

Control Of Crankshaft Distortion With An Adjustable Epoxy Chocking System

Revised September 03

BY

ROBT. L. ROWAN, JR., P.E. - ROBT. L. ROWAN & ASSOC., INC.

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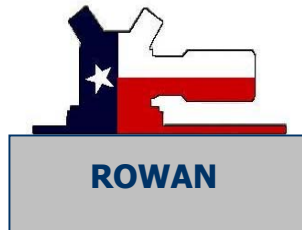
MARK GERKIN - TENNESSEE GAS PIPELINE COMPANY

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The control of crankshaft distortion through proper original alignment and periodic maintenance realignment has become a very important topic. Operators are finding it is cost effective to continue operating reciprocating compressors for 25 to 35 years. This subject can either be a planned part of maintenance scheduling or it will suddenly be thrust into the forefront with a catastrophic crankshaft failure.

When a crankshaft breaks, there is always a good reason. They don't just break by themselves. In some cases the failure can be attributed to a fault in the crankshaft material, or to an operations induced overload, but in the majority of failures being seen today, improper alignment causes a fatigue type failure. Flexing of the crankwebs, more than manufacturer's tolerances, over time, with enough stress reversals, can and does lead to cracks and breakage. With today's knowledge and technology, this type of crankshaft failure can be controlled more easily than the other two modes of failure mentioned.

Since we are going to be talking about crankshaft distortion or alignment, let's identify the major influences. The first is the alignment of the frame and mainframe saddles. Also very important is the influence on crankshaft alignment from the horizontal compressor cylinders and associated piping. Finally, the conditions of the bearings have to be considered. Bearing condition is often overlooked when crankshaft alignment is being checked by use of crankweb distortion gauges. Before correcting a poor crankshaft alignment, you need to know if changing the bearings should make the correction, or if aligning the frame should make it.

From the above, we can summarize that a properly aligned reciprocating gas engine is one where:

- a) The frame is level
- b) The gas compressor cylinders and piping are not going to distort the frame under load
- c) The bearings are good, and have proper clearance
- d) The crankweb deflections are within manufacturers tolerances
- e) The anchor bolts are tight enough to prevent frame movement

With regard to the subject of acceptable tolerances, some of the older O.E.M. manuals may say the deflections should be within .001 inches. What is not said is whether the tolerance is a plus or minus, or the cumulative effect at adjacent throws. A +.001 at #3 and a -.001 at #4 might appear to be within tolerance. Conventional wisdom today says this should be treated as .002. The rate of change and reversal from a crankweb open position to a crankweb-closed position must also be taken into consideration.

When taking web deflection, it is important to have a consistent procedure so results can be compared. While how to take proper readings is a subject in itself, important considerations are: a calibrated distortion gauge; size and smoothness of the "ping" indentation for the gauge; temperature of the frame; where the distortion gauge is zeroed; and repeatability of results. Don't make a hasty decision based on one set of readings.

The subject of crankweb deflections, as a measure of the alignment condition of a crankshaft and frame, is further complicated by other factors. One of these factors is the question of hot running alignment versus the cold alignment. Unfortunately, we have to initially align the machine in a cold, unloaded condition. Naturally this changes as the machine heats up and grows thermally and is subjected to dynamic loads. We try to estimate what the hot alignment condition is by shutting down the machine and taking deflections with the frame warm, but in a cooling cycle and without any dynamic influences. Certainly the popularity of an adjustable chocking system is because changes in the frame alignment can be made quickly so a best operating condition alignment results.

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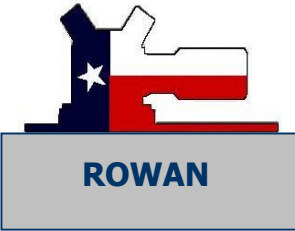
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Another important factor is the clamping force of the anchor bolts. We have learned through experience that much higher tightening torque is required to hold the frames in place than the older O.E.M. manuals recommended. If a crankweb deflection check is made, with the anchor bolts minimally tight, it is possible to get good readings. However, if the machine has a very stiff frame, as many do, and the minimal torque on the anchor bolts allows the frame, under load, to move vertically or horizontally say .005 to .010 inches, the running deflections will be different from the cold, static deflection readings. It is not uncommon in the field to see such movement, yet the operator feels the machine is within crankweb deflection tolerances. Some people have been reluctant to tighten anchor bolts since the grout or chock may have worn down and such tightening could pull the frame down, out of alignment. Again, the use of an adjustable chocking system allows proper clamping force to be re-established with the frame at the proper elevation. Instead of having to live with a bad situation, the operator is given a tool to manage the situation.

With the above several points in mind, let's review the evolution that has developed over the past 35 years from full-bed grouting of the entire machine frame to the modern adjustable chocking systems that fit under the frame at each anchor bolt. The following pictures (slides) will illustrate the development and history of gas compressor support systems.

- A.) Full bed grouting
 - 1) Cementitious grout - 1940's
 - 2) Epoxy Grout - 1957
- B.) Steel rails with 1" steel chocks - 1960's
- C.) Steel sole plates with 1" steel chocks - 1960's
- D.) First poured in place epoxy chock - 1964
- E.) Steel sole plate with dual steel chocks and .030 shim pack - 1974
- F.) Poured in place epoxy chocks combined with adjustable composite tapered plates - 1988



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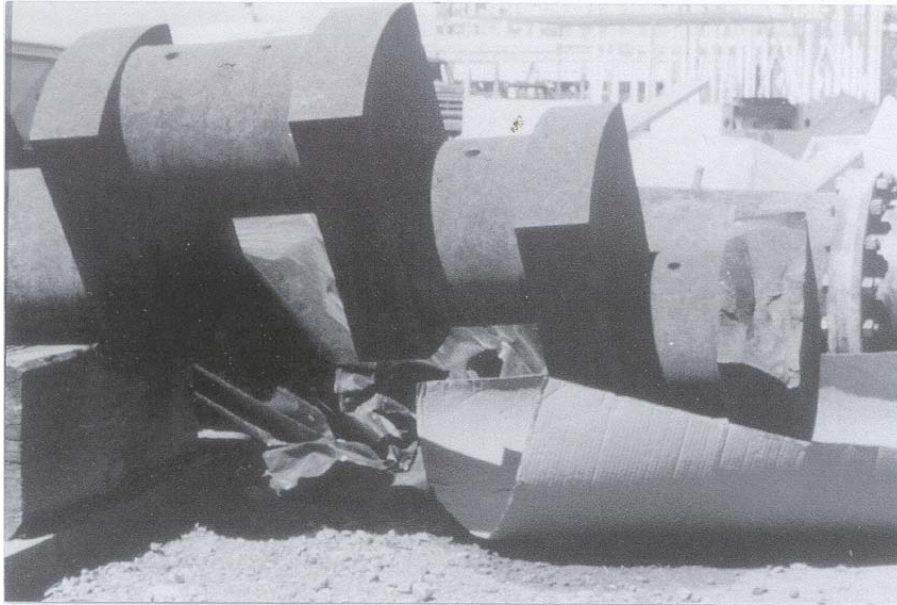


Figure 2
Crankshaft failure because of incorrect frame alignment

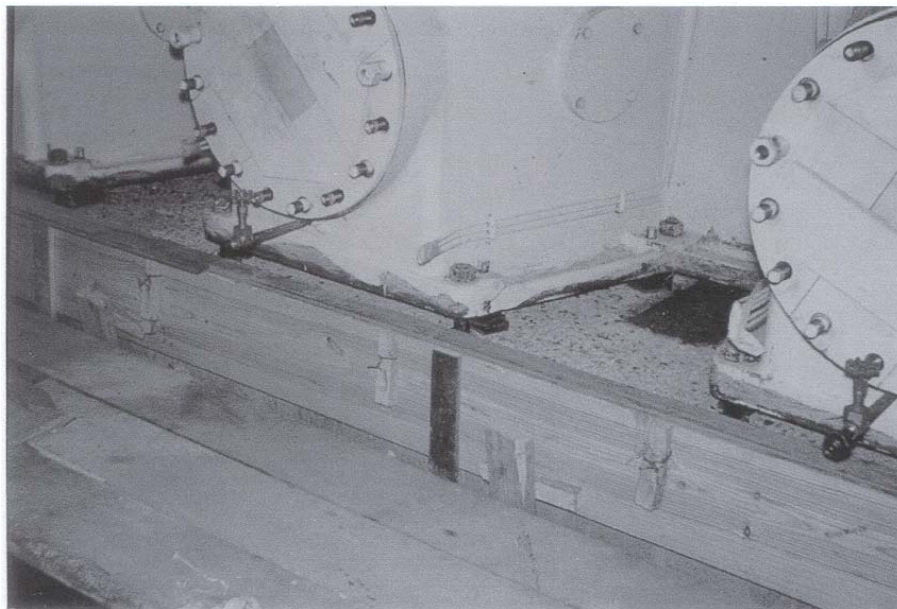
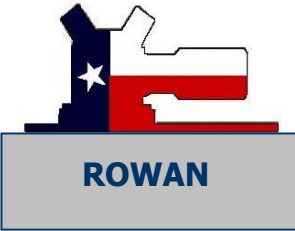


Figure 3
Typical machine preparation for full bed grouting, circa 1959

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Figure 4

Full bed grouted KVG compressor



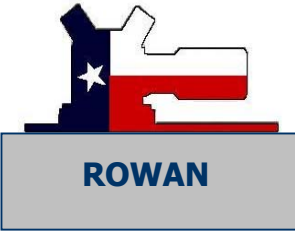
Figure 5

Typical steel rails with 1-inch steel chock prior to grouting, circa 1962

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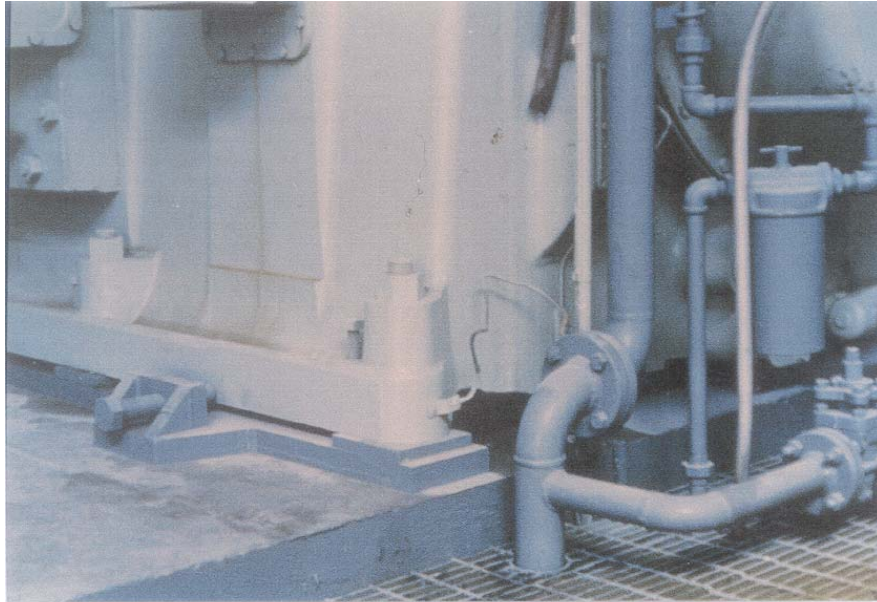


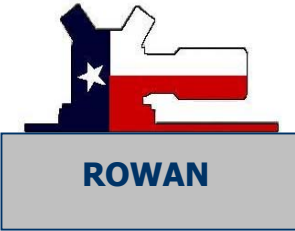
Figure 6

Grouted steel rails, 1 inch chocks and side restraints



Figure 7

Steel sole plates with 1 inch steel chocks, circa 1965



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Figure 8

1-inch dual steel chocks with .030-inch stainless steel shims

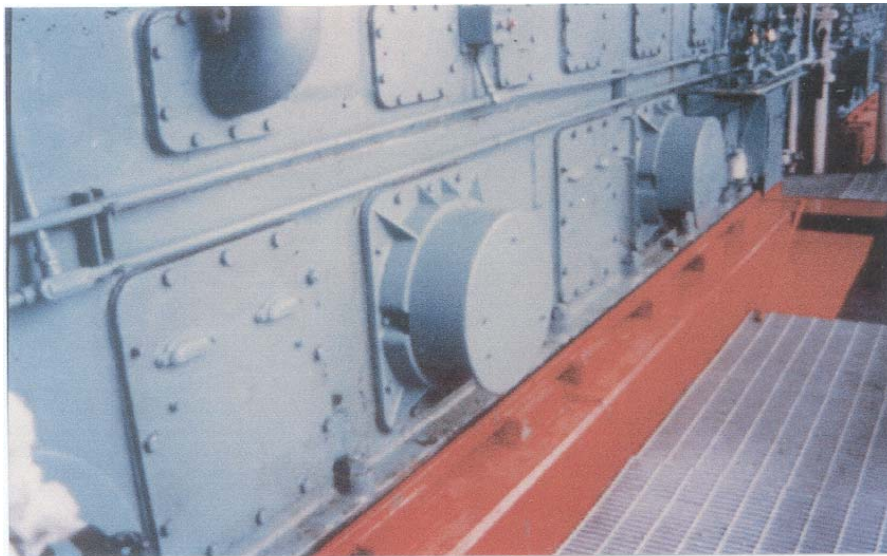


Figure 9

Poured in place epoxy chocks on 3 inch epoxy grout cap, circa 1964



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Published data,¹ the latest of which is Report No. 89-3 sponsored by PCRC², have investigated the effect on crankshaft distortion of various support systems from full bed grouting through steel chocks and epoxy chocks. The common thread is that chocking systems, either steel or epoxy, favor the crankshaft by reducing thermal humping and an adjustable system is preferable to a fixed system so the optimum alignment in a hot running condition can be achieved. A further advantage of an adjustable system is alignment corrections can be made where the misalignment is caused by foundation problems.

We all have seen full bed grouted machines set on the original epoxy grout over 30 years still operating in proper alignment. That is attributable to good stable concrete foundations. The next station down the line may have machines that have been regouted several times with the newer epoxy chocking systems and have misalignment problems or even crankshaft breakage. As we investigate these conditions as engineers, we find foundation related misalignment causes quite often, and the traditional epoxy chocking systems that are not adjustable, can't compensate for the resulting elevation changes. Certainly the trend in the industry towards putting new machines on adjustable chocking systems is a recognition that foundation related problems can and do develop over time.

Two of the most significant technological advances the gas compressor industry has seen are the invention of a dependable adjustable pourable epoxy chocking system and unique concrete foundation repair techniques. It would be nice if all bad foundations could be replaced, but this is just not economically possible. However, coupling a foundation repair with an adjustable pourable epoxy chocking system has allowed the useful life of gas compressors to be extended for many more years. The subjects of modern day foundation rehabilitation and anchor bolt upgrading are important in their own right. They also are important in the proper application of an adjustable pourable epoxy chocking system.

To illustrate the above, the following pictures (slides) will show how an adjustable pourable epoxy chocking system can be retrofitted to an old machine, in connection with foundation rehabilitation, and also how it can easily be installed under new machines. A brief explanation of how field adjustments are made will also be illustrated.



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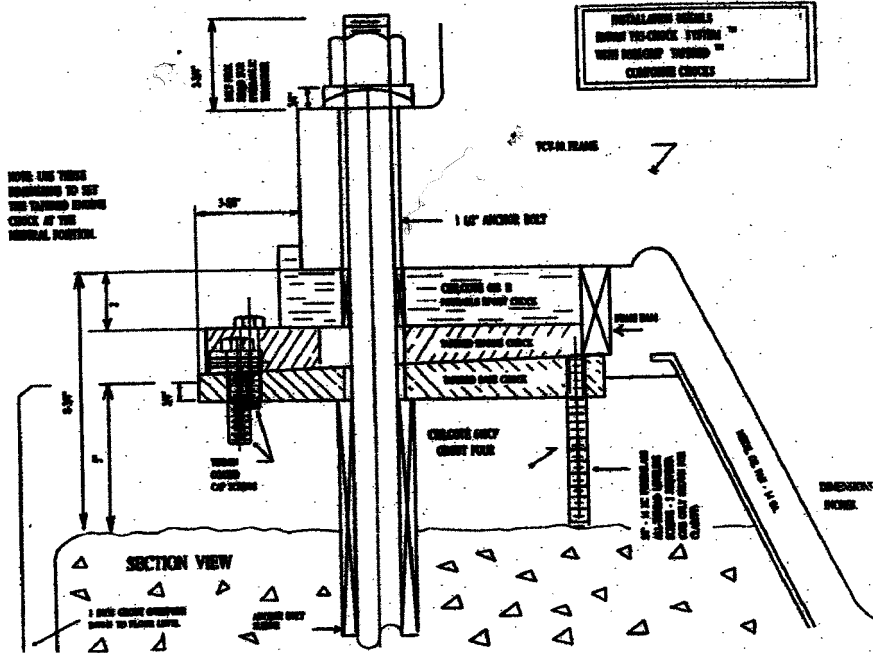


Figure 10
Cross section view of adjustable pourable epoxy chocking system

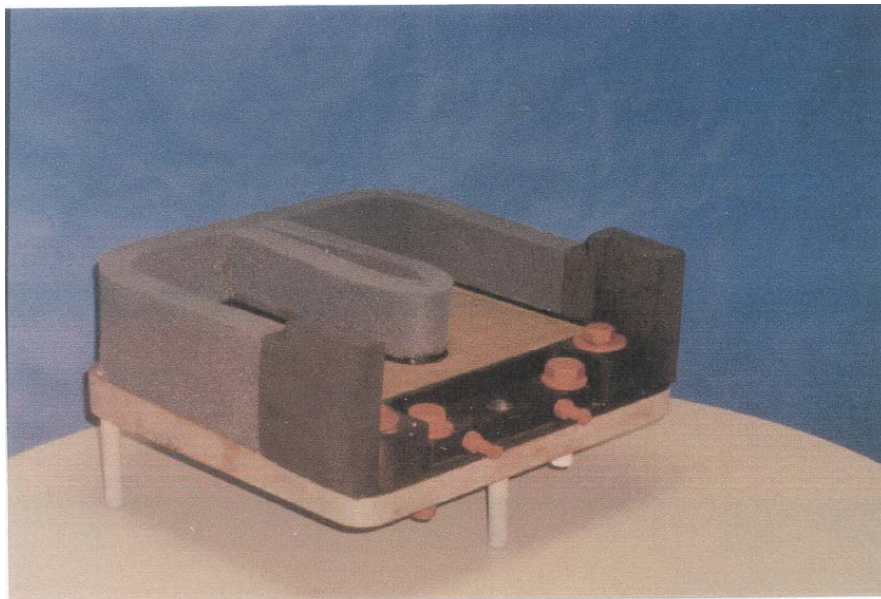
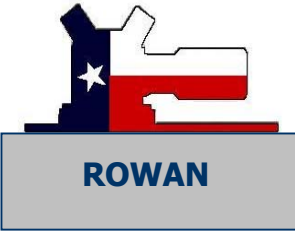


Figure 11
Tapered composite plates that provide vertical adjustment of $\pm.026$ inches

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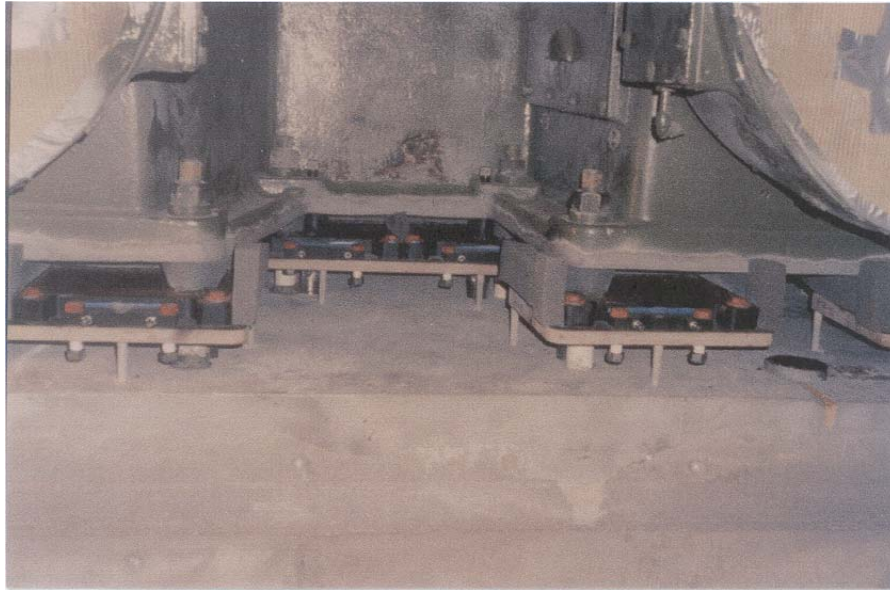


Figure 12

Adjustable composite tapered plates in place at each anchor bolt prior to grouting

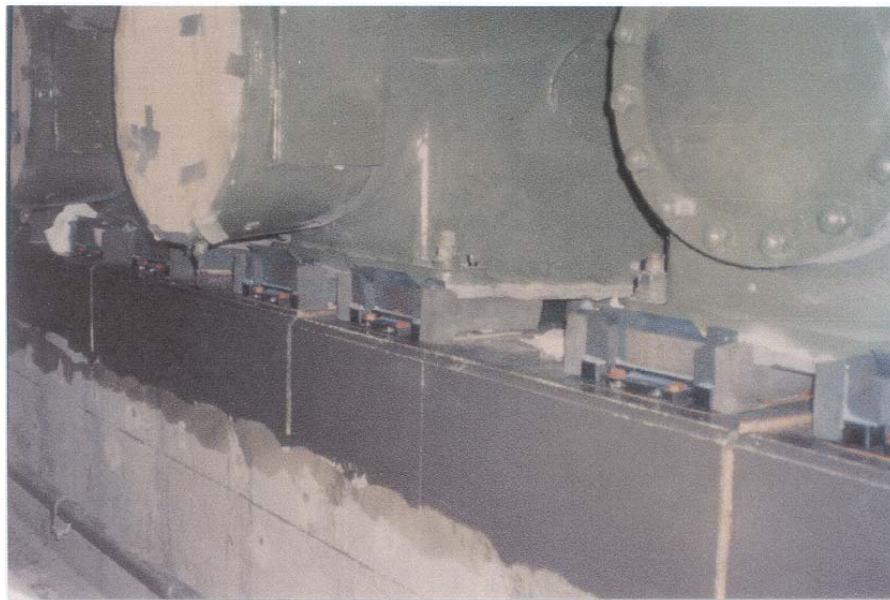
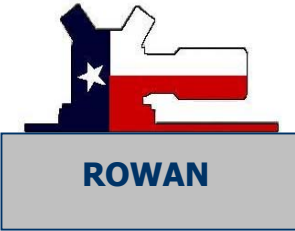


Figure 13

**After grouting, but before epoxy chocking
Note: Chock dams of foam and metal**



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Figure 14

Pouring of epoxy chocking grout into pocket on top of adjusting plates



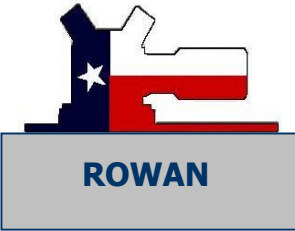
Figure 15

Completed view of retrofitting of the pourable adjusting chocking system

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Figure 16

New 412KVSR with adjustable plates at each anchor bolt. Prior to pouring epoxy chocks.

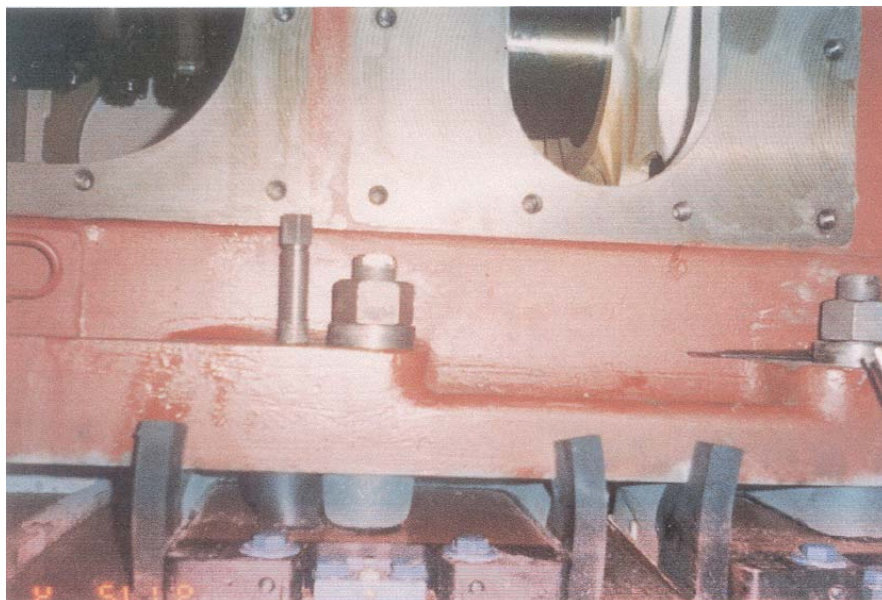


Figure 17

Close up view of epoxy cavity

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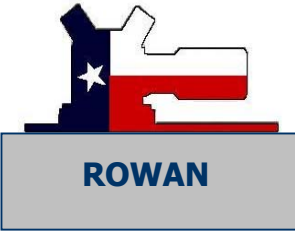
Figure 18

Pouring of epoxy chock grout into chock cavity



Figure 19

Completed installation at oil pump end with double anchor bolts



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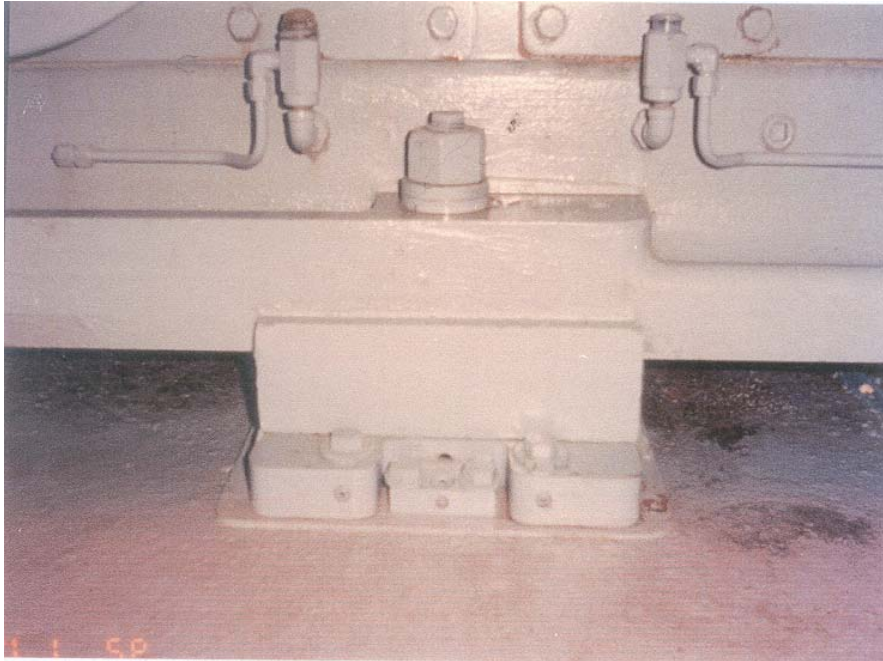


Figure 20

Typical single anchor bolt installation. Hardware for making alignment adjustment can be seen.

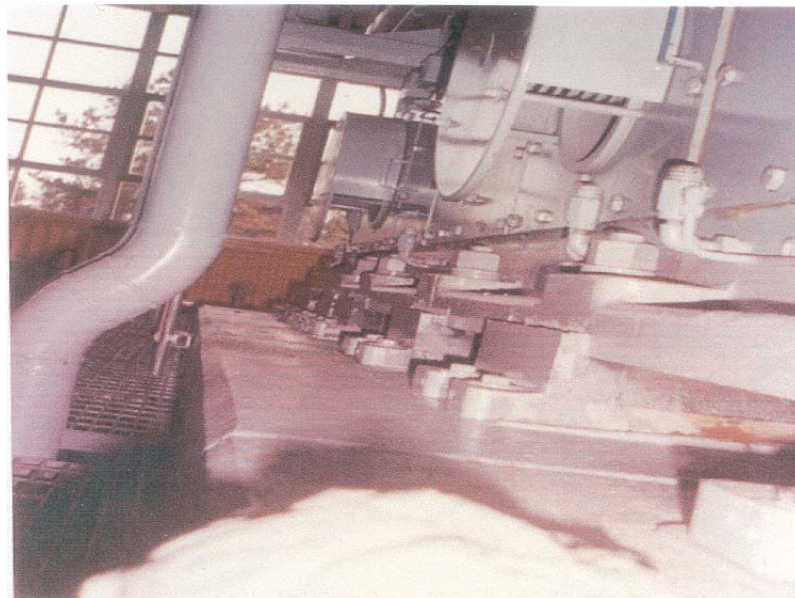


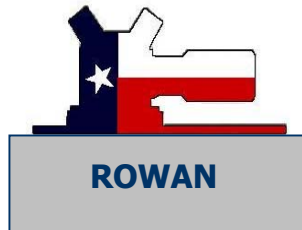
Figure 21

Side view of complete installation that shows adjustable tapered plates

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CASE HISTORY AMERADA HESS GAS PLANT - TIOGA, NORTH DAKOTA

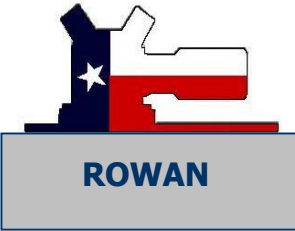
The Tioga Gas Plant first came on line in 1954 with seven low-pressure compressors with 10-psi suction to 800-psi discharge, through three stages of compression. Through the years, the plant was operated by several different companies with different operating philosophies, which resulted in varying conditions of the plant equipment. This condition was most especially prevalent with the 2000 hp Clark HLA 8, low-pressure compressors. Amerada Hess made a conscious decision to improve and upgrade the condition of the equipment after take-over of the plant during the summer of 1988.

The Clark foundations, which had been repaired or replaced many times through the years, had almost as many different designs and grout types as there were repairs. Designs included full bed grout, epoxy chocks, and steel sole plates with shims. A consulting service was brought in to assess the situation and make recommendations on repairs. Conclusions were that the Clark compressors C1E and C1F were by far the worst, but C1C and C1D would be the most economical to repair first because of their better mechanical condition. A multi-year plan was laid out to repair foundations as required, replace grout caps, and install an adjustable chock system. C1C and C1D were planned for the summer of 1989, C1F in 1990, and C1E in 1991.

The C1C compressor had cracks in the foundation block, cracks in the grout, and cracks in the epoxy chocks. The compressors were removed from the engine and the complete engine was removed from the foundation by jacking it up and sliding it onto a metal frame built for that purpose. The foundation was found to have oil contaminated cement all the way to basement floor level. The foundation was replaced using the original rebar design and high early cement. The grout used was a high modulus epoxy grout and an adjustable pourable epoxy chocking system was installed.

The C1D compressor that was completed at the same time as the C1C, August 1989, had cracks in the grout cap and in the epoxy chocks. The engine was jacked up in place and the top eighteen inches were removed from the foundation. The foundation was repaired with fast setting polymer modified concrete, the grout poured using a high modulus epoxy grout, and an adjustable pourable epoxy chocking system installed.

The C1F compressor was planned for 1990, however a thrown counterweight on the C1A compressor changed those plans. The damage from the thrown counterweight was mostly limited to the upper frame on the flywheel end. A close inspection of the engine revealed that there was a significant hump on the opposite end of the engine. This compressor, which had been regouted some five years earlier with a full bed grout, had developed a classic thermal hump. The engine was completely disassembled and removed from the foundation. The foundation was chipped down to good concrete and brought back to elevation with fast setting polymer modified concrete, regouted with a high modulus epoxy grout, and an adjustable pourable epoxy chocking system installed. The engine frame was sent out for repairs and included a remachining of all critical areas. The lower frame was set and line bored on location to insure best possible alignment. The C1E compressor was placed in front of the C1F compressor for 1991 due to several indicators indicating that it was moving on its foundation. This compressor had its complete foundation replaced in 1987 and was setting on steel chocks with shims. An adjustment was made in June of 1990 that enabled it to operate until December of that year without damaging the crankshaft. The foundation that was severely cracked had oil-contaminated cement all the way down. This foundation repair started off with a redesign of the rebar that included much more rebars and rebar in the grout cap. Because of the cold weather and the lack of a close batch plant, this entire foundation was poured with fast setting polymer modified concrete. The grout cap was poured with a high



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modulus epoxy grout and the engine set on an adjustable pourable epoxy chocking system after it had been remachined. After setting, it was line bored and reassembled with reconditioned parts.



Figure 23

Foundation prior to re-pouring with polymer modified concrete

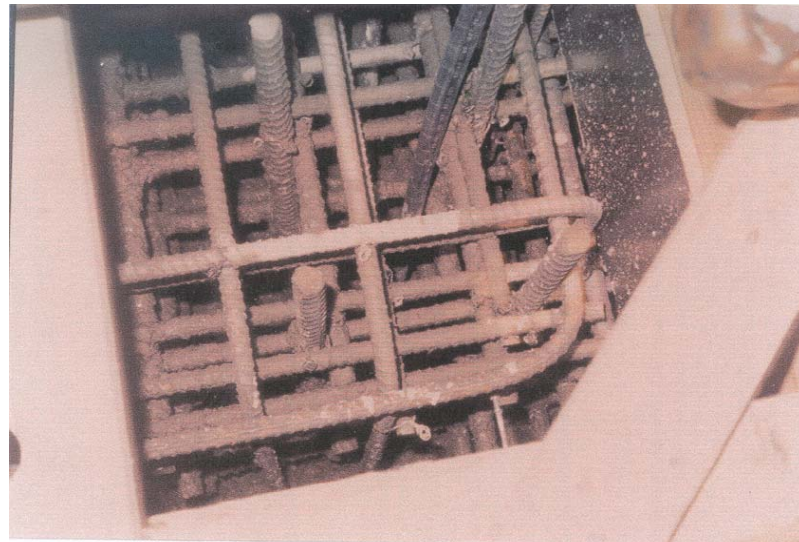


Figure 24

New design of rebar as a result of foundation redesign

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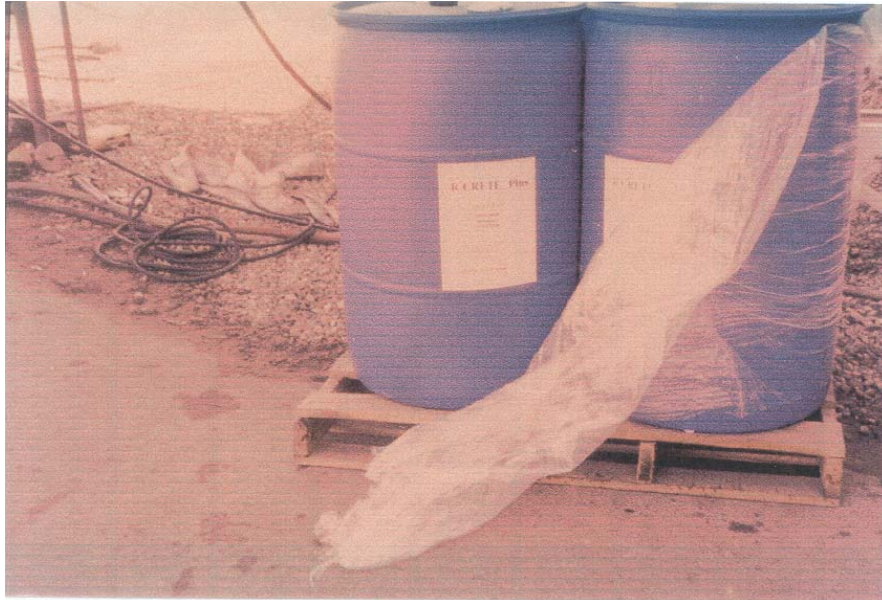


Figure 25
Bulk drums of special polymer used

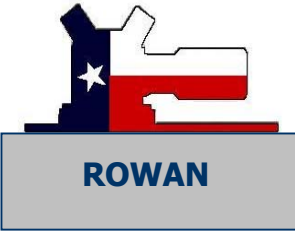


Figure 26
Accurate metering equipment used to measure polymer

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Figure 27

Jobsite mixing of special polymer modified concrete using empty readymix trucks

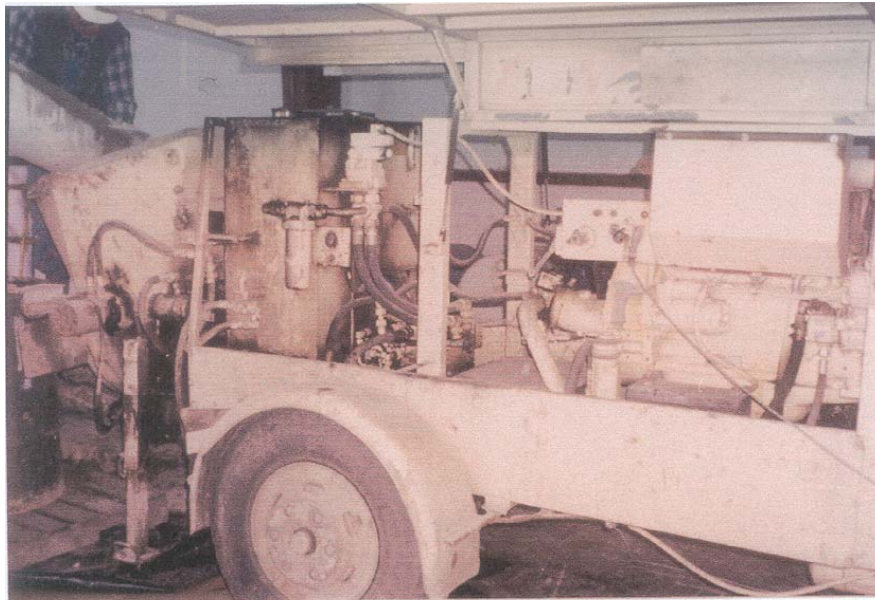


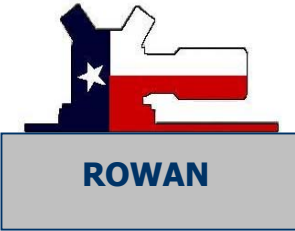
Figure 28

**Typical concrete pump used to transport the polymer-modified concrete from mixing area to foundation
125 feet away.**

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Figure 29
View showing charging of the concrete pump

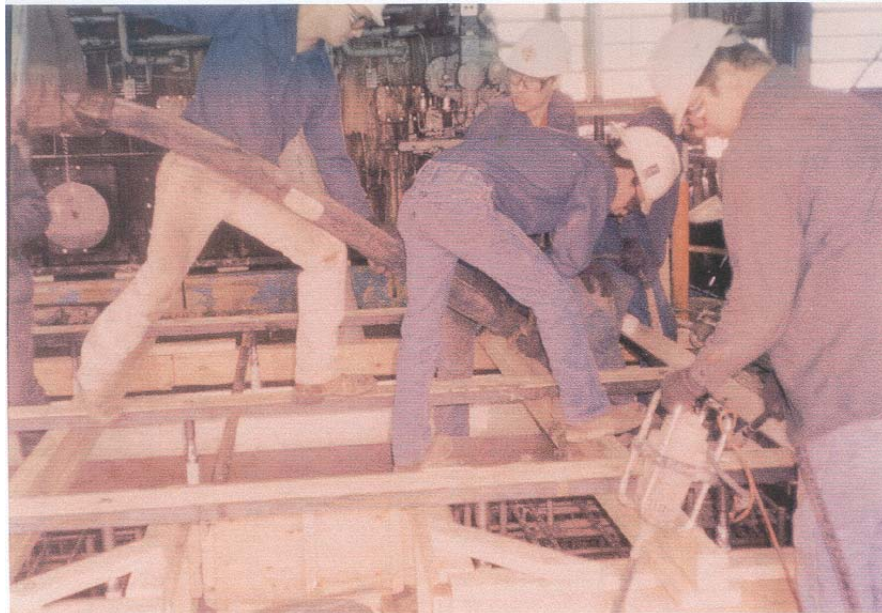
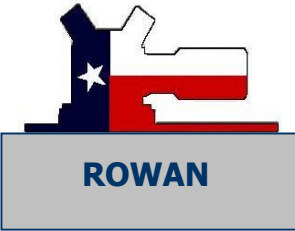


Figure 30
Flexible hose at discharge end showing polymer modified concrete going into the forms.

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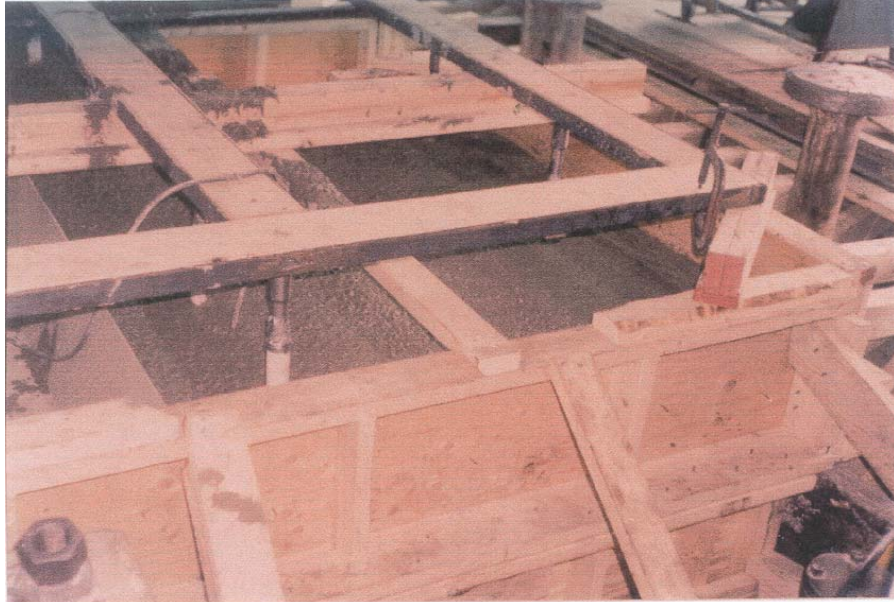


Figure 31

Installation of polymer modified concrete, after 24 hours cure, the machine was slid back over the new foundation.

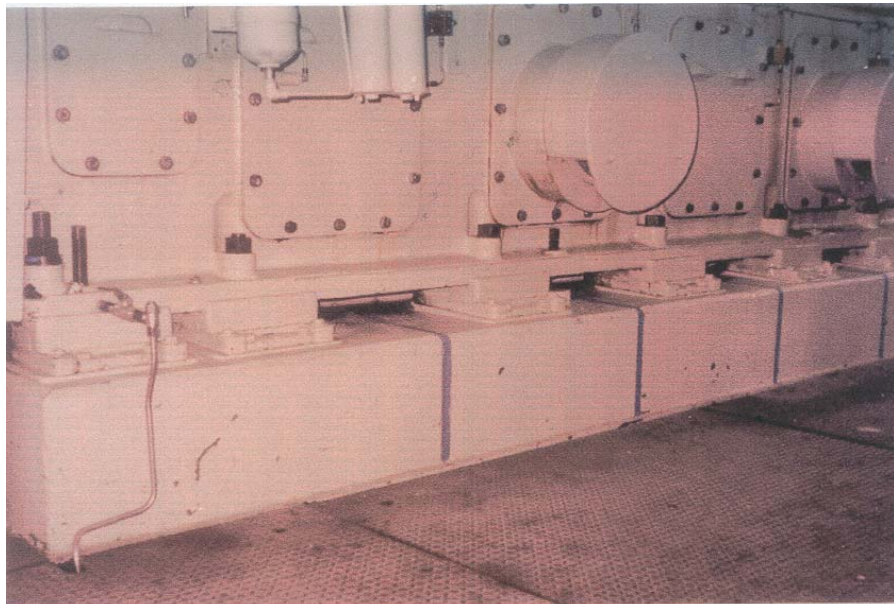


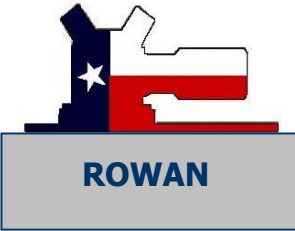
Figure 32

Completed view of new foundation with machine reinstalled

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The C1F compressor is presently being replaced with a new compressor and will be used as spare parts for the remaining Clark compressors.

In summary of the adjustable pourable epoxy chocking system installation and foundation repairs, all indicators are showing positive influences. The attached lube oil analysis summary, which summarizes all wear metals, shows positive influences on all except for the C1D machine. This machine on a recent annual inspection revealed lubrication problems on the power cylinders.