Application Notes

Bore Alignment

System Recommendations

General Bore	**L-705 Bore Laser System**
Crankcases	**L-705 Bore Laser System**
Bar Feeders	**L-705 Bore Laser System**
Cylinders	**L-705 Bore Laser System**
Boring Bars	**L-700 Bore Laser System**

Hamar Laser manufactures the most accurate and portable bore alignment laser systems on the market today. In most cases, our bore alignment systems can fit into a case that is not much larger than a briefcase. These alignment systems are available with a variety of options, including self-centering, see-through, 2-axis and 4-axis targets, hand-held readouts, and Windows-based software to display and analyze alignment data. Since data is live, a bore that is out of alignment can be quickly brought into tolerance using these laser alignment systems. For example, a 10-foot (3 meter) bore can be measured for straightness every three inches in 15 minutes or less, including setup.

Applications for the bore alignment system include bore straightness checks on individual parts, boring bar alignment, crankshaft bore alignment, stern tube alignment, tail rotor bearing alignment for helicopters, bar turning machines, aluminum can-making machinery and hinge line alignment for commercial aircraft. If your specific application isn't listed, we will work with you to solve your unique alignment problems.

The L-705/L-706 Bore Laser Systems

Superior Design Reduces Fixturing Costs

The L-705 Laser has been designed with a standard aerospace tooling diameter of 2.25" (57.15 mm). Since the laser beam is concentric to the OD to within .0005" (.0127 mm), a simple flat face and .750" (19.05 mm) hole on center is all that is needed to hold the laser (powerful magnets hold the laser flush to the face). In fact, the laser replaces the first reference target that a typical borescope would need. Hamar Laser's NORMIN procedure eliminates mounting and centering errors of the fixtures.

Long Range and High Accuracy

The L-705 Laser has a range of 50 feet (15 meters), and under good environmental conditions, it is accurate to .001" (.0254 mm) over the whole range. By carefully following the NORMIN procedure, accuracies of .0001" (.00254 mm) in 10 feet (3.1 meters) can be achieved. With simplified fixturing and self-centering targets, the system can be setup in as little as 5 minutes. And in most cases, bore straightness data can be taken and analyzed in 15 minutes or less using Read8 software.

Recommended System Configuration

L-705 Bore Laser
A-510 2-Axis, Self-Centering Target
A-510 A, B, or C Target Bore Adapters
A-510E Target Pole Extension
R-307 2-Axis LCD Readout
T-231A 25' Target Extension Cable
A-909A Shipping Case
A-909B Pole Case

Optional Accessories

R-307V 2-Axis Large Number LED Readout
R-358 Computer Interface w/0.5 Micron (.00002" Resolution)
S-1380 Read8 Software
T-218 2-Axis Large Bore Target
T-225L Large Bore Flange for T-218 Target

L-706 Long Distance Laser

For long-distance applications that exceed the range of the L-705, the L-706 Laser is equipped with the finer angular adjustments necessary to set the laser beam to the center of the far reference target. It is used for applications from 50 feet (15 meters) to 110 feet (33 meters).

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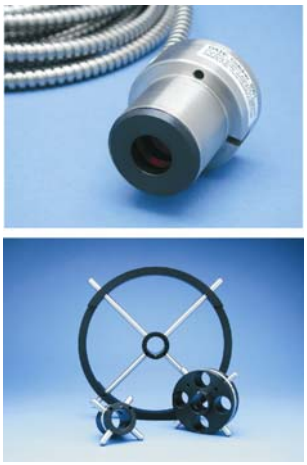
A-510 Patented Self-Centering Target Vastly Simplifies Setup

Hamar Laser has developed the world's first self-centering target that uses no moving parts. It takes just seconds to position the target in the bore for an accurate measurement down to .0002" (.00508 mm). Whether checking for bore straightness or alignment, the L-705 Bore Laser System dramatically simplifies the bore checking process.

The A-510 Target is a general-purpose, 2-axis bore target comprised of a target and an insertion pole. It is used with customized adapters to measure bores from 1.5" to 12" (40 mm to 300 mm). The adapter can be attached to the target in either Self-Centering Mode or Measurement Mode.

In Self-Centering Mode, the target automatically centers itself in any bore size that is +/- .040" (1 mm) from the adapter bore diameter (see the A-510 Target Principles sidebar below).



A-510 Target and Bore Adapters

A-510 Target Measures Bore Diameters

In Measurement Mode, the A-510 will measure changes in a bore's diameter. It works like this: First, a reference diameter is measured with an inside micrometer. The target is placed in the reference bore and the reading is noted. The target is then inverted and the readings averaged to calculate the target centering error. The corrected reading becomes the benchmark diameter. Subsequent measurement points in the bore are compared to the benchmark and the difference in target readings is the increase or decrease in bore diameter.

System Handles Large Range of Bores

Any bore, from 1.5" (38.1 mm) on up to 36" (914.4 mm) or more, can easily be measured with our L-705 Bore Laser System. For smaller bores up to 12" (30 mm), the A-510 2-Axis Self-Centering Target is used to measure bore straightness. For larger bores, the T-218 Two-Axis Universal Target and the T-225L Large Bore Flange are used instead of the A-510. The T-218 has prism that can be flipped out of its center, allowing the laser beam to pass through. This is especially useful for aligning multiple bores over long distances, such as steam or gas turbine alignment.

Alignment System Features

- Fast and simple setup
- Built-in horizontal and vertical angular adjustments for quick referencing
- Simple fixturing to mount the laser into the reference bore
- Visible laser beam straight to .0001" in 10' (0.0025 mm in 3 meters) or .001" in 100' (0.025 mm in 30 meters)
- Hand-held LCD or large-display LED readouts show alignment data in 2 axes
- Self-centering target, accurate to .0002" (0.005 mm), vastly simplifies measurement process
- Windows-based software with large color graphics.
- Large digital display eliminates long cables
- Dynamic or live display of component misalignment
- Portable enough to fit into small carrying case. Complete system weighs less than 15 lbs (6.804 kg).
- Laser runs for up to 8 hours on a standard, replaceable 9-volt battery
- Compact and rugged (4" L x 2.9" H x 1.75" W)
  (101.6 mm x 73.66 mm x 44.45 mm)
- Target uses lightweight, customized bore adapters
- Easily accommodates bores as small as 1.5" (38.1 mm)

Other Bore Applications

Cam/Crankshaft Bore Alignment

The L-705 Bore Alignment Laser System has provided several automotive and diesel-engine manufacturers with a fast, reliable method of measuring the crankshaft bore for both straightness and size. The laser system has proven to decrease inspection times significantly and virtually eliminated dedicated, expensive gauging. The laser and target are adaptable to most crankshaft bore applications. A simple holding fixture is all that is needed for mounting the laser. The A-510 Self-Centering Target and the A-510A, B or C adapters quickly position the target in the bore for ultra fast and accurate alignment checks.

The L-705 has also been used for measuring the straightness of engine block cylinder bores in both conventional automotive engine blocks, as well as the larger block designs used in trucks, farm implements and diesel locomotives.

Stern Tube Alignment

The L-705 is also ideal for measuring the straightness of stern tubes in marine applications (see drawing on Page 7). In fact, if combined with our T-261A 4-Axis Target and an adjustable fixture, the L-705 can project the axis of rotation of the engine or gearbox down into the tube for alignment, minimizing the number of moves during the final engine alignment.

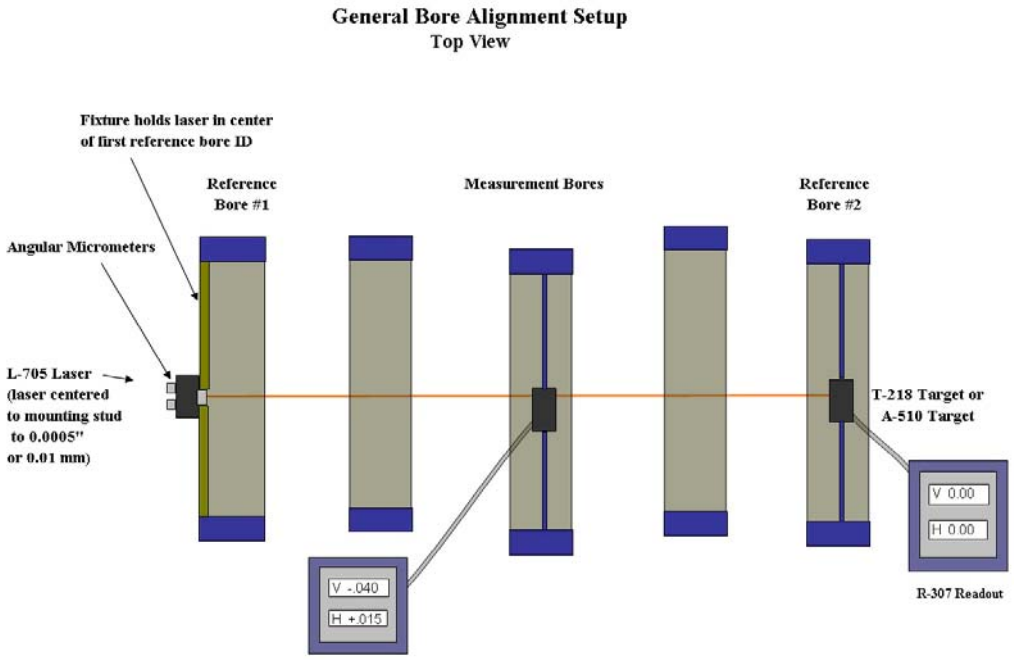
Bar Feeder Alignment

The need for rapid job changeover brought about the need to have a better method of aligning turning center-bar feeders. The existing methods, such as tight wire or knocking the feeder around until it looked like it was “close to being aligned” are no longer sufficient. Misalignment can lead to poor part centering and part loading failure.

The L-705 laser can easily be adapted to the through-hole of the turning machine and made co-incidental to the axis of rotation of the headstock. A target is then mounted to the bar feeder. The system lets the operator know exactly how far to move the bar feeder and provides him with a dynamic display of the moves as he makes them. This alignment can be done at both the front end and the back end of the feed tube.

How the Alignment System Works

The L-705 Bore Laser System was designed to reduce the number of targets necessary when performing bore alignment. Traditionally, bore alignment was accomplished with a reference system (like optics) that uses two reference targets mounted in two reference bores. The L-705’s laser beam is concentric to its housing to within .0005" and thus can be used as one of the reference targets. As a result the L-705 usually needs only one reference target to perform alignments.



General Setup

To perform alignments, the L-705 laser is fixtured into one end of the reference bore (see the General Bore Alignment Setup sketch). Next, a target (T-218 or A-510) is inserted into the far end of the initial reference bore or into a second reference bore. Adjust the angular micrometers until the far reference target reading is zero. The laser is now parallel to the end bores and the target can be moved to (or a 2nd target can be placed in) the inner bores for alignment checks. Since the laser provides live date, any alignment errors can be adjusted using the target as an indicator.

Target fixturing can consist of a 3-legged, spider-type fixture with a flange adapter (T-225) or a 4-legged, self-centering adapter (A-510A).

Bore Alignment with the A-510 Target

The A-510 Target is designed so that the PSD is centered axially between the 4 feet of the adapter, 2 of which are offset axially from the other 2. This, in effect, puts the PSD on the pivot point of the adapter and allows the angle of incidence to the laser beam to vary by up to 45º. The A-510 takes advantage of this property by making the adapter slightly larger than the bore. To insert the target into the barrel, attach the spring-loaded pole to the target and pull the target cord. This tips the target forward, allowing it to easily slide into the bore. When the cord is released, the target and adapter "jam" into the bore, finding the center automatically. The weight of the pole keeps the target centered in the bore.

Adjusting the Laser Angle

Once the laser has been inserted and centered into the first reference bore, its angle must be adjusted so that it is on center at the second reference bore. This is accomplished by adjusting the laser's vertical and horizontal angles using built-in micrometers so the target in the far reference bore reads zero, both horizontally and vertically to the centerline as defined by the two reference bores.

Measuring Bore Alignment

The T-218 or A-510 target is then placed in the desired bore for measurement, and once it is properly centered, the readout displays the bore misalignment. To truly align a bore to a centerline, two sets of readings are needed: one set in the section of the bore closest to the laser and one set in the section farthest away from the laser. The average of these two sets of reading indicates how far off center the bore is relative to the reference bores. The difference between the readings is how much angle the bore has to the reference bore centerline. To align a bore, both bore sections must be adjusted to zero, an easy task given that the readings from the target are live.

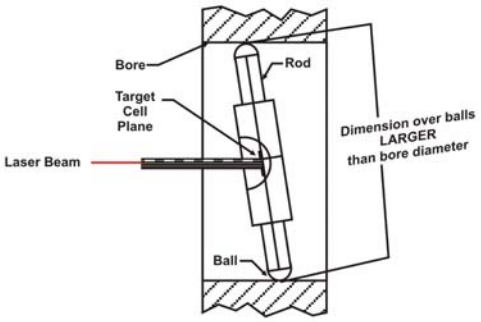
High-Tolerance Bore Alignment

For high-tolerance bore alignment applications, the target centering error (TCE) must be calculated using the NORMIN method. TCE is calculated by taking two readings, one at the 12 o'clock position and a second at 6 o'clock (horizontal and vertical calculations are done separately). The second reading is subtracted from the first and the result is divided by 2. This is the TCE and shows how far off the center of the target is from the center of the bore. This calculation creates an offset that can then be subtracted from all subsequent bore measurements to get the true misalignment number. Our Bore8 software can easily calculate TCE and even automatically remove it from the displayed reading.

The heart of the A-510 bore target is the removable adapter (the A-510A, B, or C). The bore adapters are customized for each barrel diameter, but can handle ± .040" of diameter variance. The patented target and adapter are specially designed to find the center of the bore, without any moving parts, to a tolerance of .0005" (with care, tolerances of .0002" can be achieved).

Self-centering Extruder Target Principle

If both balls at the ends of the rod are contacting the bore, then the middle of the rod is exactly in the middle of the bore. If a bore is slightly larger or smaller, the angle of the rod will change, but not the center. Thus, a laser target located at the rod center will always be centered in the bore. The target cell's calibration does not change with the angle.

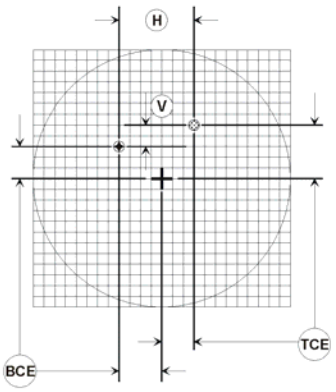


No moving parts – Perfect Center!

The NORMIN Method

The Relationship of the Three "Centers"

- You are seeking the *bore* center relative to the laser beam (BCE).
- The readout information provides the *target* center relative to the laser beam.
- The NORMal reading is taken with the target cable *down*.
- The INverted reading is taken with the target cable *up* (180°).



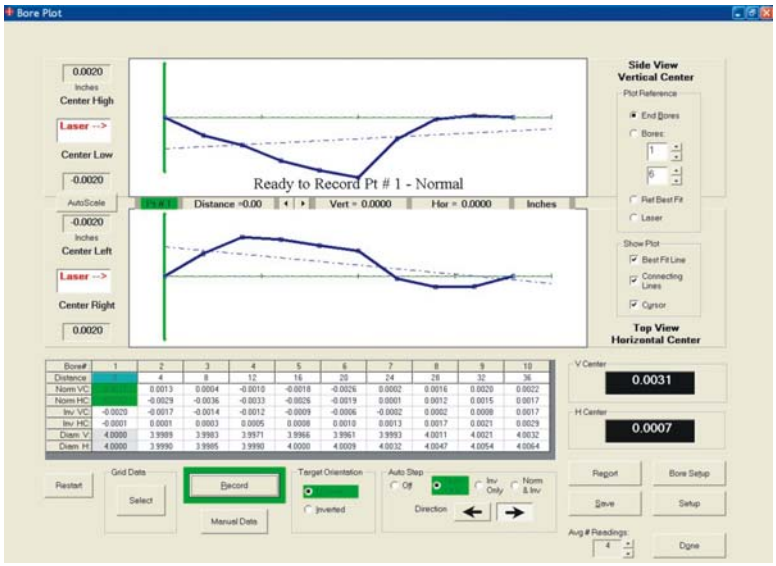
- True Bore Center
- Laser Beam Center
- Target Center
- (H) Horizontal Reading (*Readout*)
- (V) Vertical Reading (*Readout*)
- (TCE) Target Center Error *(Target Center to Bore Center)*
- (BCE) Bore Center Error *(Bore Center to Laser Beam Center)*

The Relationships

BCE=(NORMal reading-Inverted reading)÷2
TCE=(NORMal reading+Inverted reading)÷2
Normal Reading=TCE+BCE

Checking Straightness with Software

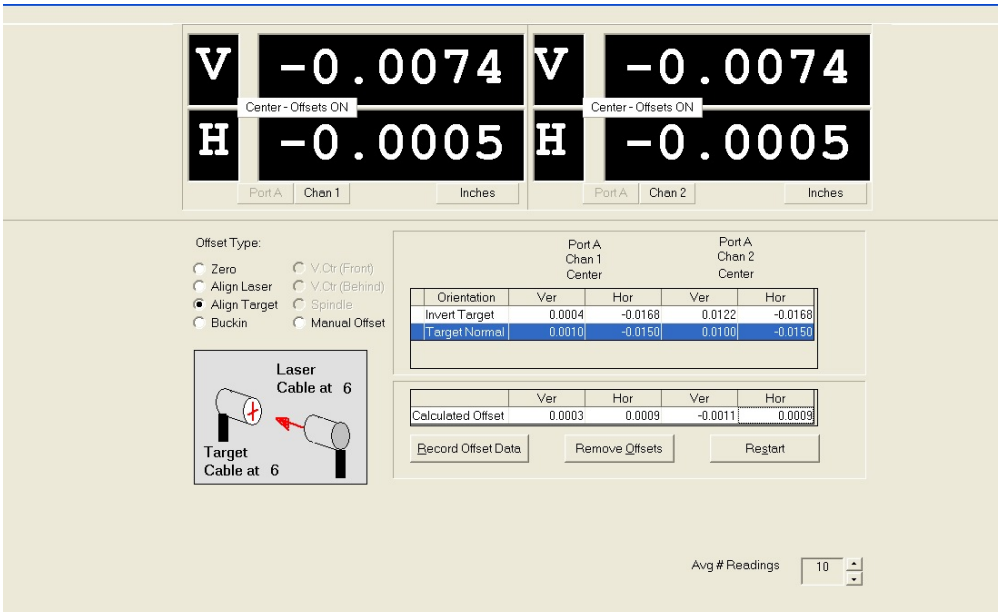
The straightness of a single bore can easily be checked without having to use the NORMIN procedure, as long as an alignment is not required. Simply fixture the laser in one end of the bore and place our self-centering target (A-510) in the other end. Adjust the laser so the readings are zero (.000" or .0000") and start taking measurements. The A-510 target uses a pole to push and position the target into each measuring point, and can take measurements up to 30' (9.144 m) into a bore.

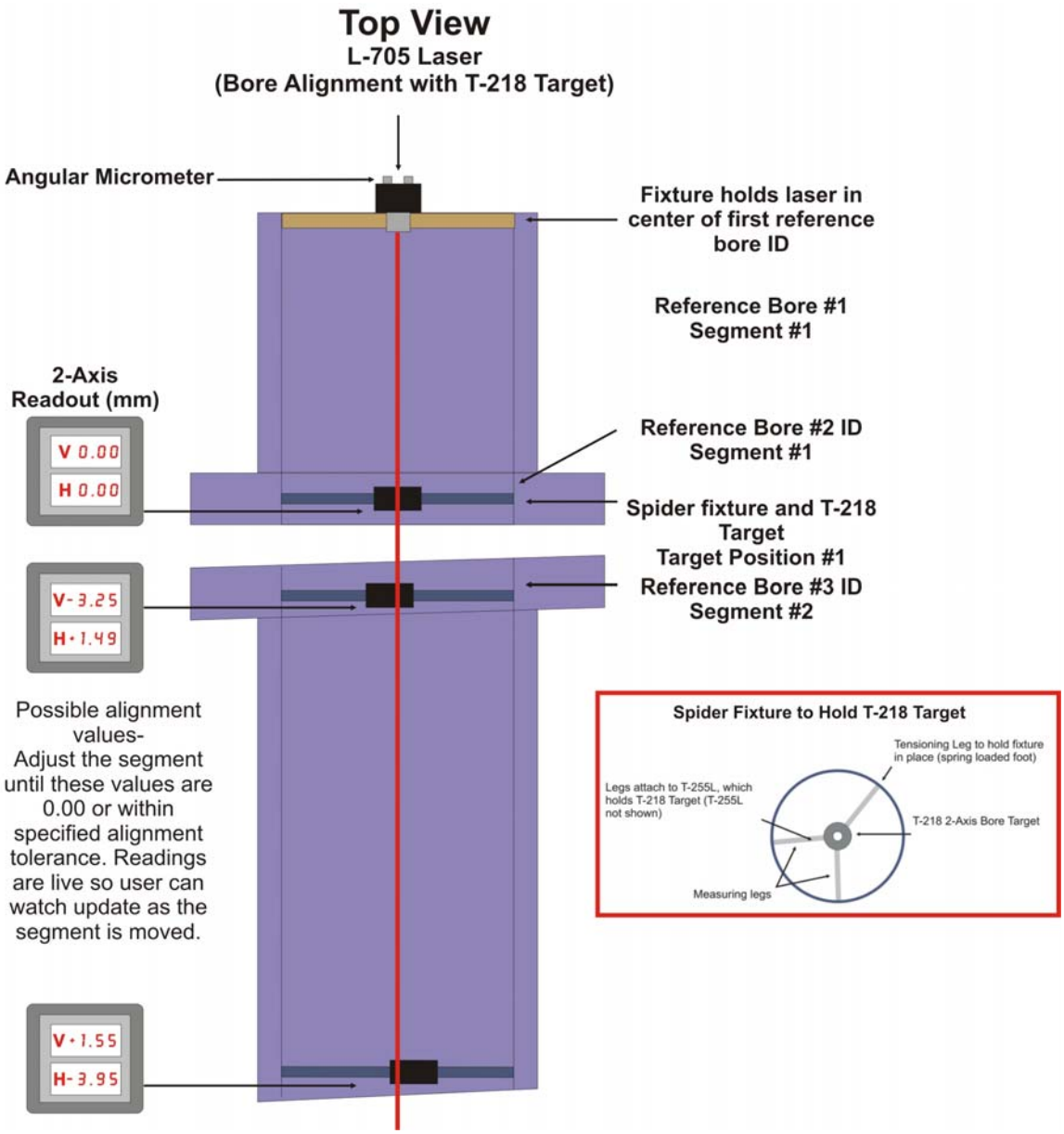


Any slope error due to the laser not being perfectly centered is then removed from the raw reading by using the least-squares best-fit algorithm built into our Read8 Software (see Bore Plot screen from the Read8 software below). This algorithm removes the slope by finding a line that "best fits" the raw data, and it is especially useful because the laser beam does not have to be exactly centered in the bore to get accurate straightness measurements.

Using Read8/Bore8 Software to Calculate Offsets

When it is necessary to use the NORMIN method to calculate the target centering error (TCE) or the laser centering error, the Read8 offset screen makes the process very simple. By clicking on "Align Target", Read8 guides the user through the 2-step process to calculate the TCE and apply it as an offset to the displayed value. Read8 automatically notifies the user when the offsets have been applied (subtracted from) to the displayed value.





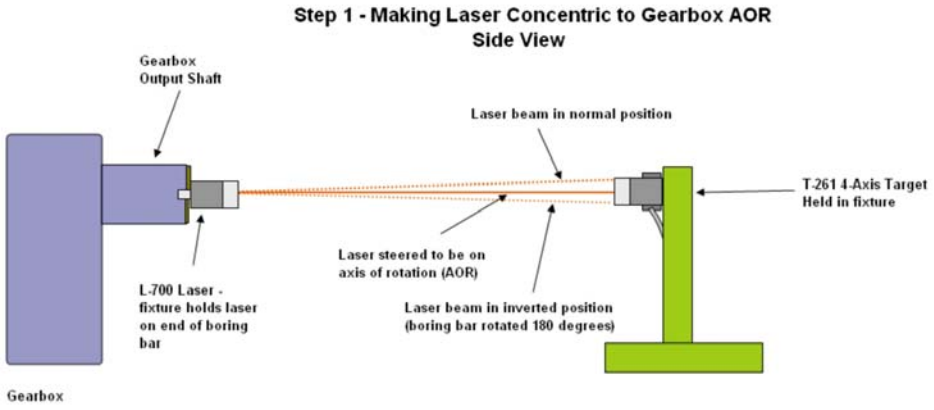
Procedure:

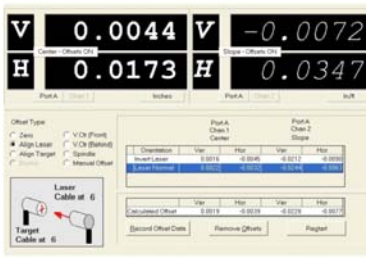
1. Center laser in Reference Bore #1 (laser beam is concentric to mounting OD to .01 mm). With a good fixture, the beam should be centered to the OD to within .01 - .02 mm.
2. Adjust the angle of the laser beam using micrometers so that the readout for the T-218 Target in Reference Bore #2 (Segment #1) reads zero in two axes.
3. Either move the T-218 Target to Segment #2 and center in Reference Bore #3 or place a second target in Reference Bore #3 (the T-218 has a feature that allows the laser to pass through the target to the next target).
4. Once the fixture has been centered (approximately 5 minutes), the reading automatically displays in two axes (horizontal and vertical). If there is an adjustment, the target can be left in place and the alignment reading will automatically update with each movement of the bore.
5. The T-218 Target and fixture can be moved to Reference Bore #4 and its readings can be determined. The T-218 can be moved to any location as long as there is a fixture to hold it in place.

Notes:

- The spider fixture requires cutting the legs to specified lengths to fit into the desired bore diameter. We offer a fixture that uses these legs to hold the T-218 Target in place. We will provide a drawing of the T-225L with instructions on how long to make the legs, or we can make them for you.
- The T-218 target has about +/- 2.5 mm (10 mm range of cell minus 5 mm of beam diameter) of measuring range. The target face can be made with reflective tape to visually display severe misalignments. In other words, if the misalignment is outside the range of the target, the laser dot will show on the face of the target, indicating misalignment.

Stern Tube Alignment Procedure





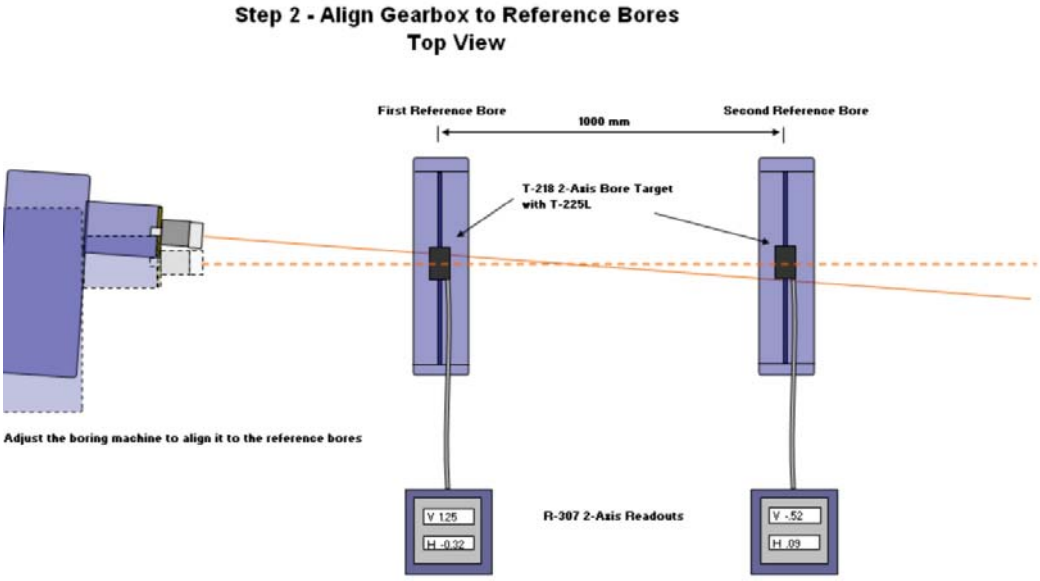
Read8/Bore8 Align Laser Screen

Setup

1. Put the fixture on the gearbox shaft and insert the L-700 Laser into the fixture.
2. Position the T-261 4-Axis Target and fixture so that the laser beam hits the center of the window. The fixture/laser should be within 1-2 feet to eliminate the possibility that the laser might rotate off the target when the shaft is rotated 180 degrees.
3. Connect the T-261 to the R-358 Computer Interface and open the Read8 with Bore8 software (see ALIGN screen below).
4. Use the following 3-step procedure to align the laser to the axis of rotation of the shaft:
   - Rotate the shaft 180 degrees (levels in the laser tell you when you are at TDC). Press the spacebar to record 4-axis readings.
   - Rotate the shaft back to 0 degrees. Press the spacebar to record 4-axis readings.
   - The software calculates how far the laser beam needs to be adjusted and then app-lies offsets to the reading display. Adjust the four axes of the laser using an Allen key until the display shows zero (this procedure should take about 5 minutes).
5. The laser is now parallel to the axis of rotation of the gearbox. Remove the T-261 and fixture and insert the T-218/T-225L in the first reference bore.

Procedure

1. Place the T-218 Bore Target in the firsts reference bore using the T-225L fixture. This shows if the bearing bore is centered to the axis of rotation (AOR) of the gearbox shaft. Adjust the bearing until the readout on the T-218 Target reads zero, aligning it to the AOR of the gearbox.
2. Place a second T-218 Target in the second reference bore. The first T-218 has a flip-up mechanism that allows the beam to pass through to the second target.



3. Align either the second reference bearing to the gearbox AOR or align the gearbox AOR to the reference bores or bearing. If the gearbox is to be aligned to the reference bores, two targets are strong recommended. In other words, the readings of the close target give the center alignment values and the difference between the first and second target gives the angular alignment value. In the graphic example above, the vertical axis of the first bearing is high by 1.25 mm and the vertical axis of the second bearing is low by -.52 mm. To align these bearings, the first would have to be moved down by -1.25 mm and the second moved up by .52 mm.
4. To align the gearbox AOR to the bearings, calculate the angle, which in the above example is (1.25 mm - -0.52 mm)/1000 mm = 0.002 mm/m. If the distance between the front and back feet of the gearbox is 500 mm, then the front feet must be shimmed by 0.002 * 500 = 1.0 mm, eliminating the angle of the gearbox AOR to the bores. Lower the gearbox until both targets read zero in the vertical axis. The same procedure is also used (at the same time) for the horizontal axis.
   Note: *The target readings are live, so the readouts can be used to align the bearings (or boring bar) to the axis of rotation.*

The L-700 Bore Alignment System for Boring Bar Alignment

Our L-700 Spindle Laser and A-510 Self-Centering Bore Target comprise a package to align boring-bar bearings up to 70 percent faster than conventional methods. With an accuracy of +/-.0002" (.00508 mm) and software with large, color graphics, this system is the perfect tool to align boring-bar bearings quickly and accurately.

Laser Eliminates Tram Bar Sag

Aligning the bearing supports of boring bars has never been easy. Using a tram bar (or other such device to simulate the boring bar) to do the alignment is subject to sag and mounting errors. At best it becomes a trial and error task. At worst, the bearings wear out prematurely. The L-700 laser eliminates the sag of a tram bar by using light to project the spindle axis of rotation out to 100'. A target accuracy of +/- .0002" (.00508 mm) means you can achieve very accurate alignments of your boring-bar bearing supports.

Alignment System Features

- Simple fixturing to mount the laser into spindle projecting its axis of rotation to 100' (30.5 M).
- Vertical and horizontal controls for both angle and center for adjustment of laser to spindle's precise axis of rotation.
- +/- .0002" (.005 mm) target accuracy with live measurement data in two axes (vertical and horizontal center).
- Visible light beam.
- Hand-held LCD or large-display LED readouts show alignment data in 2 axes.
- Laser runs for up to 8 hours on a standard, replaceable 9-volt battery.
- Compact and rugged (4" L x 2.9" H x 1.75" W).
- Windows-based software with large, color graphics.

How the Alignment System Works

The laser is mounted in the spindle chuck and is qualified, or made parallel to the axis of rotation by using our T-261 4-axis target and the NORMIN method. This procedure eliminates the mechanical mounting errors of the laser and puts it on the precise axis of rotation of the drive shaft (see the illustration on the following page). After mounting and qualifying the laser, the target is inserted into the bearing and a reading is taken in the front and back of the bore, providing both the angle and center misalignment for the horizontal and vertical axes.

Since the target can simultaneously show a live display of both horizontal and vertical readings, you can start aligning the bearings without changing the setup or moving the laser. When the readout reads zero (.000" or .0000") in the front and back of the bore, the bearing is aligned.

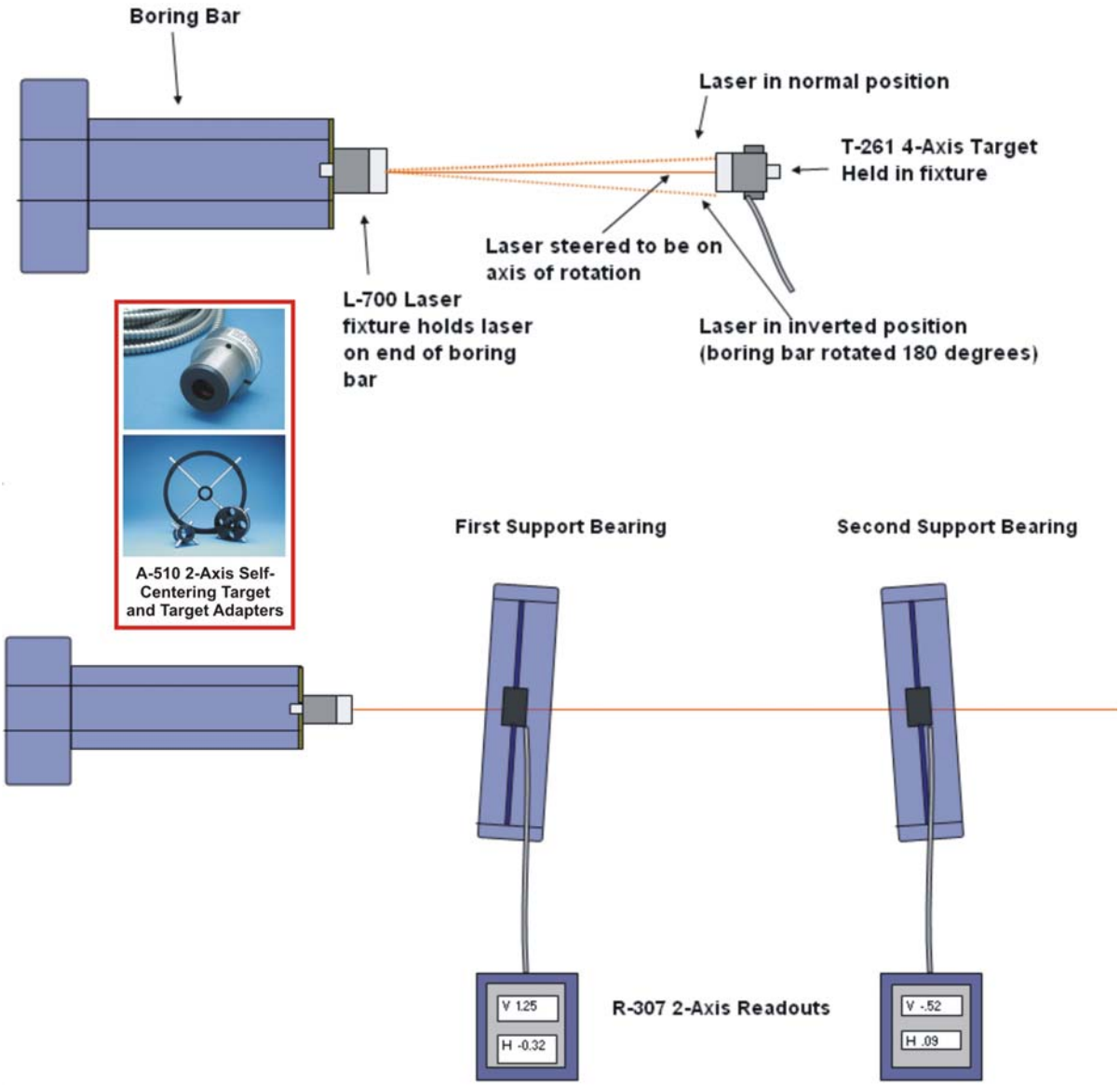
Recommended System Configuration

L-700 Spindle Alignment Laser
A-510 2-Axis, Self-Centering Target
A-510A Target Adapter-2-4" bores (50.8–101.6mm)
R-307 2-Axis LCD Readout
T-212 4-Axis Target with .0001" (.00254 mm) Resolution
A-809 Shipping Case

Optional Accessories

S-1380 Read8 Software
R-358 Computer Interface with 0.5 Micron (.00002" or .00508 mm) Resolution
R-342 Laptop Computer
R-1342 Shop-Hardened Laptop Computer

Boring Bar Alignment Procedure



Procedure:

1. Fixture the L-700 laser into the end of the boring bar.
2. Fixture the T-261 4-axis target into the first bearing (or use a target stand) to be on the approximate axis of rotation of the boring bar.
3. Record the first set (horizontal and vertical center and horizontal and vertical angle) of alignment numbers from the laser.
4. Rotate the boring bar 180° and record the second set (4 axes) of alignment numbers. Average the normal number and inverted number for each axis. This determines the setpoint for each axis.
5. Adjust the four alignment axes using the built-in adjustments in the L-700 until each axis is steered to setpoint. The laser beam is now parallel and concentric to the axis of rotation of the boring bar.
6. Place the A-510 2-axis Bore Target in the first bearing bore using the appropriate bore adapter. Adjust either the bearing or the boring bar until the readout reads zero, indicating that the bearing bore is centered to the axis of rotation of the boring bar.
7. Place a second A-510 target in the second bearing bore.
8. Align either the second bearing to the laser or the boring bar to the bearing. If the boring bar is to be aligned to the bearing, two targets are strongly recommended, as changing the angle of the boring bar to align to the second bearing will affect the center alignment of the first bearing. In other words, the readings for one target provide the center alignment values and the difference between the first and second targets gives the angular alignment values.
9. When both bearings targets read zero in the horizontal and vertical axes, align the boring bar to the bearings and the operation may begin.

Note:

- The target readings are live, so the readouts can be used to align the bearings or boring bar to the axis of rotation.