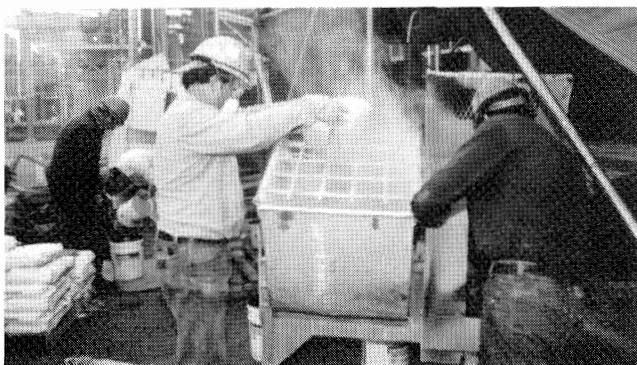


Figure 42. Aggregate Poured into Mixer, "Slowly."



Figure 45. Grout Again Being Poured So It Could Flow under the Rails.



Figure 43. Grout Being Poured from Only One Side of the Forms.



Figure 46. Site Engineer Just Couldn't Stay Out of the Way.

POSITIONING OF MACHINERY AND REALIGNMENT

Day 10: It took the crew only 15 minutes to strip the forms from the foundations (Figure 47). One man started removing the jack bolts (Figure 48) and tightened the anchor bolts to their full torque (Figure 49). While the millwrights worked on the rails, a scaffold crew removed the tent and a warehouse man moved eight units of grout to the warehouse. Since the compressor would be the first piece of equipment installed, the millwrights prepared the compressor rails first. All the jack bolt holes were degreased and filled

with RTV silicone adhesive to prevent contaminants from reaching the concrete foundation (Figure 50). The mounting surfaces of all rails were hand stoned and checked for level with a Starrett 98 level. Notice in Figure 51 that the bubble centered the indicating marks. Molybdenum disulfide dry lubricant was burnished into the metal surfaces of the rails and shims to aid in moving the compressor and turbine during mechanical alignment (Figure 52).

At 13:00 hours, the 65 ton hydraulic crane was positioned on the east end of the compressor foundation and made ready to lift the compressor. The compressor arrived at the plant site at 13:30 hours and was on the "hook" by 14:25 hours (Figure 53). Once the compressor was in the air, the mounting feet were stoned and

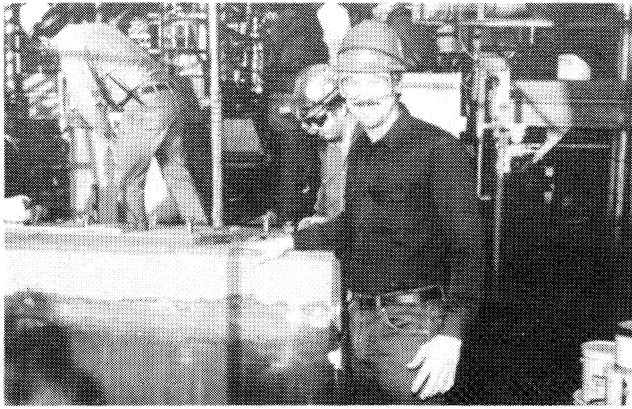


Figure 47. Forms Being Removed (and a Proud Contract Millwright Supervisor).

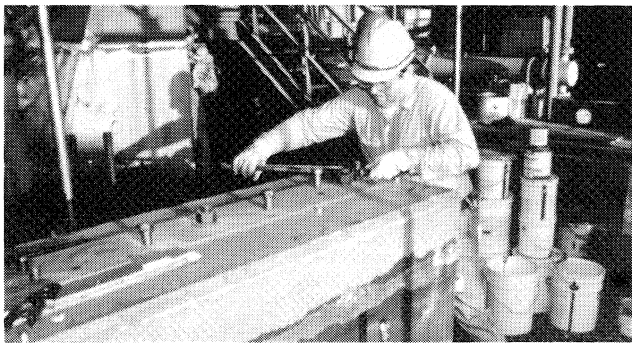


Figure 48. Jack Bolts Being Removed.

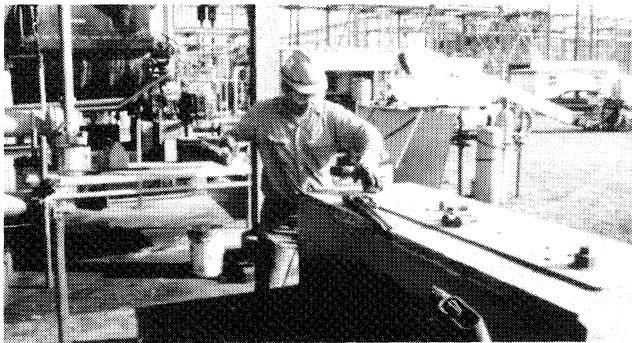


Figure 49. Anchor Bolts Tightened to Full Torque.

cleaned (Figure 54). Shims were placed under each foot and the compressor was lowered to the rails by 14:50 hours. The optical alignment crew had recommended the shim thicknesses to be used before lunch. As the rigging crew removed the last lifting sling, the crew noticed the compressor casing was contacting the grout on the north side coupling end rail (Figure 55). The compressor was lifted and the area relieved by grinding (Figure 56) while the compressor remained on the "hook." The height of the grout had been raised to within 1/4 in of the top of the rails, not knowing this would cause the compressor case to contact. The crew reacted to this unforeseen problem admirably, corrected the problem, and had the compressor back on the rails by 15:30 hours. The special lifting gig made earlier in the shutdown was positioned under the compressor and was fitted by the welder to the contour of the compressor.

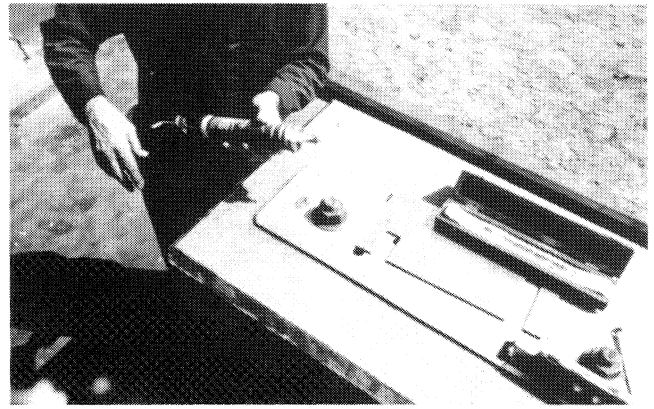


Figure 50. Jack Bolt Holes Degreased and Filled with Silicone Adhesive.

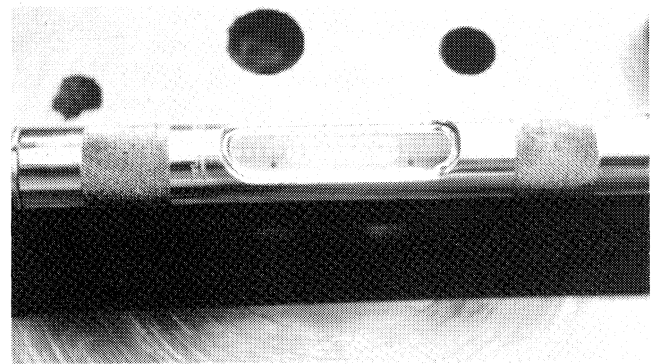


Figure 51. Soleplate Level Demonstrated.

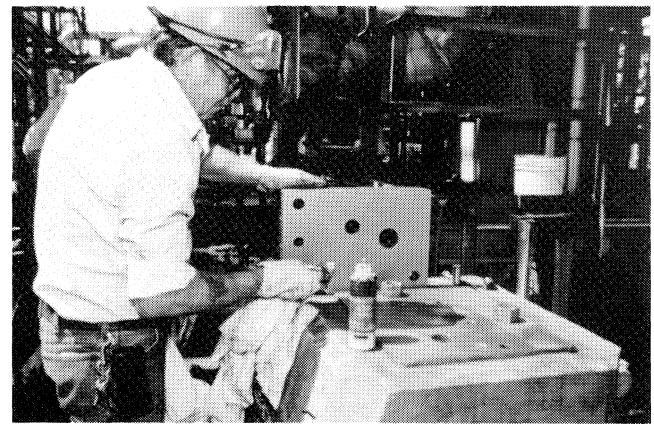


Figure 52. "Z" Powder Burnished into Surfaces of Rails.

Day 11: The compressor piping and decking above the compressor were installed (Figure 57) and part of the crew worked on smoothing the concrete at the epoxy grout bond line with epoxy putty and a grinder. Target alignment data were calculated and everything made ready to align the compressor train once the turbine arrived. The turbine arrived at site at 15:15 hours and the riggers started attaching slings. While the riggers worked, the Millwright Supervisor discovered cracks in both the steam pipe nozzles in the top half of the turbine case. Lifting was halted while the appropriate people were contacted and the decision was made to ship the turbine back to the repair shop.



Figure 53. Compressor Being Lifted into Place.

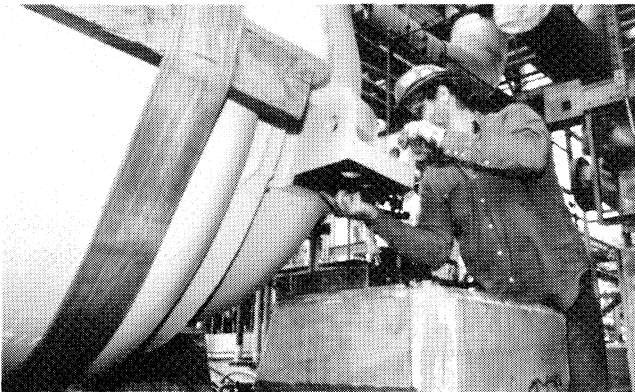


Figure 54. Compressor Feet Stoned and Cleaned.

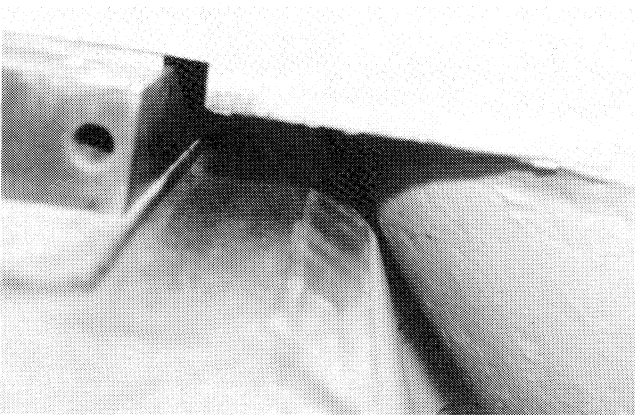


Figure 55. Compressor Case Contacting the Grout.

A meeting was held with the shutdown team to develop a plan of attack for repairing the steam nozzles. Metallurgical help was obtained and the plan was to X-ray the flanges. If they were shallow, the cracks would be radius. If the cracks were deep, they would be ground out and weld repaired. A metallurgist went to the repair shop to follow the repairs through the night.

Day 12: The metallurgist reported that one crack was 11/16 in deep and the other crack was 1/2 in deep. NDT had to be used to detect the crack depth, because the flange was 3.0 in thick and the X-ray pill would not penetrate the wall thickness. Both cracks were ground out and weld repaired. Since the crack depth was less than 20 percent of the wall thickness, stress relieving was not necessary.

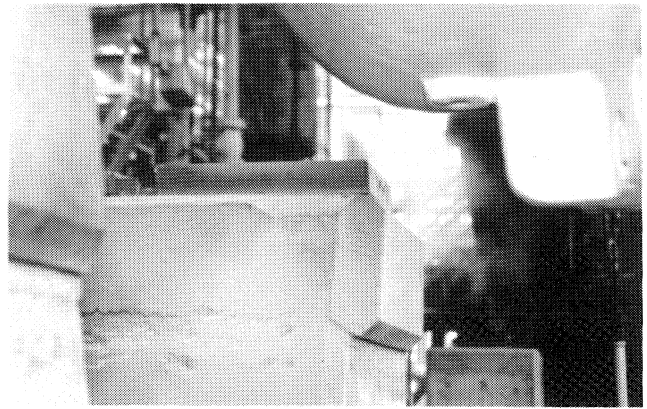


Figure 56. Area of Grout Contacted Relieved by Grinding.

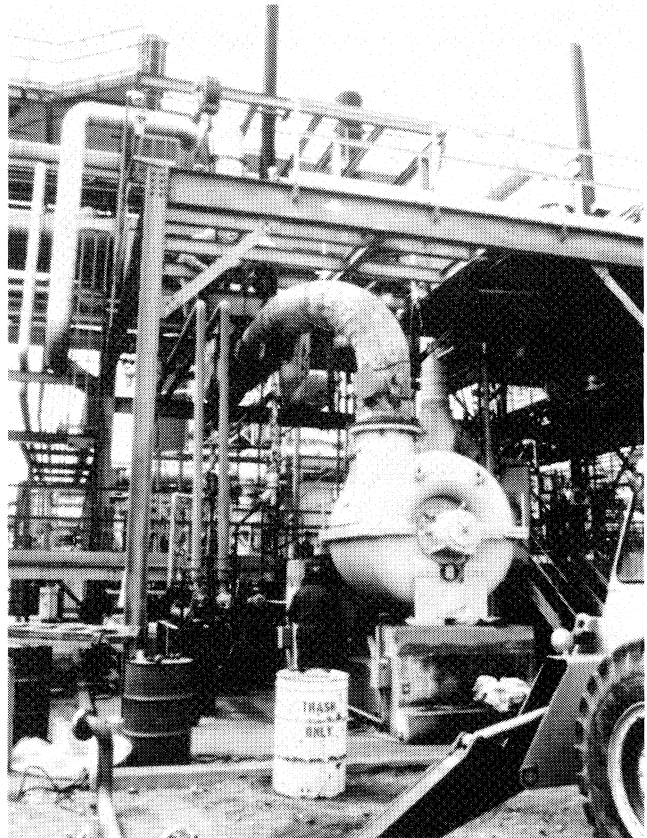


Figure 57. Piping and Steel Decking Being Installed above the Compressor.

The turbine arrived at the job site at 13:00 hours and was lifted with a 45 ton hydraulic crane (Figure 58). While the turbine was 18 in off the rails, the feet were stoned (Figure 59) and the rail surfaces prepared like the compressor. The turbine was sitting on 1/8 in shims (under each foot) by 14:07 hours, and the shaft to shaft distance had been adjusted. It was learned that the spare coupling distance piece was 0.050 in shorter than the existing coupling, so the shaft gap was set for the longer distance piece. If the shorter coupling is used, a 0.050 in spacer will have to be installed (Figure 60). In any event, the compressor would not have to be realigned. The lifting jig and mechanical positioners used to move the 20 ton compressor with ease for mechanical alignment are shown in Figures 61 and 62. Additional stainless steel shims were required

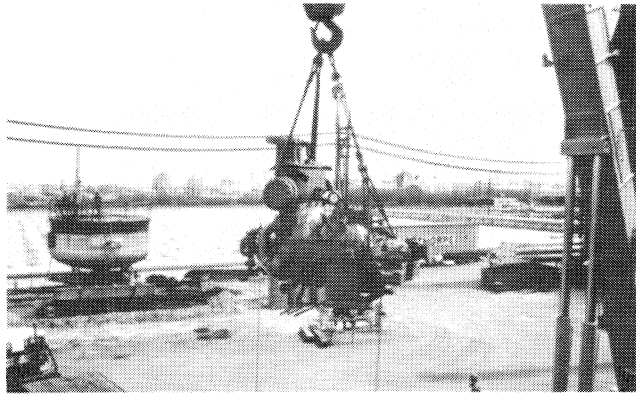


Figure 58. Steam Turbine Being Lifted.

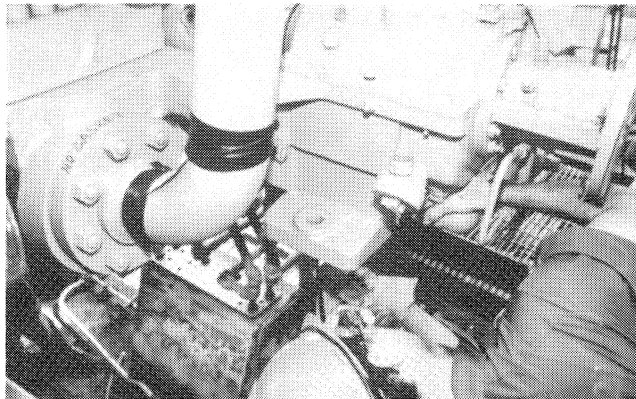


Figure 59. Turbine Support Feet and Soleplates Stoned and Cleaned.



Figure 60. Distance Between Shaft Ends (DBSE) Determined.

for the turbine, so the turbine was not bolted down until the following day.

Day 13: The millwright crew used the reversed indicator method to cold align the compressor to the turbine (Figures 63, 64, and 65). Final alignment was made after the hot optical alignment check. At this point, the regout job was considered finished and the compressor train was on standby until the test run. The finished grout job prior to startup is shown in Figures 66 and 67.

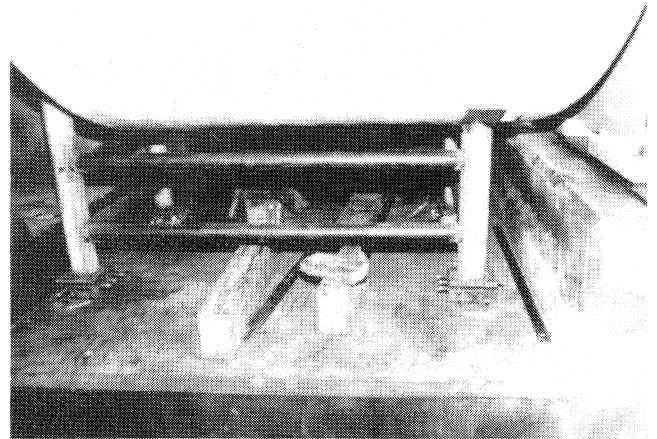


Figure 61. Cradle Supporting the Compressor during Alignment.

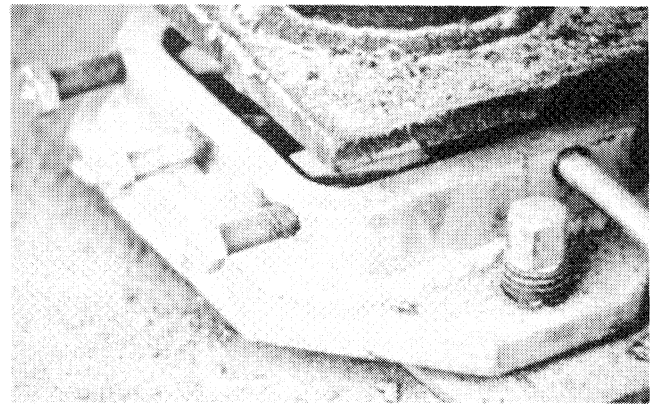


Figure 62. Mechanical Positioners Used to Align the Compressor.

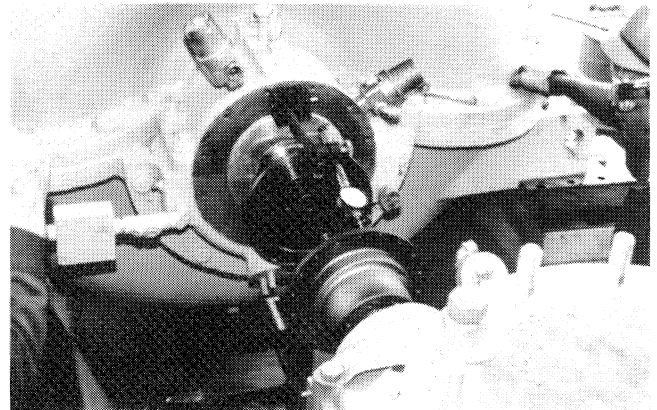


Figure 63. Axial Position Verified.

RUN-IN AND VERIFICATION

Day 20: At 04:00 a.m., steam was introduced to the turbine for heatup and approximately one hour later the compressor train was placed on slow roll at 500 rpm. Maintenance and Specialty Engineering personnel, the Mechanical Foreman, and the Contract Millwright Supervisor were all on the compressor deck when the machine was ramped to minimum governor speed (4200 rpm). The vibration response on the turbine inboard bearing was the highest at 2.3 mils as the train ramped through the critical. This was

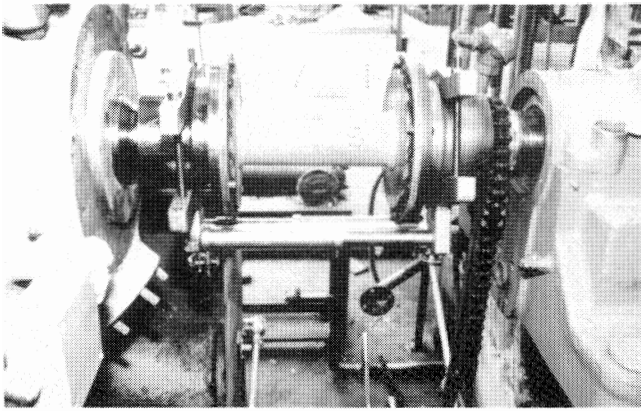


Figure 64. Indicator Reverse Alignment in the 180 degree (Bottom) Position.

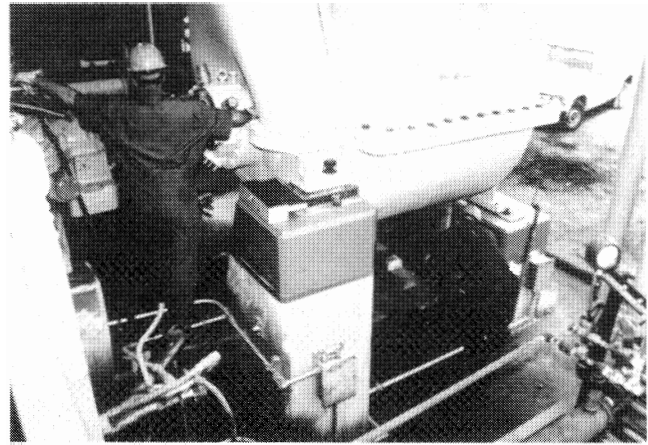


Figure 66. Finishing Touches.

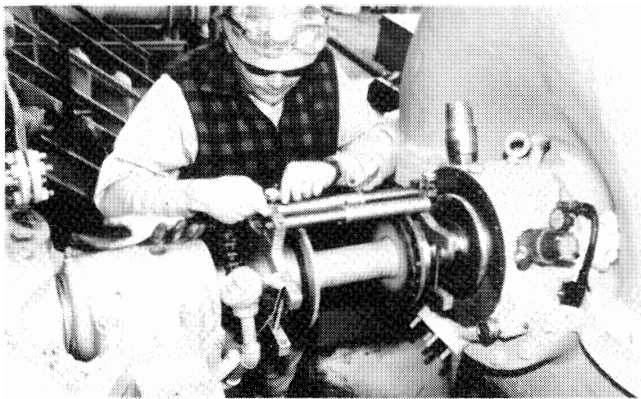


Figure 65. Indicator Brackets in the 0 Degree (Top) Position.

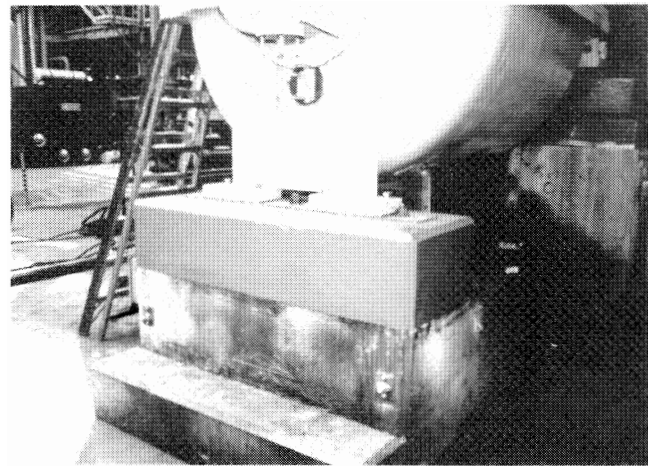


Figure 67. Job Complete.

pleasing in that the response before this job would surpass 3.0 mils. The machine was monitored for about three hours. The vibration levels all settled around 0.5 to 0.9 mils.

When the train was being ramped up to its normal running speed (6300 rpm) problems occurred at ≈ 5900 rpm. The vibration response quickly approached 2.7 mils at the turbine inboard bearing. Levels at the compressor inboard also increased. Obviously, further investigation was needed. Therefore, it was decided to take the "HOT" alignment readings at 5500 rpm, so that in the event movement was needed, it could be performed while the vibration problem was being solved.

It was noted that the turbine and compressor rotors were balanced in the shops without the coupling hubs. Also, it was noted that another coupling had been installed. The coupling came from the plant storeroom and had allegedly been reconditioned. It was not a surprise to find the coupling out of balance; it was sent out and rebalanced. While the coupling was being balanced, the compressor was moved to correct for misalignment.

Day 26: The machine was started in the same procedure as earlier mentioned. This time it was ramped to 6300 rpm and all vibration levels settled to 0.4 to 0.8 mils at running with a maximum of 2.4 mils on the turbine inboard while ramping through the critical. Alignment readings were fine. The compressor train was turned over to operations.

CONCLUSION

When all was said and done there were only five surprises on the job. They were:

- Anchor bolt sleeves were filled with grout (1974)

- The mortar mixer failed during the pour (see below)
- Compressor case contacted the new grout
- Cracks found in the turbine case
- Spacer coupling had to be balanced

About the mixer failure. It was strongly urged that there be two mixers at the site during the pour (just in case). Personnel at the site felt that it was not needed. The foundation design for this compressor train was such that there were six small pads. Four of these pads had grout in them (not all that was needed) when the mixer motor knocked off. Upon trying to restart the motor the pull cord snapped in two. When all of the crew picked their chins up off the ground, there was a real team effort in getting that mixer going (i.e., they were scrambling). Fortunately, they got the mixer going and the pour was completed with no other problems. There was, by the way, another mixer onsite before the pour was completed. The moral of the story: "Always have two mixers onsite while the pour is taking place."

While it may appear that the job ran over by one day, it was actually completed three days ahead of schedule. The catalyst repack of the reactors fell considerably behind, allowing the millwright contractor to give his personnel some days off throughout the job duration.

Again, the success of the South Process Air Compressor overhaul/regROUT job can be credited to preplanning, coordination, and paying attention to intricate details.

APPENDIX

Preparation and Specification for Epoxy Grouting—Construction Specification for Epoxy Grouting

Grout Storage

- Grouting materials (including the aggregate) must be stored in unopened containers in a dry environment at all times.
- The materials must be kept in a humidity/temperature controlled environment between 70° and 80°F for a minimum of 24 hours before mixing, so all components can equalize in temperature.
- In the event the temperature is below 65°F, the grout manufacturer's representative should be consulted before mixing begins.

Foundation Preparation

Surfaces shall be prepared as follows:

Step 1. Chip surface to good exposed aggregate to a minimum of 1/2 in deep in all areas to be grouted. No vertical or horizontal rebar shall protrude into the grout area.

Step 2. Chamfer all foundation edges to 2.0 to 4.0 in (depending on foundation width) at 45 degree angle.

Step 3. Surface should be free of oil, water, loose material, and any other contaminants.

Step 4. Use oil free air or vacuum cleaner to remove dust and loose concrete.

Step 5. All cracks should be removed or repaired.

Step 6. Concrete must be at least 3000 psi compressive strength. If concrete is weak (i.e., easy to break by hand), it should be replaced.

Step 7. The distance between the foundation or jack pads and the bottom of the soleplate shall be a minimum of 2-1/4 in and maximum of 4.0 in. (The maximum of 4.0 in can be exceeded if approved by the grout manufacturer's representative).

Note for new foundations: Freshly poured concrete must be allowed to completely cure before epoxy grout can be applied. The slightest bit of moisture can ruin the epoxy/concrete bond. Rule of thumb cure times are:

- Standard concrete (5 bag mix)—28 days
- Hi-early concrete (6-7 bag mix)—7 days

Jack Bolt Arrangements/Installation

Step 1. Jack pads are to be located such that the outer edge of the pad will be no closer than 1/2 in to the anchor bolt sleeve, and not be within 1/4 in of the edge of the 45 degree chamfer of the concrete.

Step 2. The minimum distance between the top of the jack pad and the bottom of the soleplate shall be 2-1/4 in.

Step 3. The pad edges shall have a minimum radius of 1/8 in.

Step 4. The pads shall be epoxyed to the concrete foundation using grout manufacturer's recommended epoxy.

Step 5. The jack pads shall be leveled.

Step 6. Consult Figure A-1 for typical jack bolt and pad arrangement.

SETTING SOLEPLATES

Step 1. The surfaces of the soleplate that will contact the epoxy grout shall be sand blasted to a white metal finish shortly before grouting.

Step 2. The surfaces shall then be cleaned with a solvent to remove any contaminants (oil, etc.) and coated with 3.0 mils of epoxy coating to prevent oxidation. The epoxy should be compatible with the grout material chosen. Consult with the grout manu-

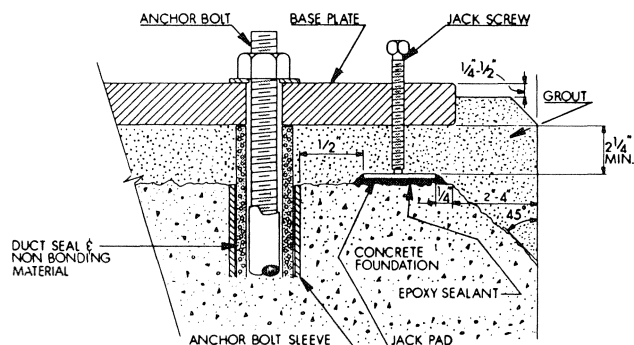


Figure A-1. Typical Jack Bolt and Pad Arrangement.

facturer. NOTE! Shop primers such as zinc, alkide, etc. are NOT acceptable for this application.

Step 3. Foundation bolts shall be covered with duct seal over the entire exposed length. Sleeved space in the foundation shall be packed with a nonbonding compliant material to prevent the annular space around the anchor bolt being filled with epoxy.

Step 4. Jack bolt threads that will be in the groove area shall be coated with an antiseize lubricant that will prevent the grout from bonding to the threads.

Step 5. The foundation shall be prepared to provide a minimum grout thickness of 2-1/4 in under the soleplates.

Step 6. The soleplate elevations shall be set to permit a minimum of a 0.250 in shims or blocks under the equipment.

Step 7. Soleplates shall be located to match the machinery bolt hole centers when the machinery is on shaft center lines. (The machine should be set on the plates for proper location and alignment; however, the machine will be removed before grout is poured).

Step 8. The soleplates shall be leveled and supported to obtain an overall level of 0.0005 in/ft or less in two directions 90 degrees apart. After final anchor bolt tightening the maximum overall elevation variation of the soleplates shall not exceed 0.010 in. The owners rotating equipment engineer will witness the final level check. When leveling is approved, work may proceed.

Forming and Final Preparations

Step 1. Before any forms are built all surfaces that will contact epoxy grout should be blown free of any loose contaminants using an oil free air supply. Then inspection will be done to make sure all surfaces are free of any foreign material, such as oil, sand, water, etc.,—anything that could have an adverse affect on any bonding surfaces.

Step 2. Form material to be minimum 3/4 in plywood and braced vertically and horizontally with 2 in x 4 in lumber or larger.

Step 3. All form surfaces which will be contacted with grout, will have three coats of paste wax or equal applied, in order to prevent grout from bonding to wood.

Step 4. Forms to be liquid tight. Seal form to vertical concrete surface with caulking material such as silicone, RTV, etc.

Step 5. Forms to have at least 1.0 in—45 degree chamfer strip at all corners and top edge of grout level. Ninety degree corners are not acceptable.

Step 6. All corners where grout comes in contact with a horizontal surface, should be chamfered at minimum 1.0 in—45 degree (such as under oil pan and floor level).

Step 7. Grout shall be poured to within 1/4 to 1/2 in of the top of the soleplate.

Step 8. Recheck anchor bolt protection and protect holes in soleplate.

Step 9. Recheck level of soleplates after completion of all forming steps.

Step 10. Provide heat, cooling, or shade to assure correct concrete foundation temperatures. The soleplate and foundation temperatures shall be maintained at a minimum of 65°F.

MIXING AND PLACEMENT

Step 1. The grout manufacturer's representative shall be present for mixing and pouring of the grout. The owner's rotating equipment engineer will inspect and approve the soleplate installation and forming prior to mixing grout.

Step 2. Ambient temperatures and material temperatures shall be within the manufacturer's recommendations (usually 65°F) minimum for use without accelerators. Grout materials and foundation shall be completely dry.

Step 3. Mixing will be done in a mortar mixer only.

Step 4. Mix only full units of grout. Mix per manufacturer's recommendation taking care to avoid over mixing and air entrainment.

Step 5. Grouting shall be done continuously for the full length of each soleplate.

Step 6. When grout is cured, the soleplate shall be checked for complete grouting by tapping the plate with a ball peen hammer. Voids are present based on a "hollow" sound given by the soleplate when tapped.

Step 7. If voids are found, a hole shall be drilled in the soleplate at each end of the void. The void is then filled without aggregate (one of the holes will be used as a fill hole, the other as a vent). A grease gun and fitting are normally used for the application Figure A-2.

Step 8. The jack bolts shall be removed and the bolt holes filled with a silicone sealant.

Step 9. Torque anchor bolts to equipment manufacturer's specification.

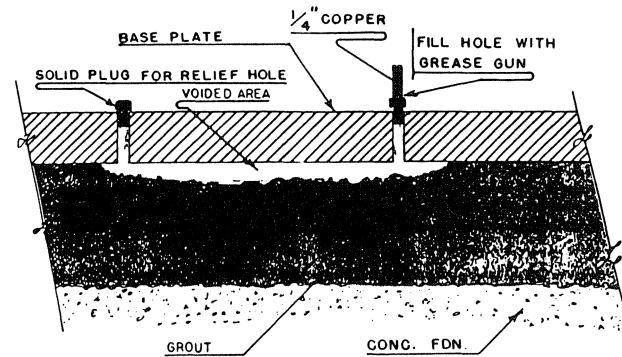


Figure A-2. Baseplate with Void.

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