Application Notes

Power Generation

System Recommendations	
Turbines	**L-705 Turbine Alignment System**
Split-Joint Flatness	**L-740 Leveling Laser System**
Rotating Equipment	**S-650 5-Axis Coupling Alignment System**

In 1975, Hamar Laser built the first steam turbine laser alignment system for Westinghouse. Laser alignment saved the company significant time over traditional methods like tight wire, feeler gages (leads) or optics. With today's advanced laser systems, the timesaving benefit, as well as accuracy, has increased dramatically. According to the Tennessee Valley Authority, their allocated time for alignment dropped by 50 percent when using our L-705 Turbine Alignment System.

Hamar Laser's second generation of turbine alignment lasers are smaller, faster and even easier to set up than their predecessor, the L-711. There is virtually no warm up period and their smaller size has eliminated one of the reference targets, which has reduced setup time by over 1 hour.

The most common method of turbine alignment is the tight wire. Although tight wire has produced good results for many years, it is increasingly becoming outdated. It takes too long to set up, is subject to vibration, which limits other work during alignment and is subject to catenary sag and other environmental influences. With power company consolidation and competitive power markets, shorter outages and more efficient turbines are critical to industry profitability.

The combination of the L-705 Turbine Alignment System, the L-740 Split-Joint Measuring System and the S-650 Coupling Alignment Systems create a powerful tool kit to significantly reduce turbine outages and increase efficiency.

There are two basic types of laser systems:

- *Straight-Line Laser Systems* designed for steam turbine bore and shaft alignment applications.
- *Continuously Rotating Laser Systems* designed for split or horizontal-joint flatness measuring applications.

Our continuously rotating laser systems come in two accuracy grades: the L-730 Precision Series and the L-740 Ultra-Precision Series. Each series offers four different laser systems with single, dual and triple plane versions. The L-730 Series is designed for those with accuracies needs of 0.00012"/ft (0.01 mm/M) or higher and the L-740 Series is for those with accuracy needs of 0.00002"/ft (0.0017 mm/M) or higher.

The L-705 Turbine Alignment System

High Accuracy and Long Range

The L-705 Bore Alignment Laser has a range of 50 feet (15 M), and under good environmental conditions, is accurate to less than .001" (.025 mm) over the whole range (although it is capable of measuring down to .0001" (.0025 mm) in 10 feet). The L-706 Bore Alignment Laser is used for longer distance alignments from 50 to 110 feet (15 M to 33.5 M). It is accurate to +/-.001" (.025 mm) in 110 feet (33.5 M) and has finer angular adjustments than the L-705. Both lasers are concentric to their OD's to within .0005" (.013 mm).

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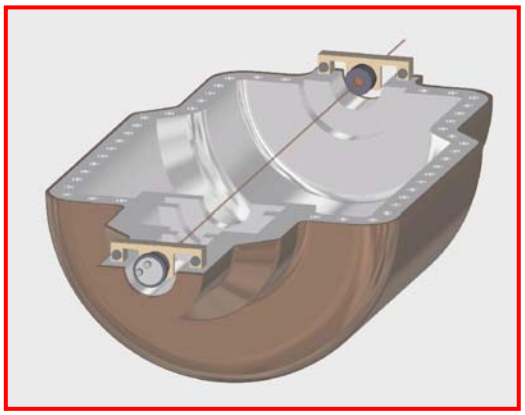
Laser Virtually Eliminates Guesswork

Laser beams and electronic detectors, unlike tight wire, do not have sag or kinks, are not susceptible to wind, and are very repeatable from one technician/shift to the next. This means that the technician will no longer record what he "thinks" the reading is; he will record what the reading *actually* is.



L-705 Aligning the Inner Components of a Steam Turbine

Fast Alignment Can Save Days Off Outage

Sometimes days can be saved off an outage just from the fact that the L-705 laser system allows for other work to take place while the laser is being used. The tight wire, on the other hand, requires a lot of time to set up and settle down, and no other work can be performed while the wire is in use, as vibration will cause alignment errors. In addition, all the components (diaphragms, seals, etc) must be installed to do the alignment; otherwise the wire will have to be repeatedly broken down and set up again.

With L-705/706 Turbine Alignment System, components can be taken in and out of the shell while the laser is being used. Furthermore, the laser provides live data, which means that while the components are being moved, a large digital display shows a live display of the misalignment.

System Pays for Itself in Days

With higher accuracy and faster alignments, a steam turbine aligned with our L-705 will require less energy to generate a kilowatt of electricity and will come on line more quickly than when using other alignment methods. This reduction in cost is pure profit and can pay for the system in a matter of days

Alignment System Features

- Set up in 30 minutes or less
- +/- .001" (.025 mm) accuracy in 110' (33.5 M)
- Large digital display eliminates need for long cables
- Simple, rugged fixturing
- Laser and sweep unit use same fixture to speed setup
- A-511 Wand Bore Target speeds data taking
- Portable, battery operated
- Dynamic display of component misalignment

How the Alignment System Works

The L-705 and L-706 Bore Alignment Lasers are perfectly designed to perform alignment of gas and steam turbine bores. The system uses a laser, reference target, measuring target, micrometer sweep device, and fixtures to hold the laser and targets. Since the laser beam is concentric to the OD of the L-705/706 housing to within .0005" (0.013 mm), it can serve as one reference target. This saves a lot of time during setup.

On most turbine alignments, the rotor bearing bores are used as the references. This means that fixtures that hold the laser and reference target must be placed precisely in these bores to the set points determined by the manufacturer of the turbine.

The fixtures are hung in the bores using angle iron and special magnetic bases. Depending upon the size of the bore, either the large (A-501) or the small sweep unit (A-501A) is used to position the fixture so that the center is exactly on the reference points provided. The sweep unit is essentially an inside micrometer that allows the fixture to be placed to any points desired (for example, .000" left, .009" right and -.010" bottom).

Once both fixtures are swept in, the laser (L-705 for distances up to 50' (15 M) and the L-706 for distances from 50 to 110' or 15 M to 33 M) is placed in one reference fixture and a target (T-218T) is placed in the opposite reference fixture. The L-705 laser is manufactured so that the laser beam is concentric (centered to) to the housing's OD to within .0005" (0.013 mm). With the fixture "swept in," the laser is inserted into the fixture and is thus centered to the reference points.

Recommended System Configuration

L-705 Bore Laser
R-307V 2-Axis Large Number LED Digital Readout
R-307 2-Axis LCD Readout
T-218T 2-Axis Turbine Target
A-501A Turbine Small Bore Sweep Unit
A-502A Turbine Reference Target Bracket
A-502L Laser Support Bracket
T-231A 25' (7.62 M) Target Extension Cable
A-509T Shipping Case for Turbine Package

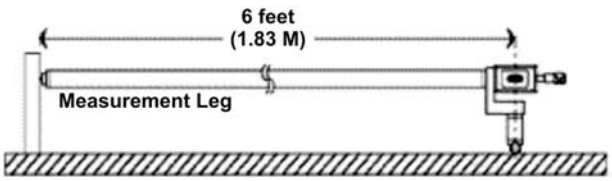
Optional Accessories

A-511 Wand Bore Fixture
A-501 Large Bore Sweep Unit (8" to 8' or 200 mm to 2.4 M Radius)
L-706 Long Distance Bore Laser (50-100' or 15-30.5M Range)

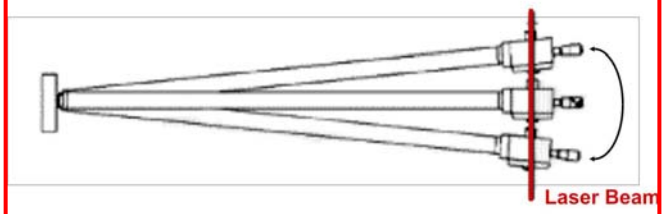
All that is needed now is to adjust the angle of the laser beam, using the two micrometers on the back of the L-705. These micrometers are adjusted until the reference target reads zero, both vertically and horizontally. The laser is now set up and ready for measurements.

For measuring an individual component, such as a diaphragm, there are two target choices. The first is the T-218T turbine target. The T-218T works much the same as the reference targets. The target fixture (A-502A) is swept into the center of the bore using the A-501(A) sweep unit, then the target is placed in the fixture and the reading is taken. A positive vertical reading means the diaphragm is higher than the reference bores. A positive horizontal reading means the diaphragm is to the right of the reference bores. Since the data is live, the diaphragm can be adjusted until the reading is zero (or to an offset determined by the engineers).

The second measuring target that can be used is the A-511 Wand Bore Target. Instead of using a fixture to "hang" a target in the center of the bore, the A-511 uses fixed-length legs that are approximately equal to the radius of the bore. Two legs are used, each 90 degrees from the other. One leg has a measuring tip on it and the other is used for support.



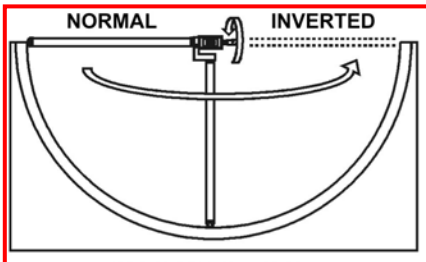
For the repeatability test, the A-511 measuring leg was cut to a length appropriate for a radius of six feet and the tip placed against a metal plate. The bracing leg rested on a flat surface.



The A-511 was then pivoted on the measuring leg to find the high point of the arc. Data was taken 10 times at the high point, pivoting the fixture between readings. The bracing leg remained in contact with the surface to eliminate horizontal errors in the readings.

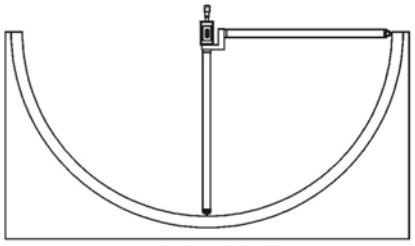
Finding Top Dead Center with the A-511 Target

To take readings, the measuring leg and tip are placed horizontally on the left side of the bore and zeroed out (the right side can be used but it is important that the "zero" side be consistent throughout the measurements). Next, the tip is placed on the bottom of the bore and the vertical measurement is recorded by swinging the target axially (in the same direction of the laser beam) through the arc and noting the highest reading. The target-measuring tip is then placed on the right side of the bore and the horizontal measurement is recorded, again by sweeping the target axially through the arc, noting the highest reading. This "sweeping-through-the-arc" method is very similar to what is done using an inside micrometer and tight wire, and eliminates potential errors if the target is not at top-dead center.



HORIZONTAL AXIS

Two measurements are taken 180° apart on the horizontal axis. The micrometer is adjusted to put the target at the exact bore center (1 radius length from the leg tip). The residual reading is the horizontal misalignment.



VERTICAL AXIS

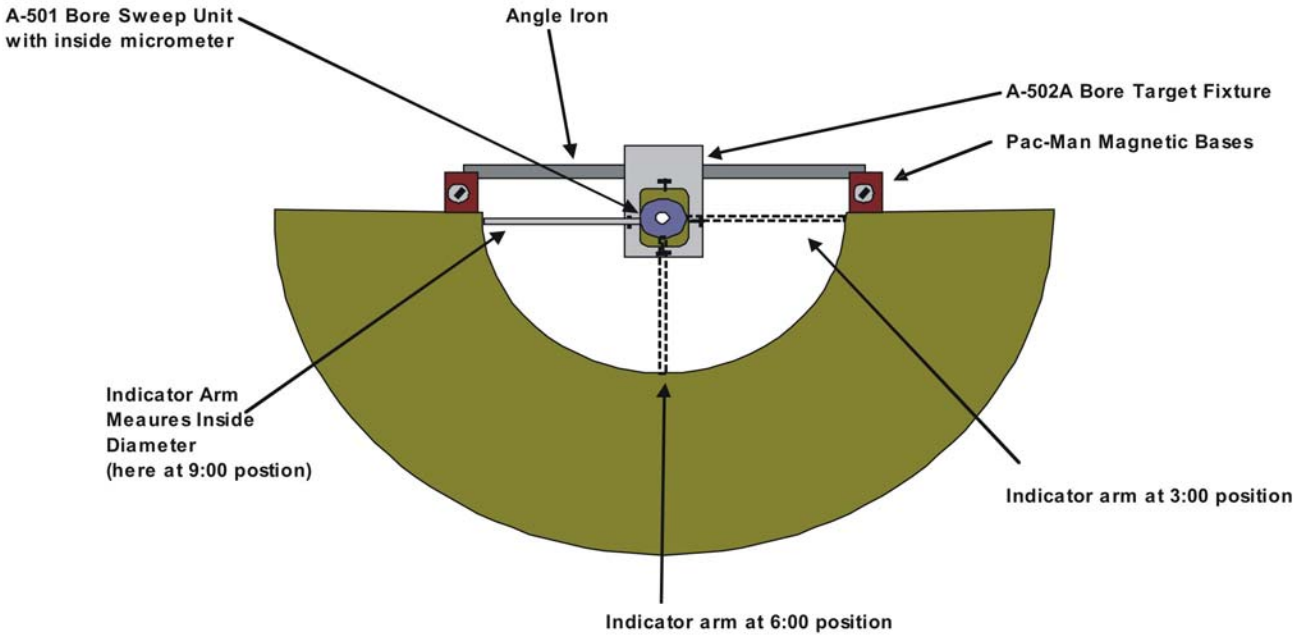
The target is then rotated 90°. The vertical center error can then be read without further adjustment or error correction readings.

Taking Measurements with the A-511

Once all the measurements are recorded, they can then be entered into a spreadsheet to determine the component moves. After the moves have been determined, either the A-511 or the T-218T can be used to align the individual components to their calculated locations. Again, the laser and reference targets do not have to be repeatedly setup and taken down when moving or replacing turbine components.

Both A-511 and T-218T measuring targets are very repeatable. However, in our experience, the A-511 is much faster at taking the measurements. To get the best repeatability, some mechanism should be employed to ensure that each point on the diaphragm or other component is marked and the measuring tip is placed exactly on the same point. Given that the surfaces inside a turbine are usually pitted and rough, a radius tip should be used. For new turbine installations, repeatability of .001" (0.025 mm) or better is easily achievable. However, for older turbines, it becomes increasing more difficult to hold .001" repeatability because of the high level of pitting and corrosion.

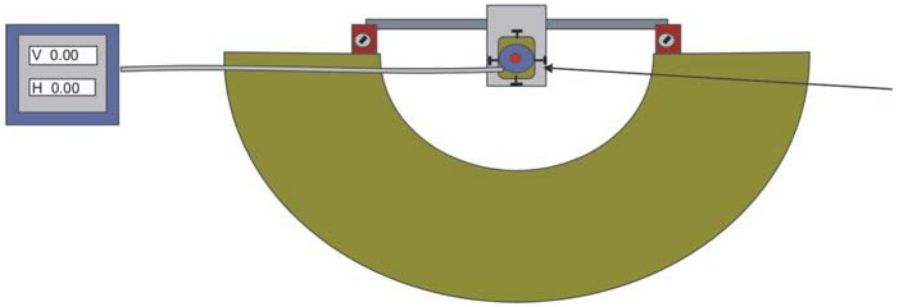
Half-Bore Alignment Setup



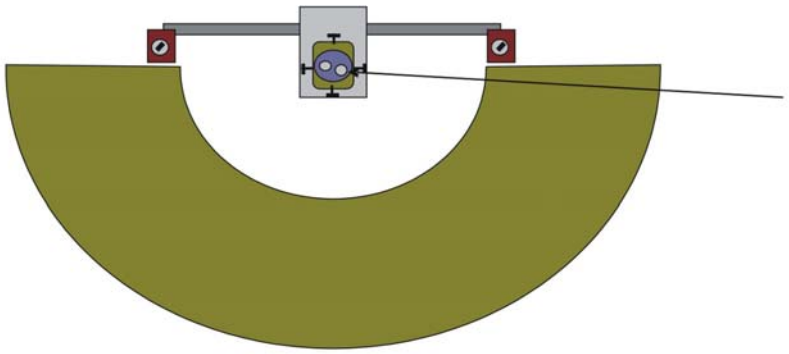

A-501A Turbine Bore Sweep Indicator Unit


A-502A Turbine Target Fixture


A-502L Turbine Laser Fixture

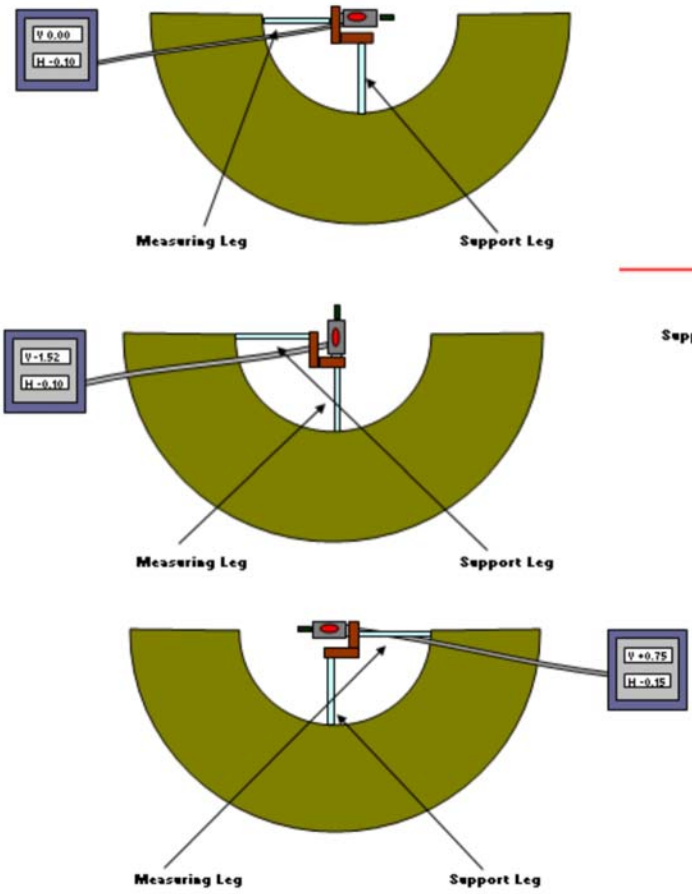


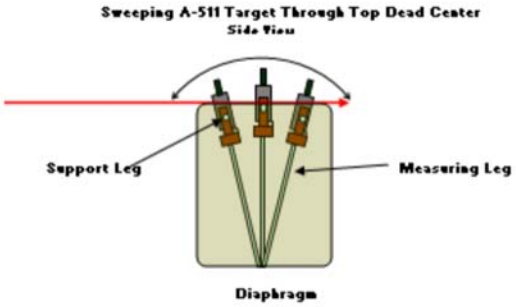
After A-502 Fixture has been set to correct bore center, the T-218 2-Axis Turbine Bore Target replaces A-501 Sweep Unit (both units have same OD - 2.250") in the second reference bore.



After A-502 Fixture has been set to correct bore center, the L-705 Bore Laser replaces A-501 Sweep unit (both units have same OD - 2.250" in the first reference bore).

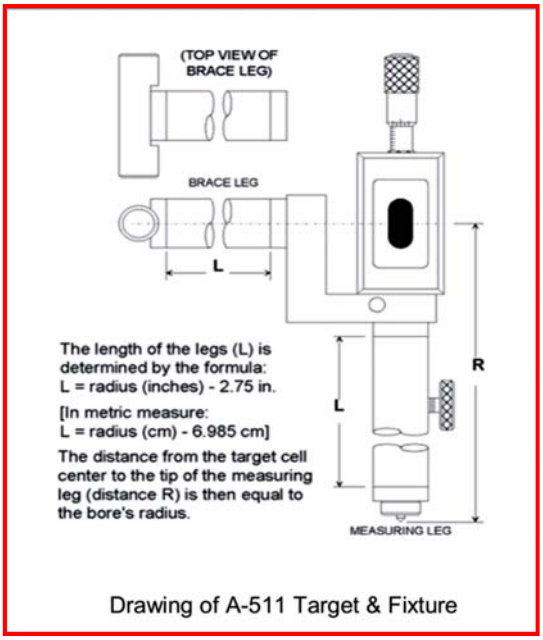
Wand Bore Fixture





Procedure (relates to previous drawings):

1. Place Pac-Man magnets at the edge of the first reference half-bore and place angle iron in them.
2. Affix A-502 Bore Target Fixture to the angle iron and roughly center using a tape measure.
3. Place A-501 Bore Sweep Unit in the A-502.
4. The indicator is usually zeroed on either the left or right side. For now, assume it is zeroed in the 3 o'clock position.
5. Move the indicator arm to the 6 o'clock position and measure vertical axis ID. If it is the wrong ID, turn the adjustments in the A-502 until it is centered.
6. Move the indicator arm to the 3 o'clock position and measure the horizontal axis. If it is wrong, turn the adjustments until it is centered.
7. Once the A-502 fixture is in the correct position, (on the centerline or, in turbine alignment, to "setpoints") remove the A-501 and replace with the L-705 laser. Since the laser beam is concentric to the housing OD within 0.01 mm, the laser beam is now on the centerline of the bore.
8. Place a second fixture in the second reference half-bore and repeat the procedure, placing the T-218 Turbine Bore Alignment Target in the A-502. Turn the L-705 angular adjustments until the laser beam hits the center of the target. The laser is now concentric with the centerline of the two reference half-bores.



Drawing of A-511 Target & Fixture

9. Use either the same combination (A-502 and T-218T and Pac Man magnets) or the A-511 Wand Bore Target to measure the other half-bores in between the two reference bores. Measuring each bore works the same as described in the diagram on the following page, but the target would be set up as described above.

Note: See www.hamarlaser.com/products/targets/targets_9210.htm#A-511 and www.hamarlaser.com/howitworks/A511 Target Rep.htm for a detailed description of the A-511 and how it works.

The L-740 Leveling Laser System

Measuring split or horizontal joints during an outage can take hours and hold up other critical work on a turbine. Traditionally split joints are measured with transits and usually require at a 2-man crew. The measurements rely on the human eye and are subject to interpretation by the operator, an inexact science.

The L-740 Ultra-Precision Leveling Laser was designed for high-accuracy leveling applications. It is accurate to about 1/4 of an arc second or 0.000015"/ft (0.001 mm/M). It is an extremely portable and very affordable alternative to traditional leveling methods like theodolites or transits. Its automatically sweeping laser plane and large-range targets with 0.0005" (.0125 mm) resolution create a powerful tool for quickly checking the flatness of the split joint.

High Accuracy Reduces Optics Guesswork

Hamar Laser's L-740 is accurate to +/-.0015" (.04 mm) in 100 feet (30.5 meters) or +/-.0001" (.0025 m) in 10 feet (3 M) under good atmospheric conditions. This accuracy turns the alignment process from an art using optics to a science using lasers. Optics can be considered an art because each operator "sees" the readings differently and essentially has to make an educated guess as to the correct number. With the L-740, this guesswork is eliminated because high resolution target electronics determine the alignment reading.

Reduce Alignment Work Crews

The L-740 only requires one operator, even on the very largest jobs. That frees up critical manpower to perform other tasks on the outage, helping to reduce the duration of the outage. In fact, the same technician can operate the L-740 Leveling System and the L-705 Bore Alignment Laser for turbine diaphragm and seal alignments.

Minimal Training Needed

The L-740 is so easy to use that it usually only requires 1 day of training and if our Plane5 software is purchased then it only adds 1 day to the training. Compared with optics where training can last up to 2 weeks, the L-740 can significantly reduce the time critical technicians are out of action when being trained.

Multiple Targets for Fast Split Joint Measurements

The L-740 Leveling Laser System can use multiple targets, which really speeds the data-taking process for split (horizontal) joints. In fact, up to 4 targets can be used simultaneously. The combination of automatically rotating lasers and multiple targets can easily reduce split-joint measurement time by 50% or more.

Wireless Targets and Readouts

With Hamar's new line of wireless targets (A-1519/A-1519HR/A-1520 and A-1531/A-1532/A-1533) there is no need to string long extension cords to reference targets. The targets have up to a 3" (76 mm) measuring range and can be used up to 100 (30.5 M) feet from the readout. Other features like electronic zeroing help to speed setup.

Most Accurate Mechanical Levels Available

The L-740 Laser uses level vials that are accurate to 1 arc second (0.00006"/ft or 0.005 mm/M). Only expensive, difficult-to-use, and fragile electronic levels are more accurate. The combination of accurate levels and automatically rotating laser planes creates an alignment tool that is hard to beat.

Color Windows-based Software

The L-740 can also be linked to our new Plane 5 flatness analyzing software. It is Windows-based software that can analyze almost any layout for flatness or straightness. Plane 5 will even analyze squareness if used with our squareness lasers (L-743, L-742, L-741, L-733, L-732 and L-731). Squares, rectangles, frames, circles, rings, and up to four sets of ways can all be easily analyzed with Plane 5. The alignment data is automatically downloaded by using our wireless data receiver, the A-908.

Alignment System Features

- Continuously rotating diode laser with 100' (30.5 meters) radius operating range
- Instant on with virtually no warm up
- Setup in as little as 5 minutes
- Laser planes flat to ½ an arc second (0.00003"/ft or 0.0025mm/M) in 180º sweep and 1/4 arc second (0.000015"/ft or 0.001 mm/M) in 90º sweep
- Laser base includes pitch and roll adjustments
- Precision level vials accurate to 1 arc second (0.00006"/ft or 0.005 mm/M)
- Standard Target: A-1519 Single-Axis Wireless Target with 0.0005" (0.013 mm) Resolution
- Uses A-1519HR Single-Axis Wireless Target with 0.0001" (0.0025 mm) Resolution for higher accuracy applications
- Laser and target fit into a small, portable shipping case
- Uses A/C adapter or battery pack
- Live data display
- Plane5 software quickly records and analyzes flatness data

How the Alignment System Works

If the machine is going to be *aligned* rather than just *measured*, then it is important to put the laser on an instrument stand. If the laser is on the same machine bed or table that is to be aligned, adjusting it will most likely move the laser and thus affect the setup.

Using Reference Points

1. Place the L-740 laser either on the split joint or and instrument stand. Level both level vials.
2. Place one A-1519 target on the split joint as close to the laser as possible. Zero the display on the R-1309. The target has now been set to zero on the first reference point.
3. Move the target along the "pitch" axis to the farthest point from the laser (this is the second reference point). Adjust the laser pitch adjustment until the R-1309 display is zero. Bring the target back to the first reference point. If the display does not read zero, re-zero the display. Repeat this process until the target in both reference points reads zero.
4. Place the target on the farthest point along the "roll" axis and adjust the roll adjustment until it reads zero. The laser is now parallel to three reference points.
5. Move the target to the desired measurement points and any deviation from zero is a measure of the flatness of the split joint.

Using 1-Arc-Second Levels Instead of Reference Points

To level a surface, put the laser on an instrument stand or stable mounting surface and level in two axes. Next, place a single-axis target (A-1531/1532/1533 or A-1519/1519HR/1520) on one reference point and zero (this is done electronically by pressing a button on the target or readout).

Move the target to a measurement point on the surface, where it displays the deviation of that point from the reference point. If the display shows a plus (+), the measurement point is higher than the reference point. A minus (-) indicates that the point is lower than the reference point. If the measurement point happens to have an adjustment pad under it, use the target and readout as a live digital indicator and adjust until the display shows zero. The measurement point is then in the same level plane as the reference point.

Recommended System Configuration

L-740 Ultra-Series Leveling Laser
L-106 Instrument Stand w/case
A-1519 Single-Axis Wireless Target w/1" Range and .0005" Resolution
R-1309 PDA Readout /Read9 Software and IR Receiver
A-909 Shipping Case

Optional Accessories

A-1519 Single-Axis Wireless Target w/1" Range and .0001" Resolution
A-1520 Single-Axis Wireless Target w/.250" Range and 1 Micron (.00004") Resolution for Higher Accuracy applications
A-1532 Universal Scan Target w/3" Range and .001" Resolution
A-1533 Universal Scan Target w/3" Range, Swivel Head and .001" Resolution
R-342 Notebook Computer
R-1342 Toughbook Laptop Computer
A-908 Wireless Data Receiver for Laptop
S-1388 Plane5 Software

The levels can be calibrated in the field using an easy 15-minute procedure and usually hold calibration for several months.

Using Plane5 Flatness Software

Our Plane 5 software can be used with the L-740 to quickly download flatness data for analysis and reporting. If the user is simply taking data, Plane5 employs a least-squares, best-fit algorithm to eliminate any slope errors in the data from the laser not being parallel to the surface. What this means is that you do not have to buck the laser into reference points to check the flatness, which saves about 10 minutes of setup time.

The S-650 5-Axis Coupling Alignment System

Hamar Laser developed the very first 4-axis live alignment system in the early 90's. It quickly became the standard by which other systems were judged. Our new S-650 Wireless Coupling Alignment System sets a new standard. With features like a robust wireless data link, 5-axis target with automatic sweep function, sub-micron resolution, the largest cell range in the market and large color graphics, the S-650 is rapidly becoming the first choice for coupling/shaft alignment applications.

S-650 Reduces Bearing/Seal Costs

Properly aligned motors and pumps will last longer, perform better and use less electricity. The S-650 is an extremely fast and highly accurate tool to align motors to pumps. Not only will you perform motor/pump alignment in record time, but you will also increase the life of your motor bearings and seals, saving you thousands of dollars annually in reduced maintenance costs. And depending on how many motors you have, the S-650 will probably pay for itself in the very first year.

Lasers Are Simply Faster

After 10 years of laser shaft alignment, it is now an established fact that lasers are simply faster than indicator based methods. The bigger the motor, the more time saved during alignments. We had one customer tell us that they reduced the alignment time on one motor from 2 days to 4 hours! This time saving can be especially helpful on critical machinery where downtime is very costly.

Live Data in 4 Axes and Shim Values Really Speed Alignments

The S-650 shows both the horizontal and vertical misalignment for both angle and center at the same time in real time. No longer will you have to guess how far your horizontal moves are going. In addition, our *Couple4* Windows-based software calculates shim values for you, saving additional time.

Indicator Methods Not Accurate Enough

With the advent of vibration analysis and thermal imaging, it is becoming clear that indicator-based methods are no longer good enough. To reduce vibrations and bearing-destroying heat, motors must be aligned very accurately. Indicator methods do a reasonable job of aligning the centers of the shafts but a poor job of making them parallel; large angular misalignments are common. By contrast, the S-650 provides the needed accuracy to reduce excess vibrations and heat so the motors last as long as the salesman says they should!

PM Programs More Efficient with S-650

If you have a preventative maintenance program, you will be glad you have the S-650. Whether you are changing a worn-out motor or simply performing a PM check, the S-650 can be set up and displaying misalignment data in about 5 minutes, allowing you to know instantly whether you have to align a motor or not. And with our computer-based laser system, generating reports and saving alignment data has never been easier.

Automatic Sweep Function Saves Even More Time

The S-650 uses an accelerometer to provide rotation angle measurements, eliminating the "clock method" many other systems still use today. This rotation sensor automatically detects "start" and "stop" points, and works with a sweep angle of as little as 60°, which is especially useful in cramped conditions.

S-650 Even Works in Direct Sunlight

With our new internal light meter, the S-650 actually provides a display of how sunlight is affecting the readings. In most cases, the S-650 will actually work in direct sunlight without having to put up tarps or other shade devices.

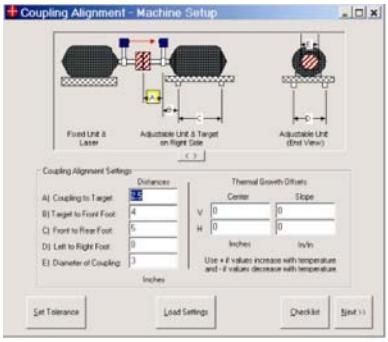
Universal Brackets Eliminate Bulky Accessories

One set of mounting brackets is all that is needed to align 95% of the motors out in the field. The brackets accommodate shafts from 1/2" to 12", without modification, and the can be easily expanded to fit larger shafts to 18". They even have built-in magnets for extremely large shafts. About the only bracket accessories that are needed are offset brackets used for very short shafts.

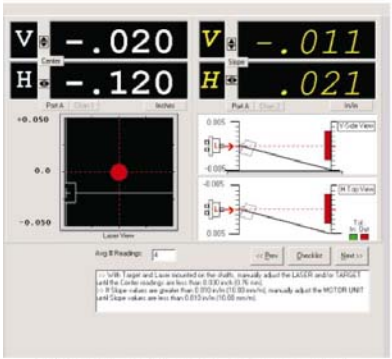
Alignment System Features

- 4-axis simultaneous live graphics in a large, concise, color display
- Robust, infrared-based wireless communication
- Adjustable laser beam for quick set-up
- Live alignment data shows corrections of all 4 axes (vertical center and angle and horizontal center and angle) as they are being made
- Rugged laptop computer is designed for shop-floor environments
- Rugged laptop computer is designed for shop-floor environments
- 40mm target measuring range handles large thermal offsets
- Sub-micron resolution (angular accuracy is 10 micro radians)
- Automatic target sensing of "start" and "stop" points. Sweep angle can be as little as 60º
- Up to 30-foot operational range between laser and target
- With optional PCMCIA portable color printer, reports can be generated in the field quickly and easily
- System can store a virtually unlimited number of alignment reports and set-ups
- Target and laser are pre-aligned to brackets. Many flexible mounting configurations available

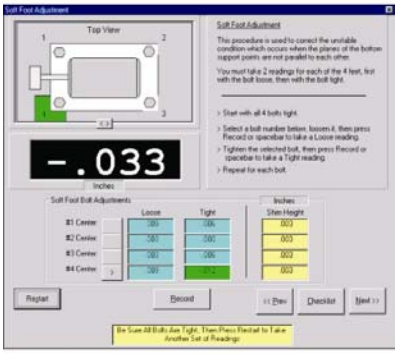
How the Alignment System Works



Coupling4 Step 1 - Motor Setup



Coupling4 Step 2 - Laser Setup/ Rough Alignment



Coupling4 Step 3 - Soft Foot Correction

With any shaft-to-shaft alignment, it is important to find the axis of rotation of one shaft relative to the other to eliminate the effects of mounting errors on the measurement. Traditional methods, like the rim and face method, attempt to do this but in reality still rely on machined faces and rims for accuracy. It is easy to see that an error in the flatness of a coupling face or the concentricity of the rim can affect the measurement.

The S-650 (and S-640) takes care of this problem by using software to perform a procedure that is similar to our NORMIN method. By rotating the laser and target together through 180º and taking multiple points along the way, the mounting errors can be calculated and programmed out of the alignment numbers.

To perform an alignment with our S-650, (S-640 is slightly different) the following 5-step procedure is followed in the Coupling4 software:

Recommended System Configuration

L-775 Dual-Beam Adjustable Laser
T-1275 5-Axis Wireless Target
A-908 IR Receiver for Laptop Computer
R-1342 Toughbook Laptop Computer
S-1393 Coupling4 Software
A-907 Universal Bracket Set
A-509D Pelican Shipping Case

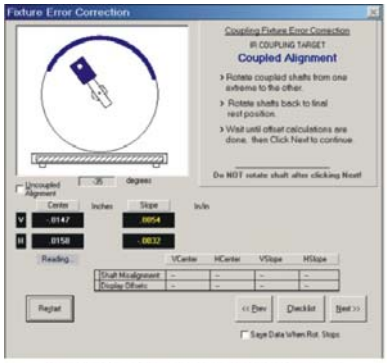
Optional Accessories

A-907A Offset Bracket Set
R-342 Notebook Computer
R-1353C PCMCIA Portable Color Printer (4 ppm)
R-1342A Backup Battery
Alternative System: *S-640 Coupling Alignment System*

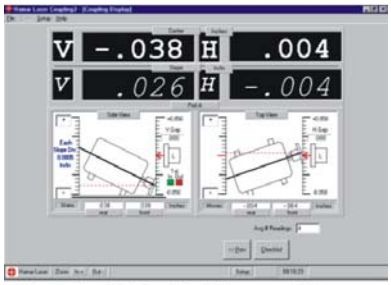
STEP 1: In the MOTOR SETUP SCREEN enter the motor's foot dimensions, machine description and desired alignment tolerances. Thermal growth offsets (the amount the motor grows from a cold start to operating temperature) are also entered at this stage.

STEP 2: The LASER SETUP SCREEN displays and the laser and target are placed on the brackets and adjusted until the readings are within +/- .030" (0.8 mm) of zero. Adjustments to the vertical center are made by moving the laser up or down on the brackets. Adjustments to the horizontal center are made by an adjustment knob on top of the laser. For new motor installations, this screen is used to "rough in" the motor's large angular misalignment.

STEP 3: The SOFT FOOT SCREEN displays an easy-to-follow routine that finds potential soft-foot problems and recommends corrective action. This routine is best used with a motor uncoupled to the driven unit. This is because a large pump and rigid coupling can prevent the laser from finding soft-foot problems. The laser measures shaft deflections caused by a soft foot, and if the shaft is rigidly coupled to a driven unit, it may not move much at all.



Coupling4 Step 4 - Taking Data



Coupling4 Step 5 - Alignment Screen with Shim Values

STEP 4: The DATA TAKING SCREEN displays and prompts the user to rotate the laser and target for data collection and analysis of mounting errors. The system (S-650 only) automatically senses when the laser and target are being rotated and when they stop. When rotation stops, the software automatically calculates the mounting errors and subtracts them from the misalignment readings. The user has choice of a coupled or an uncoupled routine.

STEP 5: The MISALIGNMENT SCREEN shows a graphic display of misalignment, including center and slope readings corrected for mounting errors, and shim values in all 4 axes. The readings and motor graphics automatically update when moves are made or shims added. The data-updating speed (averaging) can be adjusted to smooth out fluctuations in the readings due to air turbulence or vibration. Shim values displays are replaced by "IN TOLER." when the alignment comes into tolerance. The DATA TAKING and MISALIGNMENT screens also show a light meter that warns the user if bright light, such as the sun, is affecting the readings.

For motors with large misalignment, steps 4 and 5 may need to be repeated. In general, however, one set of shims and moves is all that is needed to perform the alignment.