ALIGNMENT USING WATER STANDS AND EDDY CURRENT PROXIMITY PROBES

by

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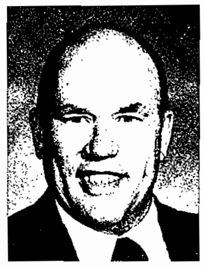

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PREFACE

This paper covers one of seven techniques in alignment being presented at an alignment tutorium at Texas A&M University's Ninth Turbomachinery Symposium. The specific procedure will be covered only, without delving into the sideline topics, such as shimming, defects from poor alignment, low sag reverse indicator bar designs, and many, many areas related to proper alignment work. Other areas (optics, laser, extension gages, bearing-to-bearing mount bars, coupling monitoring, reverse bars and tooling) will be covered separately at this Symposium.

SYSTEM CONCEPT

This system utilizes standard fixed references which are water stands, e.g., two-inch pipe with cooling tower water flowing through the pipe stand. This stand will generally attach by direct bolting to a solid slab of steel in the foundation referred to in the trade as a "sole plate". This stand holds two (or three) eddy current probes which sense the movement of a machine (turbine, compressor, pump, gear). The target material for the probes are either the shaft directly (first preference) or an "L" shaped target mounted to the bearing housing (second preference) or the casing (third preference) of the machine to be monitored for alignment.

Since the eddy current probe, or proximity probe as used in vibrations for axial displacement, is basically a noncontacting electrical micrometer, it is quite accurate and can sense a rotating shaft or stationary shaft with similar accuracy. The usable range of measure is 100 to 130 mils (2.54 to 3.30 mm) or greater. Normally, the more linear 80 mil range is satisfactory.

The stand and target arrangement allows readout on a shaft or housing and axial growth of the shaft using axial mounted probes. Case or bearing mounted targets are nickel plated (one-third mil) steel and allows optics scale mounting, if necessary.

Figure 1 shows a water stand probe holder designed to read either side of a Bendix coupling with six channels. Two are vertical (each shaft end), two are horizontal (each shaft end) and two are axial shaft growth (each end). The probe span was twenty-six inches for a 416 coupling, i.e., sixteen inches diameter and eighteen inches B.S.E. and five inches diameter hydraulically dilated coupling hubs.

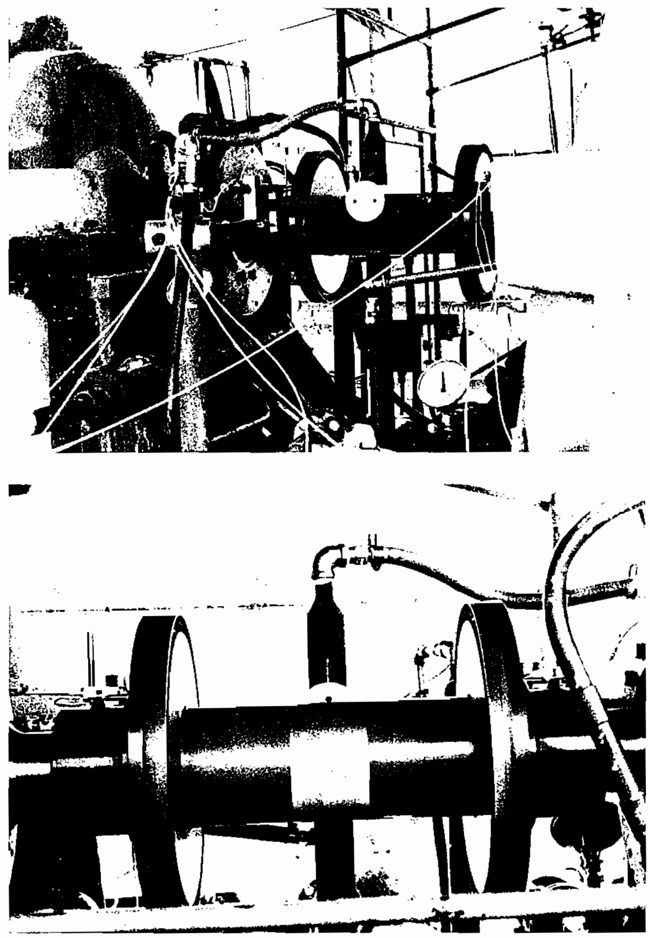


Figure 1. Single Water Stand Holding Two Brackets on Either End of a Bendix Coupling. Six probes (4 radial, 2 axial) are held in these two brackets. 1a shows the stand on the right hand side of the coupling. The vertical and horizontal turbine probe and vertical compressor probes are visible plus the stand and water hose. 1b shows the vertical and axial probes as seen from the left hand side of the coupling. Vertical, horizontal, and axial movement data is recorded from each shaft end on continuous DC voltage using pressure sensitive tape.

Figure 2 shows a stand arrangement to read a bearing housing "L" target. Figure 3 shows two types of "L" targets used. One is bolted in place. The other can be bolted or dowel

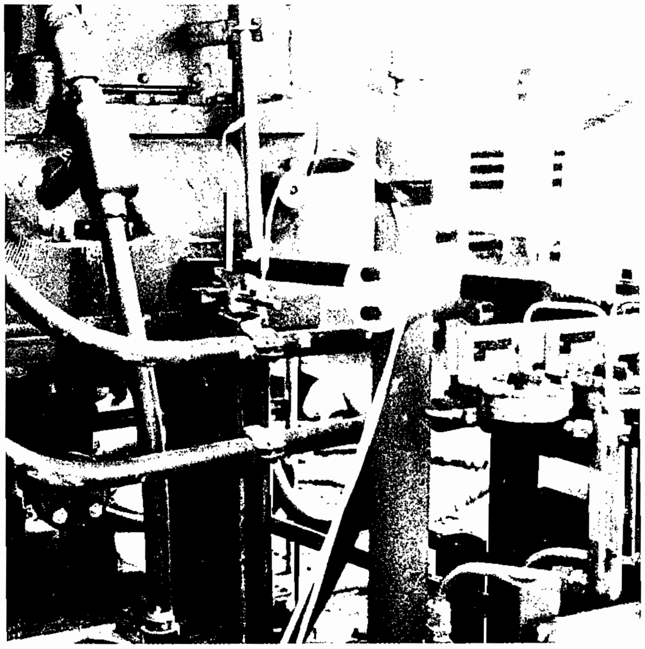


Figure 2. Water Stand Setup to Read the Vertical and Horizontal Movement of the Left Hand Side of a Turbine's Bearing Housing at the Wobble Plate.

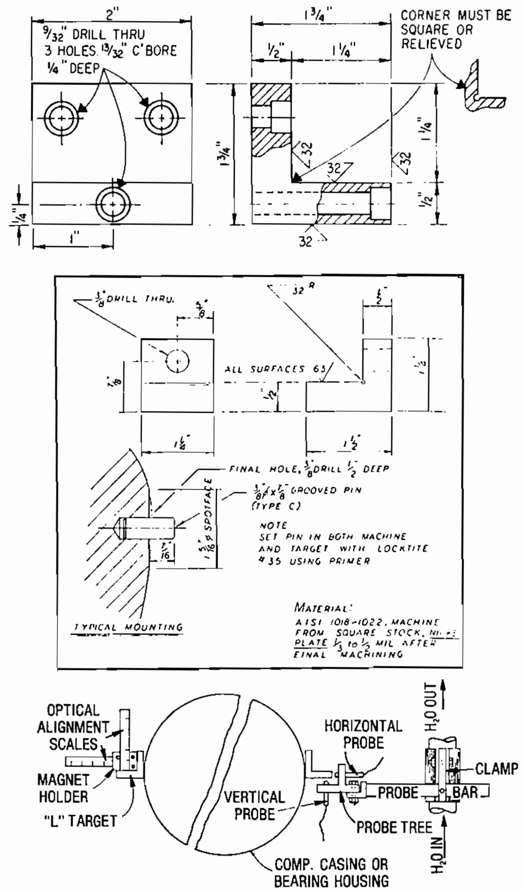


Figure 3. "L" Shaped Targets. These can be made two ways — one for bolting, one for spot facing, dowel, and epoxying. The larger bracket better accommodates dual use optically.

connected to a machine with a pilot drilled, spot facing tool operated from a one-half inch drill, i.e., prepared for retrofit work.

Figure 4 shows a blind flange attached to a sole plate early in installation to receive the water stands later on when measurements are needed.

Figure 4. Blind Flange Installed Early in an Installation to a Sole Plate to Receive a Bolted-On Water Stand Later. The "L" target on the turbine bearing housing can be seen near the coupling guard.

Figures 5 and 6 show this system in early pipe stress checkout of a turbine as the steam piping was brought to

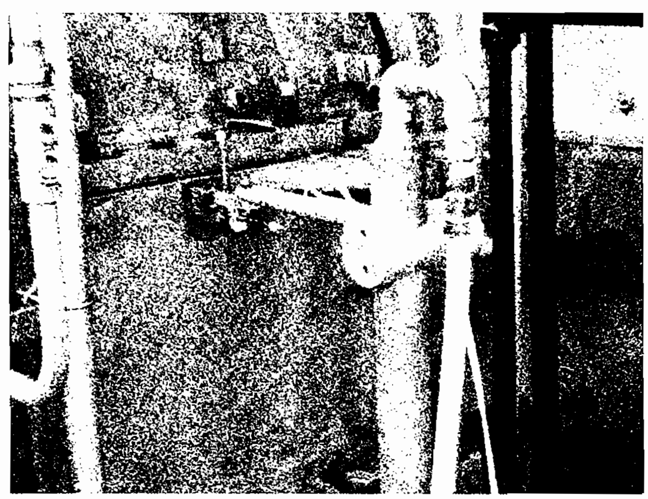


Figure 5. Water Stand and Probes Setup Early to Check the Pipe Stress Movement in the Flanging-Up Stage and the Heating-Up Stage to the TT Valve on a Front Bearing of a 30,000 HP Turbine.

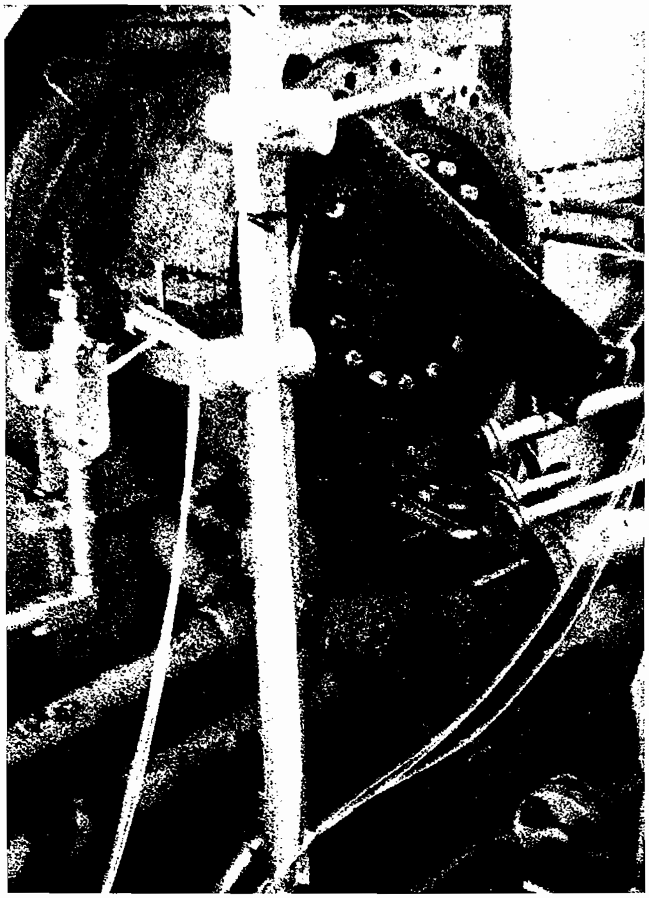


Figure 6. Water Stand and Probes on the Exhaust End of the Turbine Shown in Figure 5. There are also probes connected reading the shaft directly which are undisturbed should the shaft start to rotate (which happened more than once).

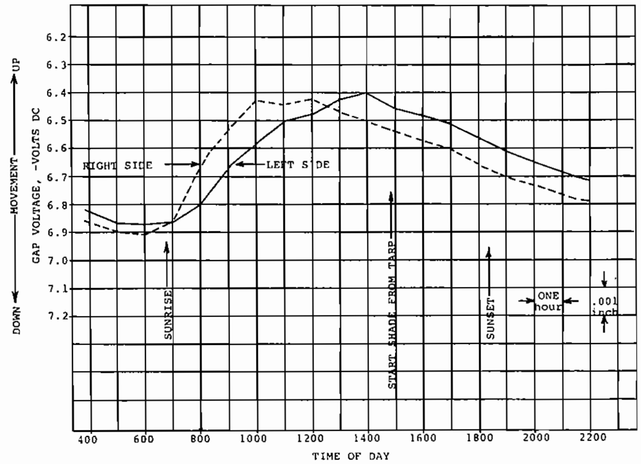


Figure 7. 30,000 hp, 1250# Steam Turbine High Pressure End Vertical Movement. This shows the effects from the front bearing shown in Figure 5 receiving the heat from the sun as it passed from east to west (turbine was oriented south-west to north-east).

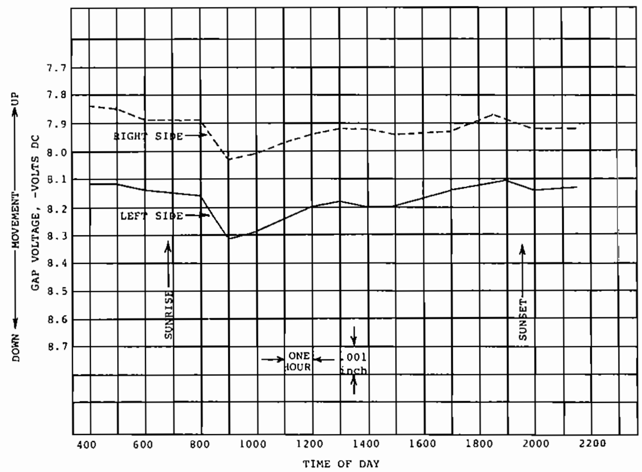


Figure 8. 30,000 hp, 1250# Steam Turbine Exhaust End Vertical Movement. This shows very little movement of the exhaust end which was covered by a tarpaulin.

pressure and temperature. This test was to a disconnected turbine to conclude whether harmful pipe stress was being applied to a 30,000 horsepower turbine operating with 1,250 psi, 900° F inlet steam, extracting at 450 psi, and condensing at twenty-eight inches Hg.

Figures 7 and 8 show the movement of the turbine primarily due to a twenty-four hour ambient cycle (sun and wind). The turbine was exposed to the sun on the front bearing pedestal and unexposed (under a tarpaulin) on the coupling end of the turbine. No heat stress was applied to the turbine at this point of measurement.

Figure 9 shows a typical log sheet for recording movement. Each channel has a voltage vs distance calibration curve. Figure 10 shows a typical alignment instrument. Figure 11 shows a pressure sensitive strip recorder which is coupled to the instrument to continuously record movement. There are two channels per recorder (no ink is required) and calibration is 0.1 volt per mil. Recording paper speed can be in the range of one-half to one foot per hour. Transient heat rise will generally stabilize on large compressor trains in thirty hours. Pumps can stabilize in as low as two hours.

Figure 12 is a graphical plot of the stages of alignment. All data must be plotted on vertical lines corresponding to measurement locations. Reverse indicator readings are plotted at indicator span locations. Probe measurements are plotted at target locations. Shim corrections are determined at support locations. Therefore these generally are not the same locations (some can be — all cannot), but the system is linear. Figure 12a is a plot putting the machine in best guess using the reverse indicator method. Figure 12b shows the actual shimming changes to put the machine in the original position of Figure 12a. Figure 12c shows the redrawn map for cold alignment based on data obtained by hot rise data measured at the targets.

In shimming, one must remember that the center of the machine foot is generally used for shim determination, *but* these feet can vary in width from four inches to thirty inches and the edge effect on positioning can greatly affect the response tending in general to cause one to "overshoot" on the first correction if the foot support is wide. Probably the easiest compromise is determining shims at the *edge* and at the *center* and selecting a shim thickness between the two values.

CONCLUSION

This describes a system that may seem expensive to some; however, consider this in its evaluation:

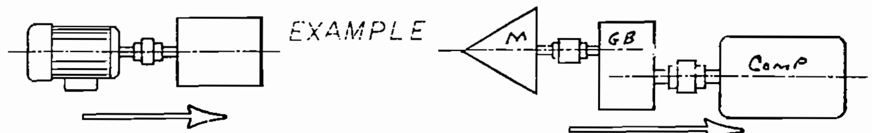
1. It records day and night in rain, sun, or fog.

DATE 7-16-80
LOCATION Ch. Bayou PLANT Olefins
PROCESS Fuel Gas Compressor

ITEM No 95C1
EQUIPMENT DESCRIPTION E-M Motor → Lufkin Gear Increaser → (E) 8 Stg. Compr. 29M8T @ 12,388 RPM

SHEET 1 of 2
AMBIENT TEMP. 100 °F
WEATHER CONDITIONS Hot, Dry Extremely Sunny

EXAMPLE



Accel. Start up Time 1st Run 8.8-8.9 sec
" " " 2nd Run (60% Ld) 9.0 sec

Sensitivity : 0.1 v = 1 mil (0.001")

NOTE: ALL PROBE ORIENTATION ARE DESCRIBED AS VIEWED FROM DRIVER END TOWARD DRIVEN END OF TRAIN!

PROBE LOCATION		Motor Blind End				Motor Cplg. End				Gear Box (Motor End)				Gear Box (Compressor End)				Compressor Drive End (Disch.)				Compressor Blind End (Suct.)													REMARKS
		RH		LH		RH		LH		RH		LH		RH		LH		RH		LH		RH		LH		RH		LH		RH		LH			Start-up @ 1815 (First) Start-up @ 10:17 A (Second)
		V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
CHANNEL		1	2	3	4	5	6	8	7	9	10	11	12	13	14	15	16	27	18	25	26	37	38	39	40										#7/#8 are correct but not in order.
Probe Orientation		↓	←	↓	→	↓	←	↓	→	↓	←	↓	→	↓	←	↓	→	↓	←	↓	→	↓	←	↓	→									H2O ON	#27 Circuit Sub'd for #17
7/16/80	1720	6.3	7.2	9.4	6.3	5.9	7.7	6.6	7.5	8.1	5.9	7.0	7.5	8.0	5.1	7.9	6.85	5.9	9.3	6.9	7.9	9.3	10.7	10.0	10.2									✓	
7/16/80	1800	6.3	7.3	9.4	6.3	5.9	7.7	6.6	7.5	8.1	5.9	7.0	7.5	6.9	9.7	7.9	6.9	5.9	9.3	6.9	7.9	9.3	10.7	10.0	10.2		Gear Vib			Comp. Vib				✓	#13/#14 Regapped - N.T By Millwrights
7/16/80	1845	6.3	7.7	9.5	6.5	6.0	7.9	6.7	7.8	8.0	5.7	6.7	7.2	6.8	9.6	7.7	6.7	6.4	9.1	6.8	8.1	9.7	10.7	10.0	10.0	Pinion	0.75			Suct.	Vert Hor	½ mil "		✓	Start-up @ 1815
7/16/80	1925	6.0	8.1	9.0	6.9	6.1	7.9	6.1	8.1	7.7	5.8	6.5	7.0	6.6	9.75	7.5	6.8	5.7	9.2	5.9	8.6	9.4	10.8	9.7	10.1	Bl. End	0.3			Disch.	Vert Hor	" 0.4		✓	Check #13 Reading @ 1800
7/16/80	2010	5.8	8.5	9.2	7.2	6.1	8.2	6.1	8.6	7.7	5.8	6.9		6.6	9.8	7.5	6.9	5.5	9.4	5.7	8.9		10.8	9.7	10.25	Pinion Cplg.	0.7 0.2							✓	Compressor Loaded
7/16/80	2040	5.8	8.9	9.2	7.2	6.2	8.5	6.0	8.6	7.7	5.9	6.9		6.6	9.7	7.5	6.9	4.8	9.4	5.8	9.0		10.6	9.6	10.3									✓	
7/16/80	2054	5.8	9.0	9.0	7.5	6.2	8.5	6.0	8.6	7.7	5.9	6.9		6.5	9.8	7.4	6.9	4.9	9.5	5.5	9.0		10.8	9.7	10.3									✓	Comp Tripped - Seal D.P. Instr. Failure*
7/16/80	2200	6.1	8.7	9.4	7.3	6.2	8.4	6.3	8.6	8.1	6.0	7.2	7.2	6.8	9.9	7.6	6.9	4.9	9.6	5.8	9.0		11.1	9.8	10.7									✓	*Support Pin Failed on Bellows
7/16/80	2300	6.2	8.5	9.3	7.3	6.2	8.4	6.3	8.4	8.0	6.0	7.2	7.3	6.8	9.9		7.1	4.9	9.5	6.0	8.8		11.0	9.8	10.6									✓	Comp. Down Cooling
7/16/80	2400	6.2	8.3	9.2	7.25	6.2	8.3	6.5	8.25	8.0	6.0	7.1		6.7			6.9	5.0	9.5	6.1	8.6	9.3		9.8	10.6									✓	
7/17/80	0100	6.25	8.2	9.3	7.1	6.2	8.2	6.5	8.1	7.9	6.0	7.0		6.7			6.8	5.0	9.4	6.3	8.5	9.25		9.9	10.5									✓	Cool Down
7/17/80	0200	6.25	8.1	9.3	7.0	6.2	8.2	6.5	8.1	7.9	6.0			6.6				5.1	9.3	6.4	8.4	9.25												✓	
7/17/80	0300	6.3	8.1	9.4	7.0	6.2	8.2	6.5	8.0	7.9	6.0							5.1	9.3	6.5	8.3	9.3												✓	
7/17/80	0400	6.3	8.0	9.4	6.9	6.2	8.2	6.5	8.0	7.8	6.0							5.2	9.2	6.5	8.2													✓	
7/17/80	0500	6.4	8.0	9.5	6.9	6.2	8.1	6.6	8.0	7.8	6.0							5.2	9.3	6.6	8.2			10.0										✓	
7/17/80	0600	6.4	7.9	9.5	6.9	6.2	8.0	6.6	7.9	7.8	6.0							5.2	9.2	6.6	8.1													✓	
7/17/80	0700	6.5	7.9	9.5	6.9	6.1	8.0	6.6	7.9	7.8	6.0			6.5				5.2	9.2	6.7	8.1													✓	
7/17/80	0800	6.5	7.9	9.5	6.8	6.1	8.0	6.6	7.9	7.8	6.0		7.25	6.5				5.9	9.2	6.7	8.0	9.25			10.4									✓	Preparing to Restart
7/17/80	0900	6.5	7.7	9.6	6.7	6.1	7.8	6.6	7.8	7.8	6.0		7.25					5.9	9.0	6.7	8.0	9.25	10.9	9.9	10.2									✓	
7/17/80	10:20	6.4	7.6	9.5	6.7	6.1	7.8	6.6	7.7	7.8	5.9		7.1		9.7	7.5		6.1	9.0		8.1	9.25	10.7	9.7	9.75									✓	Restart at 10:20
7/17/80	1100	6.1	8.0	9.3	7.0	6.0	7.9	6.3	8.1	7.7	6.0	6.9	7.0		9.7	7.4	6.9	6.0	9.0	6.3	8.5	9.4	10.8	9.6	10.1									✓	Heat Up
7/17/80	1200	5.9	8.6	9.3	7.3	6.1	8.1	6.1	8.6	7.7	5.9	7.0	7.1		9.7	7.3	6.9	5.4	9.2	5.8	8.8	9.4	10.8	9.6	10.1									✓	
7/17/80	1300	5.9	9.2	9.3	7.4	6.1	8.3	6.1	9.0	7.7	5.9	7.0	7.0	6.5	9.7	7.3	7.0	5.2	9.3	5.65	9.1	9.3	10.6	9.5	10.1									✓	

Figure 9. *Complete Log Sheet. This was used to record the first heat rise data off a motor-gear-compressor train operated under load, but suffering one shutdown due to an instrument failure and a second shutdown later due to a reversal of alarm and shutdown temperature limits. Little discomfort is caused by delays.*

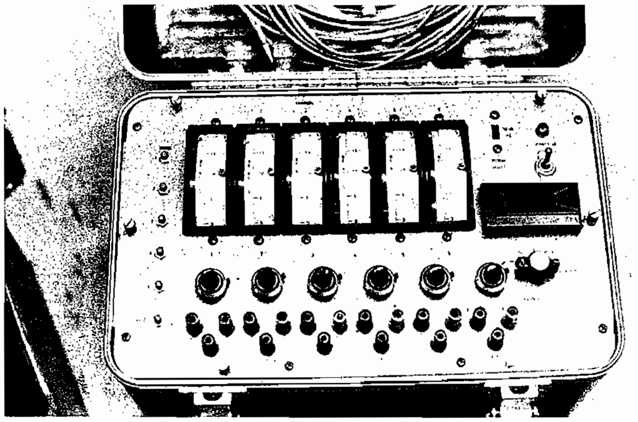


Figure 10. Typical Six Channel Alignment Box. Pots are for calibration. Cables for probes enter through the hinge to allow quick closure in bad weather. Outputs go to recorders. A DVM parallels for back-up and calibration.

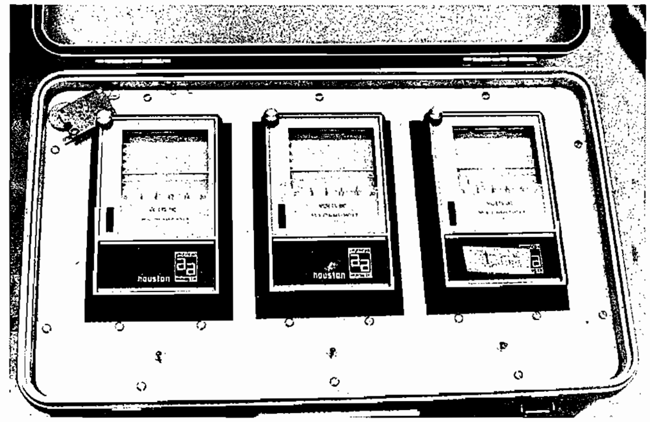


Figure 11. Typical Six Channel Strip Recorder Using Time Share Dual Channel Units Which Use Pressure Sensitive Tape Traveling at 6 in/hr.

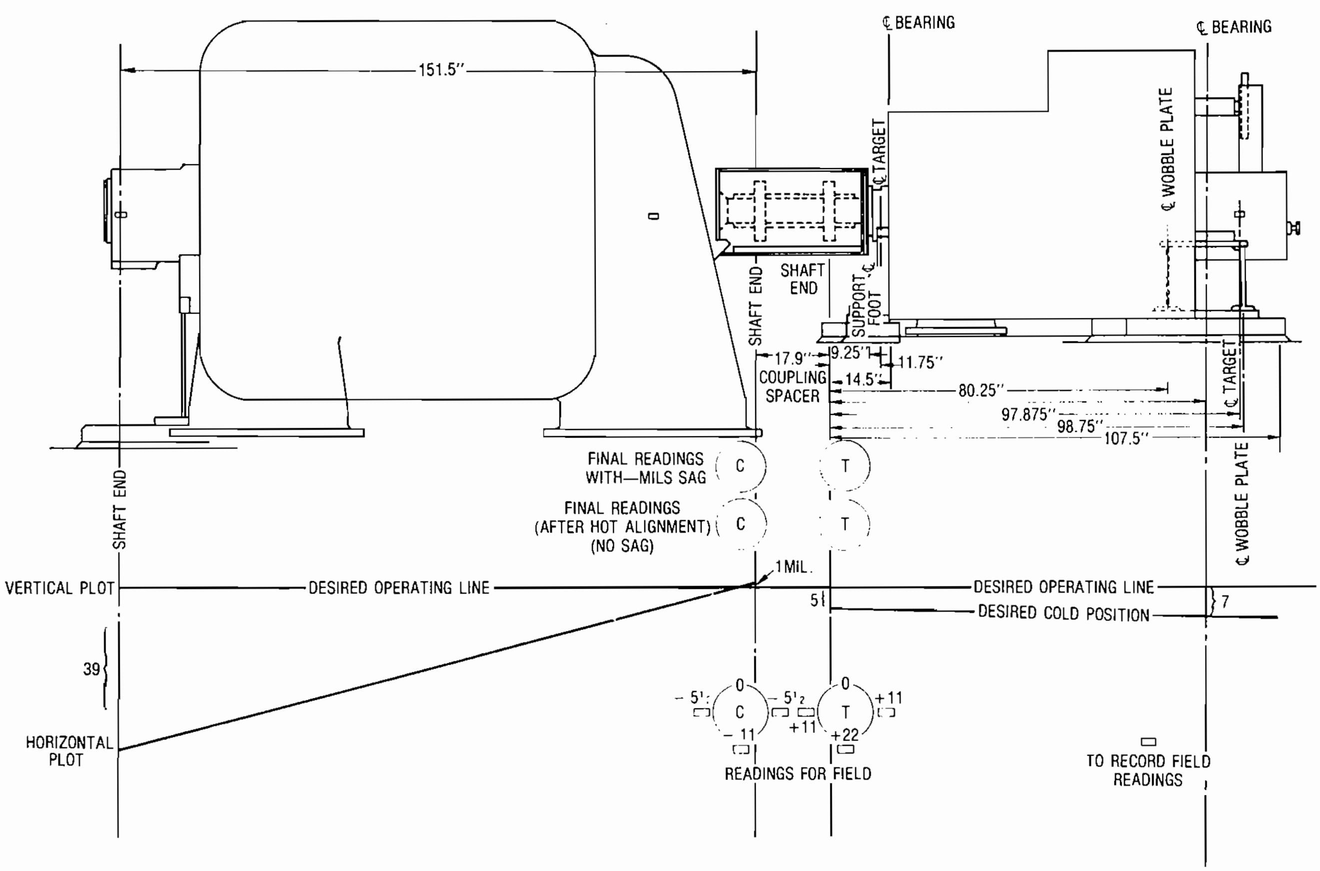


Figure 12a. First Plot Layout of Known Information, e.g., Heat Rises by Builder, Dimensions of Machinery to Scale.

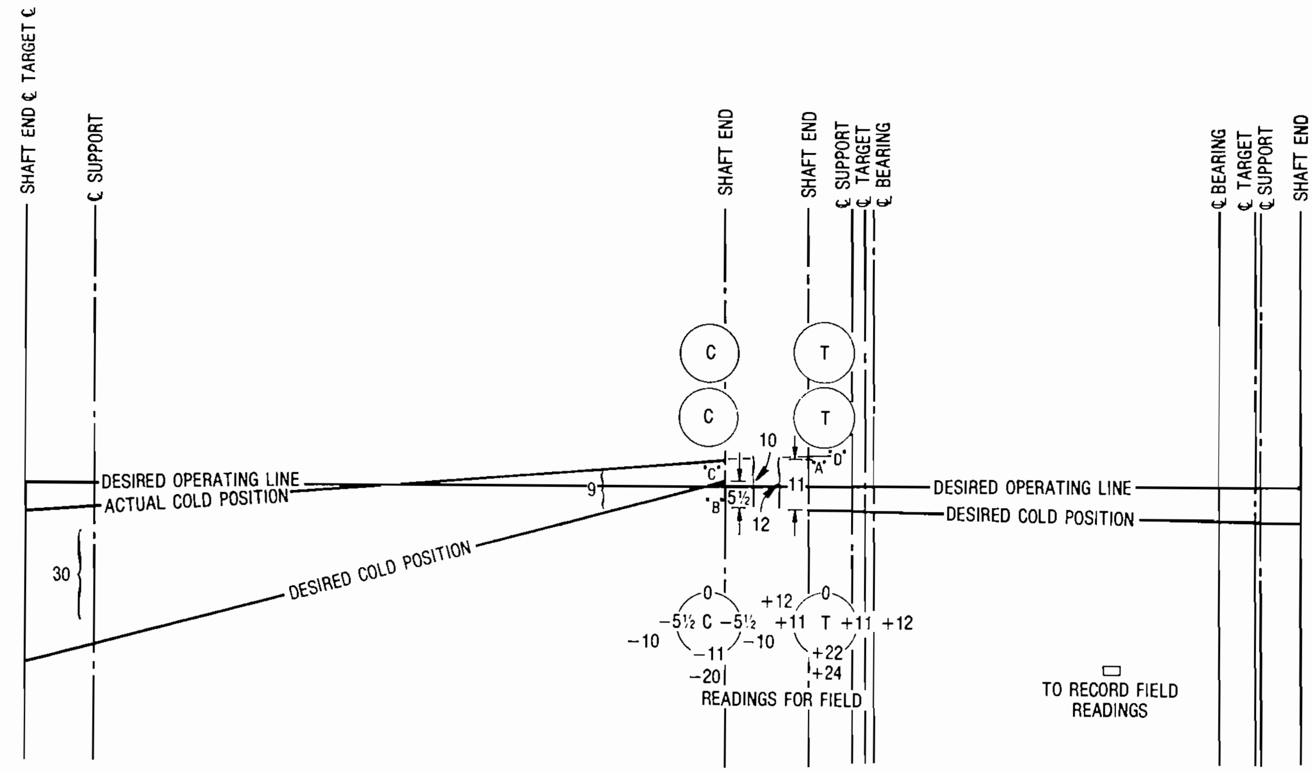


Figure 12b. Plotting Actual Shaft Positions for Obtaining Shim Corrections.

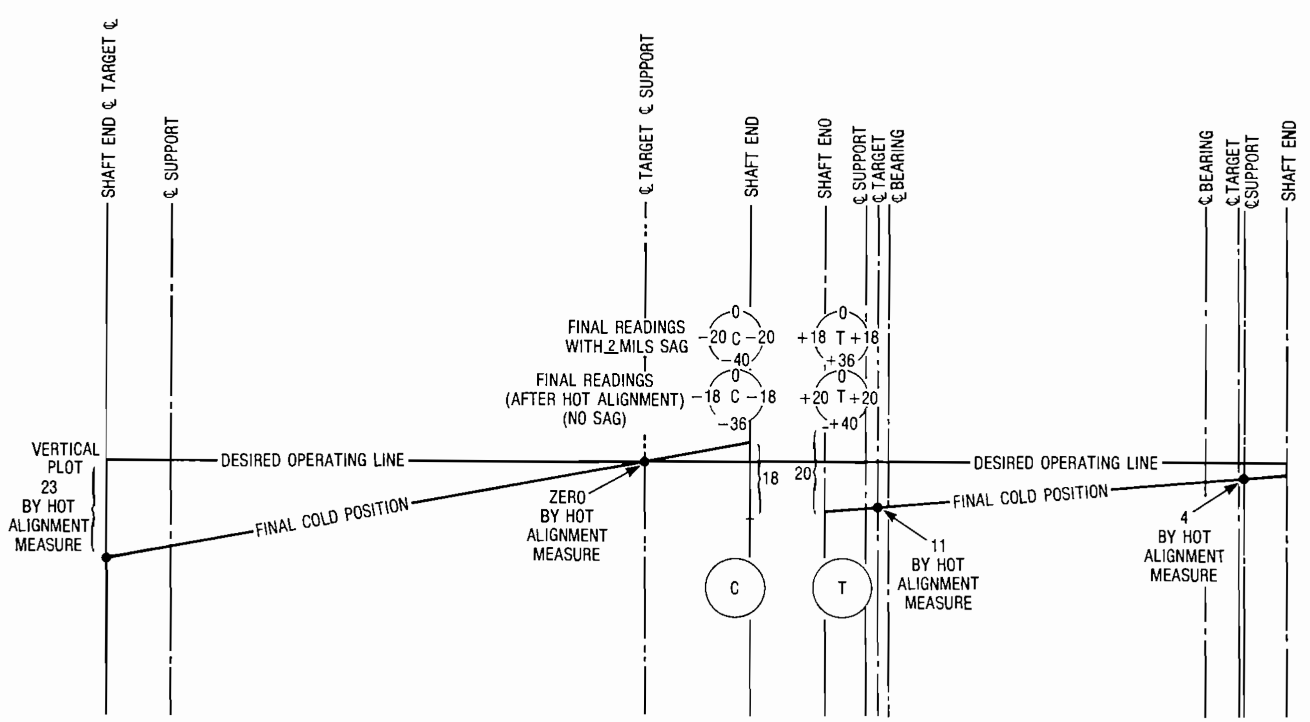


Figure 12c. Revisions to Plot in Figure 12a After Hot Alignment Data are Obtained. Plot in Figure 12c Would be Identical to Plot in Figure 12a if Heat Rise Predictions Were Accurate.

2. The instrument can be reused from one job to the next and does not become a "one-shot" expendable item.
3. Cooling tower water heat loads remain constant for the most part through night and day; therefore, the stand varies little in its temperature, or growth.
4. A continuous recording is provided which few systems can boast.
5. The tooling is not complicated and also can be reused.
6. Only blind flanges or bolt drillings in the sole plates remain permanent to each job and they can be reused at a later date.
7. While any system must be protected from spider monkeys (clumsy people who crawl around the machine or platform without permission during alignment runs), it is difficult to totally default the system. Defaulting the probe is one way; however, regapping a spare probe at the same gap with short time intervals will still provide continuous data. A minor bump to a stand is normally undetectable. A severe bump or probe damage is distressing but correctable, if detected quickly. One should carry either a bottle of "Maalox" or a "big stick" and use whichever seems right for the specific incident, when unwanted personnel interfere with data.
8. If one has never been involved with alignment or the effects from all the factors, one may become emotionally disturbed. Among those are:
   a. Ambient weather conditions can easily move a machine six to ten mils during a day's cycle.
   b. Loosing a machine foot support prior to shimming might cause a movement of ten to forty mils, i.e., a soft foot.
   c. Indicator bars have been discovered with "sags" greater than fifteen mils, to align equipment within two to five mils.
   d. Establishing oil flows only to bearing pedestals at 120° F design inlet temperatures may cause a machine to rise six mils or greater.
   e. Predicted heat rises by a manufacturer probably are based on factory test conditions measured only at discharge (compressor) or exhaust (turbine) and may not relate well to the customer's specific outdoor geographical installation. The vendor data is often based on a cold machine (no hot oil flowing) and under test stand conditions.
   f. There are so many factors that they can never be totally listed. A system that incorporates all effects is necessary.
9. This system assumes the sole plate is stable. Fabricated baseplates could cause detrimental effects if they are *not* stable. In some cases, a mounting plate (slab of steel) has been grouted to the concrete foundation for alignment purposes only. However, fabricated baseplates are not preferred by our machinery groups and sole plate mounting is specified.
10. In some instances, this system has been coupled with optics if there are advantages. A recent concept calls for optics reference of all machines relative to a common benchmark on a platform or mezzanine to be rechecked, through the years, for unequal foundation curing or settling. The "L" target easily accommodates that set of data generally recorded within two hours after all alignment work is completed.

APPENDIX

HISTORICAL BACKGROUND LEADING TO THIS CONCEPT

Looking back on the development, three main concepts were melted together:

1. In the early 1950's, it was my pleasure to work with Mr. Ray Mann, Dresser-Clark. On several occasions, "U" shaped water pipes were attached to the baseplates of a compressor. Angle iron ("L" shaped) extensions were welded to this pipe in such a manner that it covered two sides (vertical and horizontal) of a piece of one-half inch key stock which was welded to the outboard end plate of the compressor near the shaft centerline or inboard. The key stock was placed vertically below the shaft on the IB end plate. Drilling a hole through the angle to accommodate a depth micrometer allowed one to take systematic vertical and horizontal measurements of the machine relative to this fixed reference.
2. Adjacent to this work, thrust deflections monitoring on steam turbine rotors were designed by Monsanto (contributors were Howard Blackburn, J. Art Kelley, and C. Jackson all of Mechanical Technology and R. Schurwon of Instruments). Dual (or single) air nozzles can be arranged as air gauges to sense (impinge on) a disc, often the train balance disc, on a turbine rotor. On calibration, a calibrated parabola can be plotted with the assemtote in the float zone and each side of the parabola respective to active or inactive movement for a sensitivity of 1 psi/mil of movement (back pressure); however, 25 mils is about the limit on the range. (Reference C. Jackson, "An Experience With Thrust Bearings Failures", *Hydrocarbon Processing*, January 1970, Pg 108).
3. In search of a non-contacting sensor which could give 60-80 mils of range, and mil sensitivity, a set of eight Bently-Nevada probes [then called proximitors (probes) and detector drivers (proximitors)] were ordered. Using a -18 volt DC power supply (battery, zenner diode, and resistor), a Triplett VOM (readout), and a cigar box holding trimmed 18-20 gauge leads as a patch box, a turbine driven screw compressor was measured for heat rise over twenty-four hours from water pipes in 1964. The instrument progressed to a Bud Transicase with Simpson voltmeters and a gold plated contact switch; later to a contracted case by Bently Nevada with internal power supplies, backup batteries, recorder and scope outputs, sealed fiberglass cases with cord clamps, etc. The probes quickly became 300 mil tips, four-inches long, three-eighths inch diameter (unthreaded) with twelve-inch lead length, and thirteen-feet-long extension cables.

Conclusion:

The earlier work with water stands and mikes, the measurement needs of thrust and alignment, plus the availability of eddy current probes all combined with some tooling work to lead to the system now described. Need is still the mother of invention.