

Chapter 2

PRESS ALIGNMENT

Importance of Proper Alignment. Good press alignment is important to profile surface quality and tolerances, as well as equal flow in all ports of the die. As close tolerances and predictable die performance have become more important and section walls have become thinner, alignment has become more critical. Misalignment also causes mechanical problems in the press --- uneven wear, tooling damage, and even “popping” movements as the misaligned press corrects itself during the stroke.

This chapter presents information on press alignment from a variety of sources:

- Press Alignment and Its Impact on Extrusion Performance, from a webinar by Richard Dickson, Hydro Aluminum, and Chris Jowett, Rio Tinto Aluminum. Page 2-3
- Alignment Principles Page 2-15
- Alignment Procedures Using Traditional Mechanic’s Tools Page 2-16
- Use of the Alignment Tool Stack Page 2-24
- Quick Checks of Press Alignment Page 2-26
- Modifying the Press for Easier Adjustment of Alignment Page 2-28
- Laser Tracker Measurement Technology for the Alignment, Correction, Condition Monitoring, and Refurbishment of Extrusion Presses, from Joseph Mulder Page 2-30

Information in this chapter is largely derived from the following sources:

- Mulder, Joseph E. V., and Smith, Gavin J., “Extrusion Press Alignment with Modern Technology,” Proceedings of 7th International Aluminum Extrusion Technology Seminar, Vol I, (2000), p.455-463.
- Mulder, Joseph, “Laser Tracker Measurement Technology for the Alignment, Correction, Condition Monitoring, and Refurbishment of Extrusion Presses,” Proceedings of 11th International Aluminum Extrusion Technology Seminar, (2016), p.555-565.
- Anthofer, E.J., “Press Alignment,” Proceedings of 2nd International Aluminum Extrusion Technology Seminar, Vol. I, (1977), p. 169-173.
- Freese, Howard W., “Alignment of the Extrusion Press,” Proceedings of 3rd International Aluminum Extrusion Technology Seminar, Vol. I, (1984), p.105-111.
- Bergman, John, “Press Alignment Using 3D Laser Technology,” presented at AEC Press Maintenance Seminar, (2002), Chicago.

- Dickson, Richard, and Jowett, Chris, Press Alignment and Its Impact on Extrusion Performance, AEC Webinar, 2014.

The following section is adapted from a Webinar offered by the AEC – Aluminum Extrusion Council – in 2014 and is offered here with permission of the authors.

PRESS ALIGNMENT AND ITS IMPACT ON EXTRUSION PERFORMANCE

By Richard Dickson, Hydro Aluminum Metals USA,

and

Chris Jowett, Rio Tinto

Why is Press Alignment Important?

Press alignment is a complex series of issues, both mechanical and thermal, that when done right ensures that there is no inappropriate metal-to-metal contact causing accelerated wear, nor any 'skull' metal scraped from the container and injected in to the die. It also ensures that the billet metal is presented to the die in the best manner for optimum extrusion.

Effect on Extrusion. Misalignment causes:

- speed differences in multi-cavities, resulting in different run-out lengths
- flow differences that move the shape, affecting tolerances
- inflow, leading to poor surface quality of extrusions

The biggest cause of problems for these issues is poor die to container alignment, which should be better than 0.060 inches (1.2mm) or better center to center.



Build Up on Stem and Dummy Block

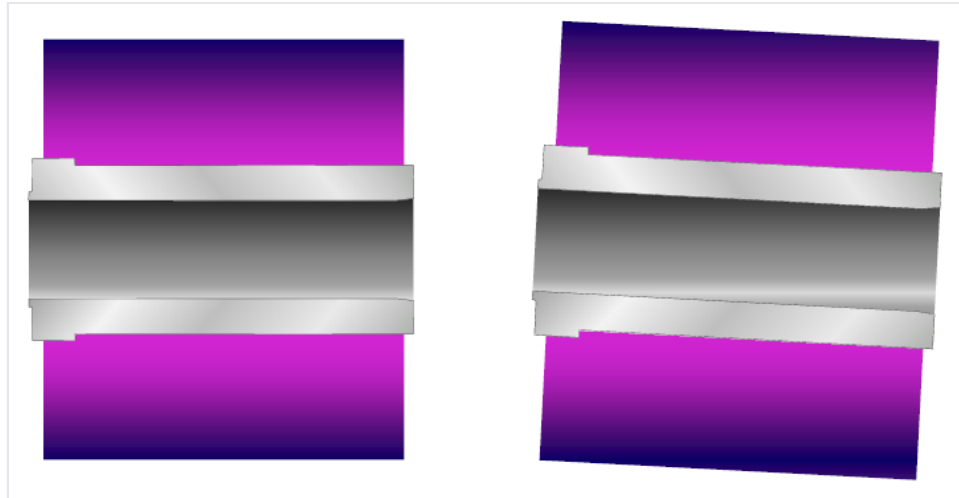
Effect on the Press. Misalignment results in:

- Wear of components- Dummy block, container liner, guides
- Build up on stem
- Safety issues on how to remove aluminum – never use torch
- Aluminum build up also covers up cracks in the stem

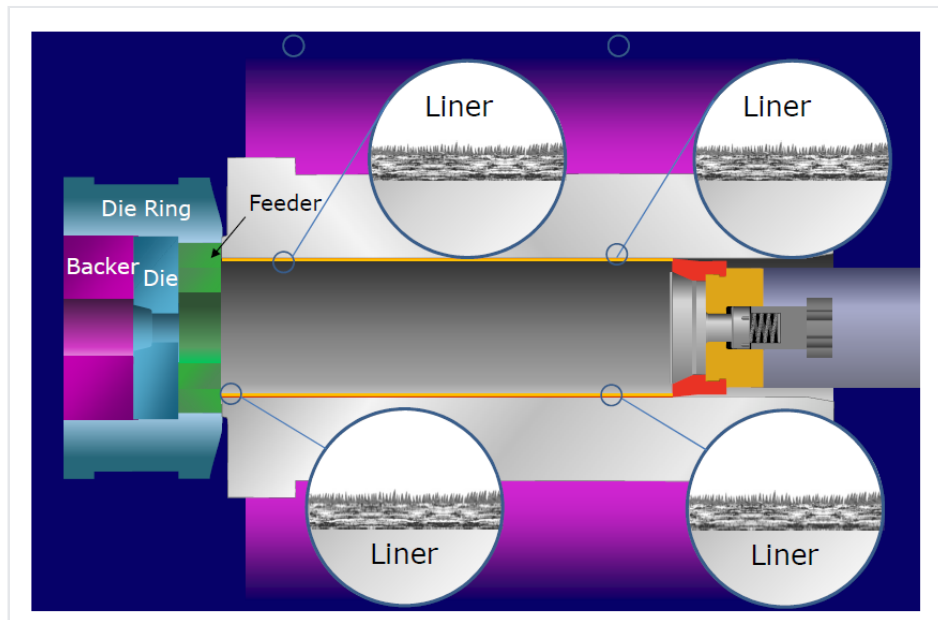
The biggest cause of problems for these issues is container to stem alignment, which should allow a uniform skull in the container.

The dummy block should be sufficiently centered in the liner that inflow of billet skin and trapped air is minimized.

Container vs stem alignment must be correct not just in the vertical axis; also is the container “cocked” at an angle?

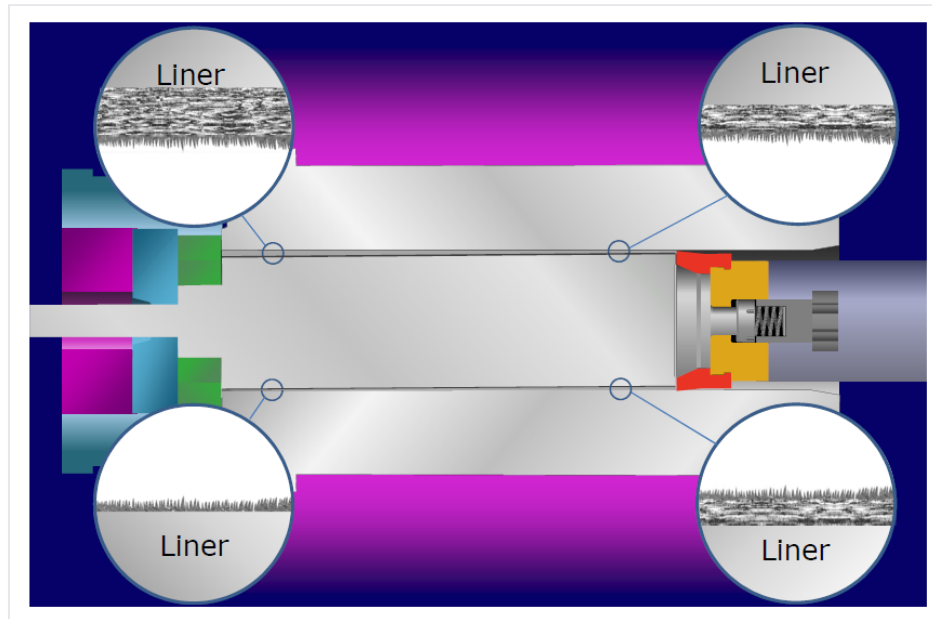


Container Correct – Parallel to Centerline Container “Cocked” or Tilted



Container with Uniform Skull

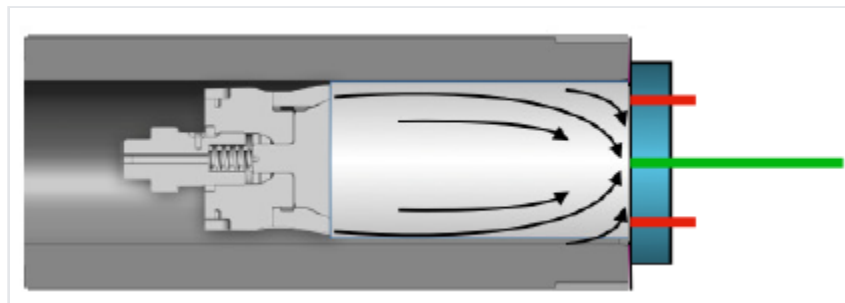
Tilted or “Cocked” Container



Skin Flowing into Extrusion Causes Bad Surface Quality

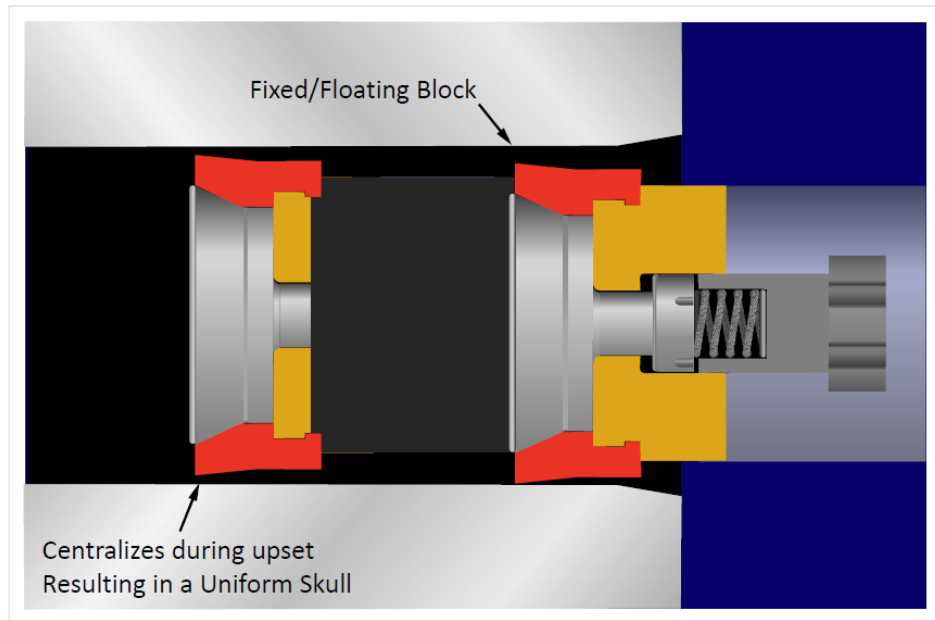
Effect on Die Performance. The die maker designs the die with the assumption of a standard flow of metal arriving at the die face

- The metal flow near the container is slower, at the start, due to friction with the container
- The bearings on the die are reduced towards the container's edge
- But if the relative position of the container/die is wrong then the bearings are wrong



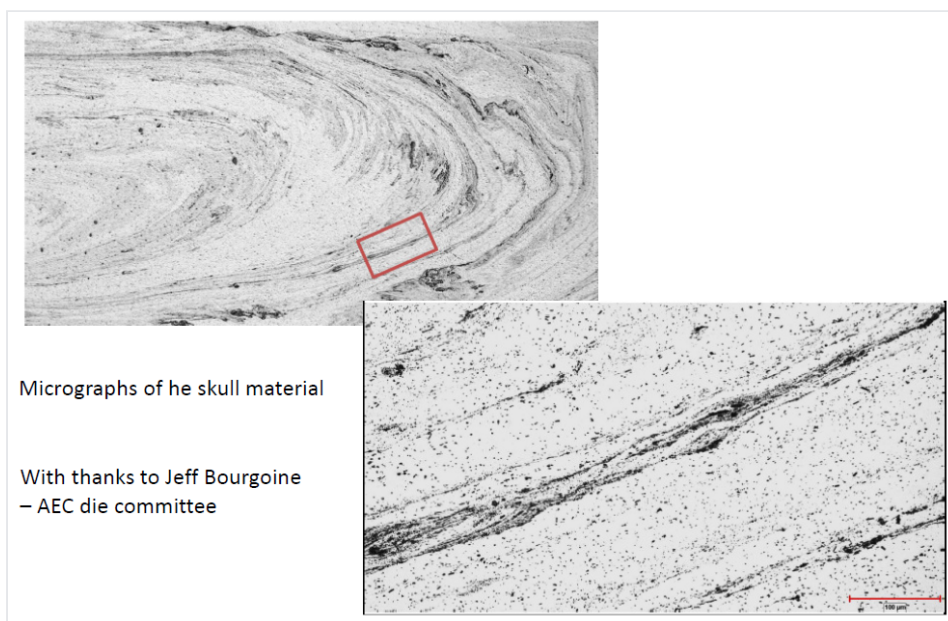
The relative location of the container to the die matters

The dummy block self centers a small amount:



Why the skull is so bad for extrusion

Oxides and other impurities from the billet surface can migrate to the skull and into the extrusions, causing surface defects.



Micrographs of the skull material

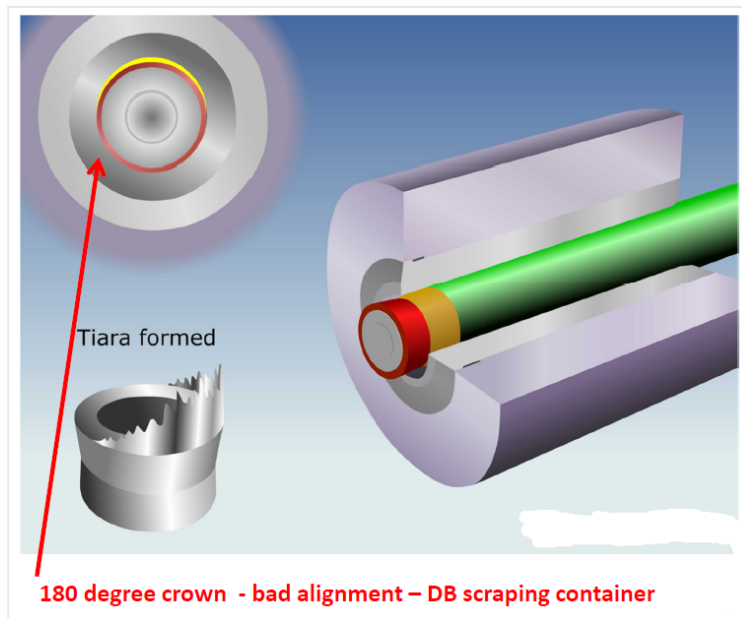
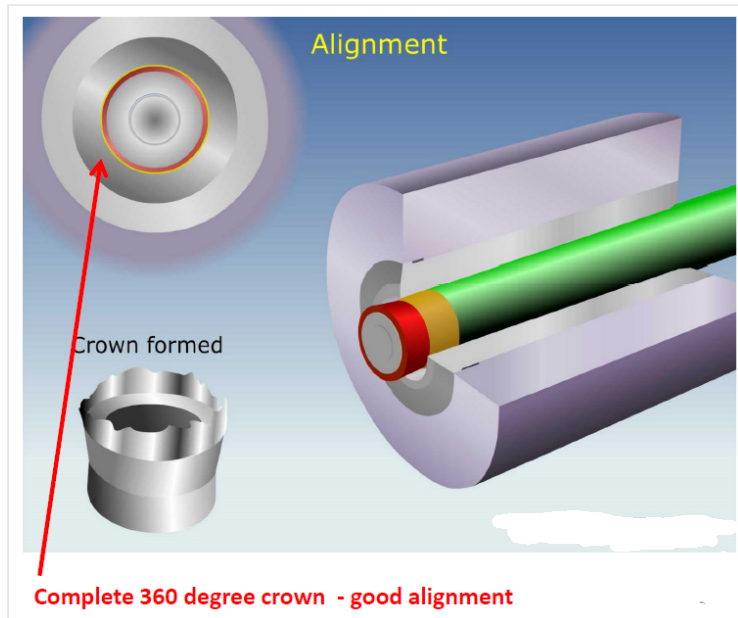
With thanks to Jeff Bourgoine
— AEC die committee

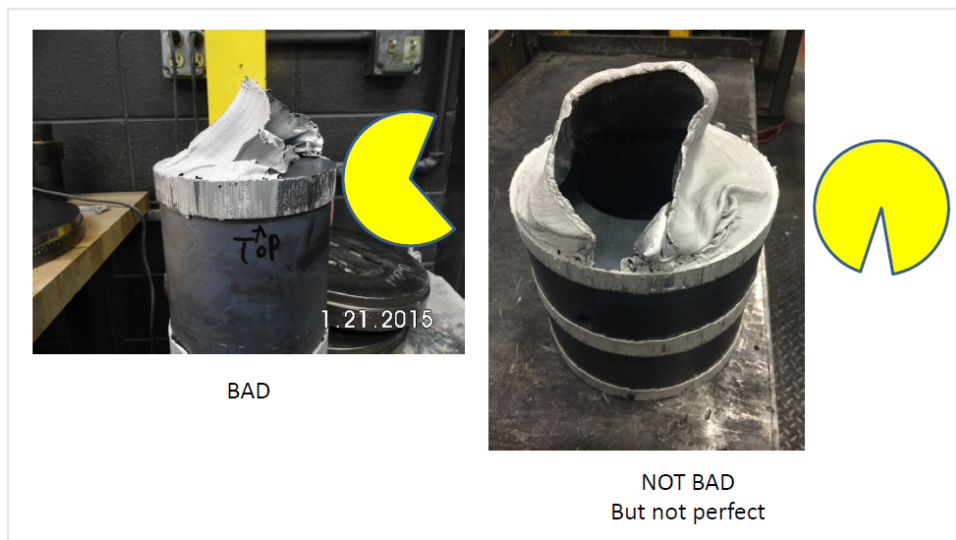
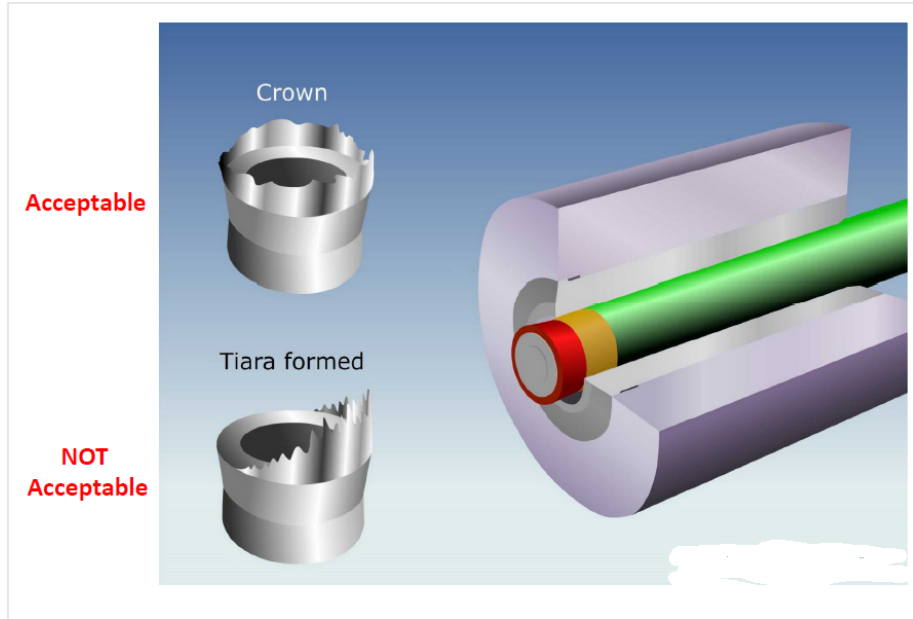
For additional information the effects of alignment on profile surface quality, see references on page 2-13.

Daily Alignment Checks – Two Methods

First Method: Check stem to container alignment using a cold cleanout block. (Cold blocks must have expansion slots). The shape of the “skull” is an indicator of stem to container alignment, as follows:

- Uniformity of skull around the circle is good alignment
- Not a full circle – not good alignment





Weigh the skull. This can be used to calculate the thickness of the skull in the container. The weight should be charted to monitor dummy block condition.

- If the weight is increasing, the dummy block is wearing
- If the weight is decreasing, the dummy block is over expanding – may be cracked

Second Method: Check container to die alignment, using various methods:

- Visual inspection using a special dummy tool stack
- Target die
- Leave a butt on the die

However, with either of these methods there are issues with temperature and pressure, and when the test is conducted.

Visual inspection using a special dummy tool stack. There are many negative issues:

- Size of the dummy tool stack
- Condition of the press – not at working pressure
- Condition of the press – not at working temperature
- Not numerically measurable

Using a target die. There are many positive issues and one negative:

- Condition of the press – at actual working pressure
- Condition of the press – at actual working temperature
- Measurable
- Negative: some lost production time



Target Die in Die Holder Billets with Impression of Target Die

Note: a variation of this method is presented on page 2-14 of this chapter.



Close-up view of billet with impression from Target Die

Leave a butt on a die. There are many positive issues:

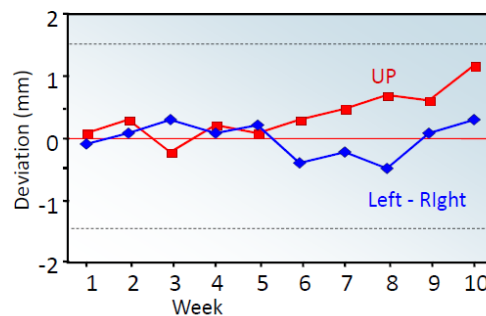
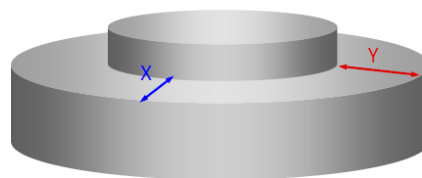
- Condition of the press – at actual working pressure
- Condition of the press – at actual working temperature
- Accurately measurable
- Zero lost production time
- Negative: Extra caustic (but you do get two cleaned die rings every day)

Measure butt end offset on die

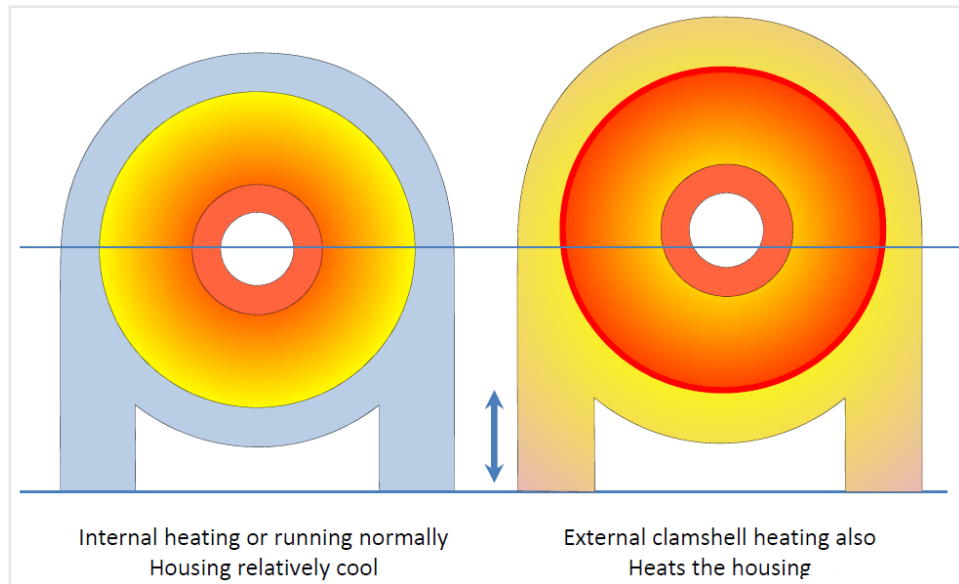
- Measure N, S, E and W
- $(N-S)/2 = \text{up down C2C}$
- $(W-E)/2 = \text{LEFT RIGHT C2C}$

Charting for preventive maintenance

- Keep inside 60 thou control limits
- Watch for trends



There may be issues with press temperature when the alignment is checked. If the press is idle for a time but container heat is on, the important dimensions may change, as the container housing is also heated.

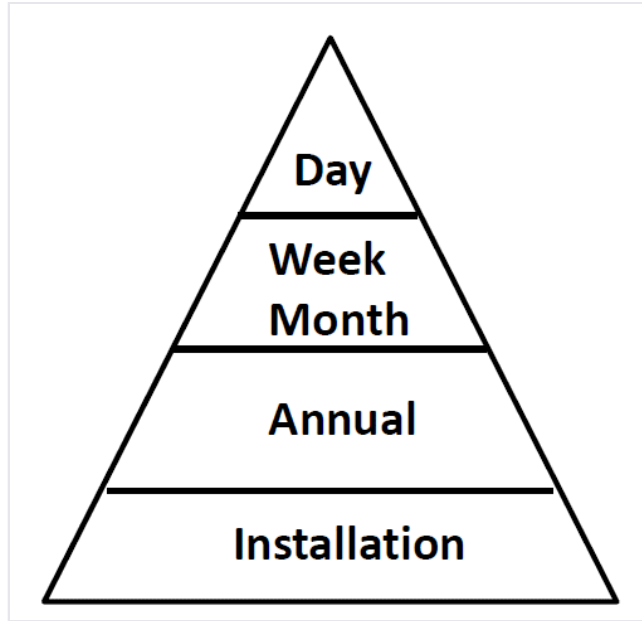


Important notes on die-container alignment

- If the die is high, there may be dirt in the die holder/slide
- If the die is low, look for worn wear components in the die slide
- If it is a 2-position die slide, compare slide 1 to slide 2
- Sometimes the die may be tilted if the pressure ring is not flat; you only see this under pressure
- The above may not be seen with a dummy tool stack
- Often if there are differences between sides of the die slide, there are issues with moving the slide

Frequency of Alignment Checks

Die to Container
Container to Stem
Check Tie Rod Pre-stress Nuts
Check Wear on Dummy Block and Liner
Stem to Press Centerline
Platen Pressure Ring flat and Square
Stem Square to Piston (Main Ram) Base
Flat, Level, Bolted Down
Tie Rods Level and Parallel
Cylinder and Tie Rods Parallel
Press Platen Square



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Alignment standard tolerances

- Press base must be square and level within 0.0005 inch/ft.
- Front platen and main cylinder platen must be parallel (same 0.0005 in/ft), and perpendicular to the guides.
- Tie rods must be level (within 0.0005 inch/ft), the max variation between tie rods must be within 0.003 inch/ft (measured across the press, rod to rod, horizontal, vertical, front and back).
- Level and align the main cylinder.
- Pre-stress tie rods to 10% over the rating, inside nuts tight and locked. When relaxed no clearance between platen and outside nuts.
- Container to stem must produce a full crown from a cleanout block
- Die to container must be within 0.060 inches (1.5mm) center to center

Order of alignment:

- Align the stem to the press
- Align the container to the stem. Do not move the stem to match the container
- Align the die to the container. Do NOT move container to align with die; container to stem alignment would then be wrong
- If the container is raised to correct die/container the container will be 'cocked'

Thanks to the authors:

Jerome Fourmann, Rio Tinto Aluminum, offers the following references concerning the importance of alignment and tooling condition to profile quality:

From **Defects Affecting Extrusion – Streaking, Die Lines, and Micro Die Lines**

Light Metal Age, April, 2016, page 27.

“Inside the container, the metal adhering to the container wall after extrusion is of poorer quality than that which has been extruded because it consists of a mixture of inverse segregate and ingot skin heavily oxidized during casting, homogenization, and reheating. However, if the adhering layer is allowed to build up on the container wall by use of incorrect tooling, such as a damaged or incorrect size dummy block or a misaligned press container and stem, then parts of the container coating may eventually be detached and drawn into the extrusion. This may result in small surface or sub-surface streaks resembling pickup, and may sometimes be associated with die lines and micro die lines occurring anywhere along the extruded length.”

From **Defects Affecting Extrusion – Streaking Visible after Anodizing**

Light Metal Age, June, 2016, page 27.

Streaking characterized as:	Oxides	Grain banding	Back-end (Coring)	Transverse Weld
Billet quality				
Alloy composition (Fe, Ti, Mn, Cr)	X	X		
Casting	X	X		
Homogenization		X		
Tooling aspects				
Bearing Length, undercut, square		X		
Flat face w/feeder	X		X	X
Pocket w/feeder	X		X	X
Feeder design (dead metal zone)	X			X
Bolster & backer hardness/flatness		X		
Polishing technique	X	X		
Nitride condition, case depth	X	X		
Die heating practices	X	X		
Press conditions and extrusion practices				
Container & dummy block condition			X	
Press alignment	X	X	X	X
Shear design, condition, clearance	X		X	
Nitrogen application	X	X		
Butt Length	X		X	
Temperature: exit metal, container...	X	X	X	X
Quenching		X		
Two piece billet	X	X		
Weld scrap			X	X
Amount of billets run	X	X		
Stretching		X		

Table I. Classification of streak-type defects.

From **Defects Affecting Extrusion – Inclusions from Billet Handling and the Extrusion Process**

Light Metal Age, June, 2017, pages 28-29.

“Inclusions originating from billet handling or during the extrusion process almost always result in poor surface finish and sometimes in complete failure of the die or tooling. They can be metallic or non-metallic. Most of the time, once such inclusions come in contact with the die bearing, they cause permanent damage resulting in a deep die line easily identifiable by the naked eye. As a consequence, increased die maintenance is required or tooling needs to be replaced.

"These inclusions can originate from contamination during billet transportation, storage, and handling. Alternatively, damage to the tooling can occur, such as with flaking of the die's nitride case, dummy block erosion, or wash-out of the container liner (due to chemical reaction between aluminum and steel). During die maintenance, incomplete removal of caustic residue (Al and Al oxide), sand blast media, and abrasive flow machining media can cause surface finish problems. Other contaminants such as concrete dust and steel or plastic brush fragments can become embedded in the billet surface.

"Dummy Block Erosion and Wash-Out of the Container Liner: The alignment of the stem, dummy block, and container are fundamental to achieving a balanced metal flow through the die and to prevent steel tooling erosion. Figure 7 illustrates a steel particle with a shape suggesting interaction between dummy block and liner bore. EDX spectrum analysis of the steel reveals a composition of Fe, Cr, Mo, V, Si, and C. The peaks were characteristic of H13 steel composition. The defect, therefore, comes from the press tooling. After investigation on the press, the particle was confirmed to have come from the liner. It could have also come from the dummy block (floating or loose) as the steel composition is identical; however, one would hope this would be observed during the regular changing of blocks. Container temperatures are typically controlled around 400oC and the liner surface is near 500oC during extrusion. After a typical life of a year, the combination of time and temperature can be long enough for a Fe/Al intermetallic to form, which can explain the presence of a thin intermetallic layer on these types of inclusions.

"Once one starts to question the condition of the liner surface, one is introducing the possibility of all sorts of defects. Wash-out of the liner means billet skin is being retained in the container. Although the billet skin tends to emerge primarily with coring, it can also appear at any stage of the process; and once it enters the die, it will come out in the extrusion at some point. Hence, it is recommended that a clean-out block be used frequently in order to maintain a clean liner that is free of aluminum oxide build-up. In addition, regular checks should be carried out on the container alignment and of the liner condition to check for excessive wear.

"The skull thickness is approximately 0.25 mm, depending on the exact diameter of the liner and fixed dummy block. Ideally, a "best practice" operation should run a clean out block at the beginning of each shift and prior to an alignment check. It is also recommended to do a check when switching alloys from a medium strength alloy (i.e., 6061) to an alloy being used for high quality surface finish products. There is also a benefit to monitoring on a weekly basis how much skull is removed and the uniformity and distribution around the liner. The data obtained regarding dummy block clearance, alignment, and whether the liner is "bellying" (i.e., a blister issue) becomes vital information to maintain good life expectancy. Regular weighing of the skull is also a very good way of controlling the wear and functioning of both the dummy block and liner."

Alignment Principles. The geometric or dimensional aspects of an extrusion press are fundamental to proper press alignment, which is required for maximum production quality and minimum downtime. The press should be installed according to the original manufacturer's specifications, especially with respect to

tolerances. If their instructions and recommended procedures are carefully studied, the ideal 3-D geometric relationship of the press components can be determined. In general, the main 3-D geometric relationships of the static components of a simple extrusion press are as follows:

- the press base or bedplate should be level with respect to gravity, and the relevant contact points should lie in a flat plane.
- the back or resistance platen should be fixed perpendicular and the front platen located perpendicular to the base, with both platens parallel to each other.
- the pressure ring bushing should have its hole centered in the front platen with its front surface flat and parallel to the front platen.
- the guide ways for the crosshead and container should be straight and parallel longitudinally to the base, and should be symmetrically spaced about the press center line with the correct dimensions.
- the main cylinder, bearing bushing, flange, and ram piston should be concentric and centered on and perpendicular to the back platen.
- the crosshead should be center-mounted on the ram and fitted with a straight and centered extrusion stem perpendicular to the back platen.
- the press center line is the line joining the platen centers, and all the platen-centered components should lie on this line.
- the geometric center lines of each of the four machined tie rods or columns should be parallel to and symmetrically located about the press center line so that their mean is parallel and lies on the press center line.

It is clear that, as more components are added, a more complete 3-D model is built up equivalent to the original design drawings and, with the specified tolerances and critical dimensions, that this is the mathematical inspection template used during measurements for compliance of any of the press components.

Similarly, the 3-D geometric relationships of the moving components of the press are as follows:

- the ram piston and the extrusion stem move along the press centerline over their full stroke.
- the center line of the container bore is coincident as it moves along the press center line from its open to closed position, under container pressure and during various extrusion loads.
- the centerline of the tooling stack is coincident with the press center line in its closed state, under container pressure and during various extrusion loads.
- the billet loader positions the billet so that its centerline matches the centerline of the container and stem before it is loaded into the container.

These relationships must be correct when the press is at operational working temperature to allow for thermal growth effects. The above also implies that some sort of monitoring process of the major press components should be carried out during the various operational load and event conditions of ram and container pressure and extrusion.

Alignment Procedures Using Traditional Mechanic's Tools

The procedures and frequency for press alignment will vary according to the press design and condition and the quality control procedures of the plant. The original recommendations of the press manufacturer, if available, should always supersede the procedures described below. However, in the absence of complete alignment instructions from the press supplier, these will be helpful in setting up an alignment program.

Press Alignment procedures may be divided into two parts:



Figure 2-2: Three-plane laser level (See www.hamarlaser.com)

- **Alignment of the main press frame and components**, which must be carried out very precisely when the press is first installed; again after any period of neglect, for example, when beginning a new program of regular preventive maintenance; and rechecked periodically thereafter.
- **Routine re-alignment of wearing components**, which frequently vary due to steady wear and tear or replacement of components.

Laser alignment tools and methods are emerging as the best technology for quick and accurate press alignment, often replacing the **mechanical devices** used since the 1950's. At this time the laser tools may not be available to all extruders, so both types will be presented in this chapter.

Recommended Tools

The tools recommended for performing press alignments may include the following:

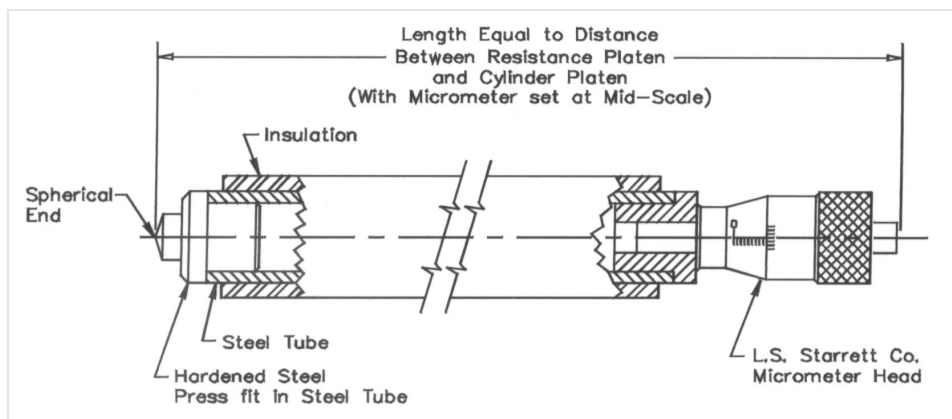


Figure 2-3: Trammel Rod device.

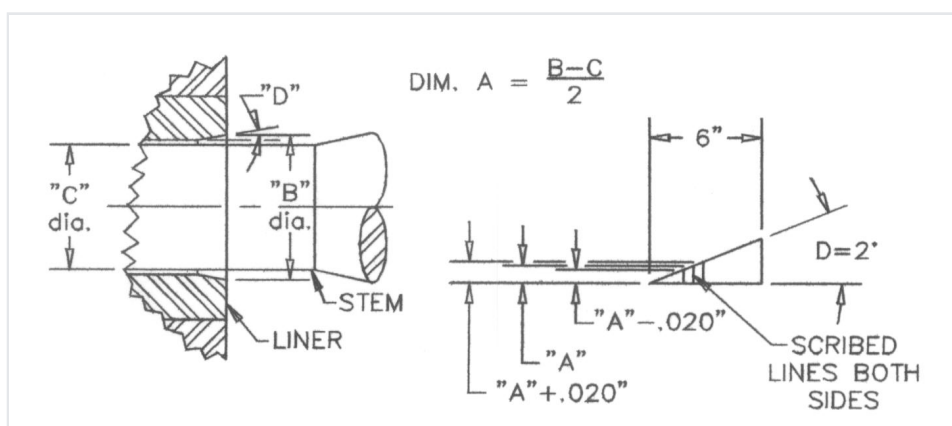


Figure 2-4: Container Taper Gauge

Machinist's Level. A precision type level, it should have minimum 10-second accuracy (one division equals 0.0005 inches/foot or 0.004 mm/Meter). **Do not use on hot surfaces!**

Surveyor's Precision Optical Level (Transit). Typical accuracy is 0.0001 inches/foot.

Laser Level (1, 2 or 3 Plane). (Now commonly used in place of transit.) The 2- or 3-plane lasers will require fewer set-ups to complete the leveling. (Figure 2-2)

Trammel Rod. These are custom-built devices designed for measuring the distance between platen flanges (or between tie-rod nuts). A steel or aluminum tube is fitted with an inside micrometer or dial indicator on one end, and a spherical-ended pin on the other (see Figure 2-3). For accuracy, the trammel rods must be designed and supported to avoid deflection from their own weight; and insulated to avoid expansion from heat transferred by the press container heat.

Container Taper Gauges. Custom-made gauges as shown in Figure 2-4 are **fabricated of** an easily-scribed material such as aluminum, about 6 inches long with angle taper slightly greater than the taper of the container inlet or taper seal taper. Scribed marks indicate the accuracy of ram centering within the container.

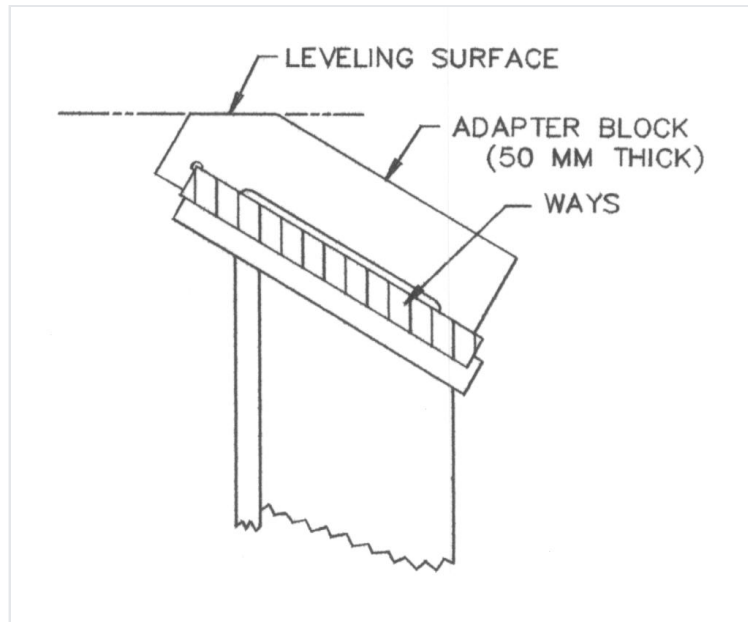


Figure 2-5: Adapter Block for Angled Guide Ways.

Adapter Blocks for Angled Guideways (two required). For presses equipped with angled guide ways, these custom-made adapter blocks (Figure 2-5) provide proper reference points for leveling of the press frame.

Piano Wire (or **Music Wire**). Diameter 0.4 mm to 0.5 mm (0.015" to 0.020"); tensile strength 250,000 to 500,000 psi (1700 - 3400 N/mm²).

Fixtures for Piano Wire Tensioning. Use of music wire for locating the press center line may be simplified by use of custom-made fixtures as shown in Figures 2-6 and 2-7, for tensioning and positioning the wire at the press platen and ram stem.

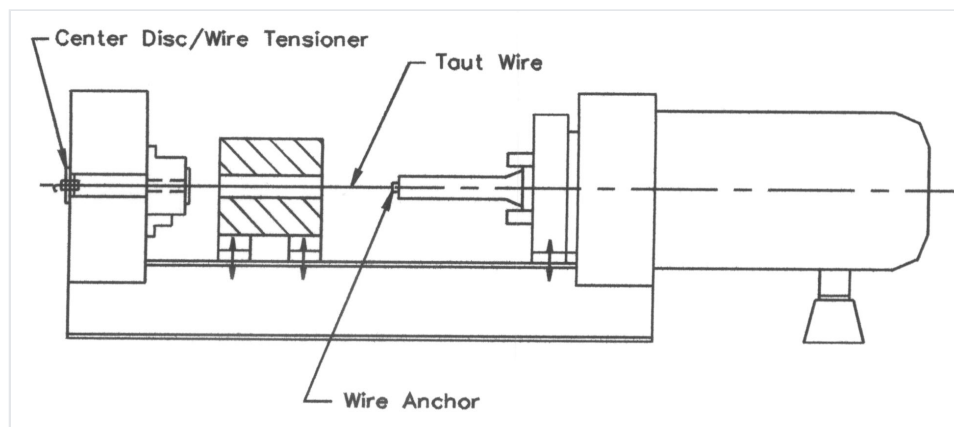


Figure 2-6: Alignment with piano wire

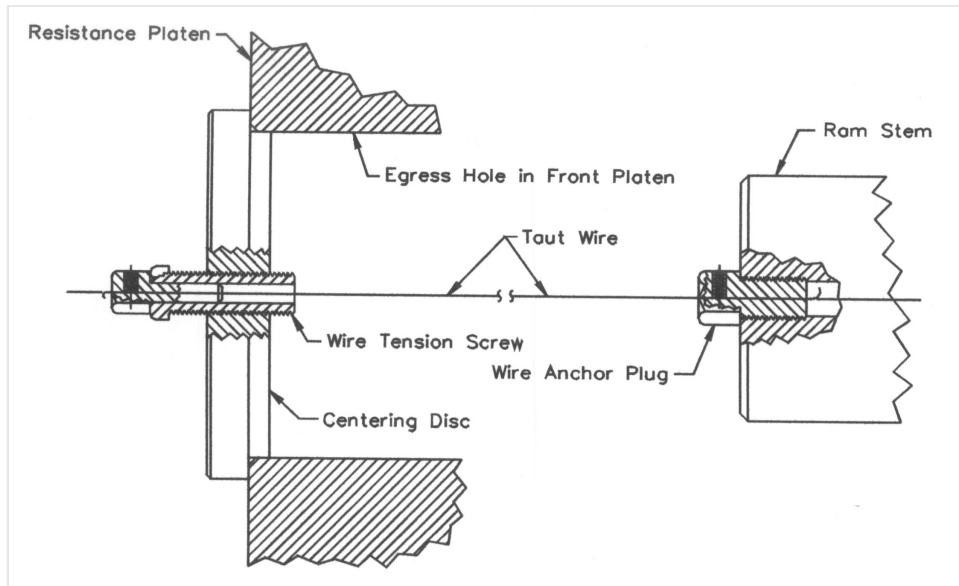


Figure 2-8: Precision Tube Fixture

Precision Tube Fixture. Alternative alignment techniques may use a custom-machined tube, along with fixtures for the press platen and ram stem, as detailed in Figure 2-8.

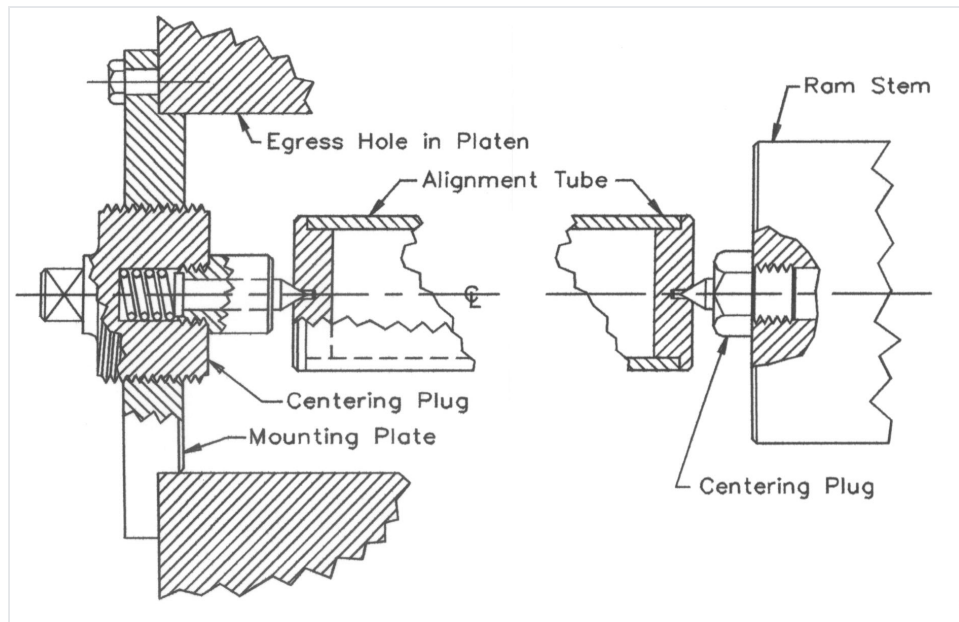
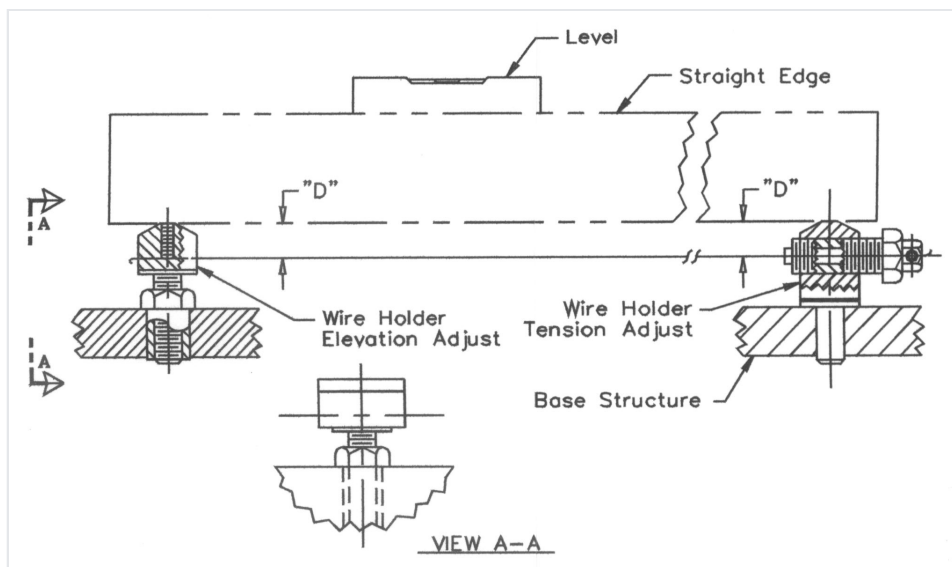


Figure 2-9: Fixture for Base Centerline Method



Base Centerline Fixtures. Another system uses precisely located holes in the press base, along with special fixtures as detailed in Figure 2-9.

Dummy Dies and Tooling Stack. An alignment tooling stack with an appropriate center hole (Page 2-11) is used for checking centering to the container, stem, and pressure plate. An alternative type of dummy die with precision scoring (shown in Figure 2-12) may be used to quickly measure tooling-to-container alignment.

The following additional standard measurement tools are recommended:

Dividers*, Calipers*, and Hermaphrodite Calipers*

Precision Square*

Straightedge* (typical 8 feet long)

Plumb Bob*

Feeler Gauge*

Note: the items marked (*), plus the music wire, machinists level, surveyor's level, and inside micrometer for trammel rod, are generally available from tool suppliers; for example, from McMaster-Carr Supply Co., , Telephone 630-833-0300, Fax 630-834-9427, www.mcmaster.com. **Alignment and Leveling of the Fixed Press Components**

The press base must first be square and level. When first installed the press base is usually set on shim packs on top of the press foundation, leveled, and then grouted in place. Normally, ½" to 1½" of grout is used. Anchor bolts should be tightened against the shim packs, which are located on both sides of each anchor bolt to avoid distortion of the frame. Leveling accuracy is normally 0.0005 in/ft (0.04 mm/meter).

With the passage of time, it is possible that the press base is no longer level. Possible problems include:

- settling of the foundation or the soil underneath
- deterioration of the foundation
- deterioration of the grout
- loose anchor bolts
- environmental conditions
- modification or mechanical damage to the press frame

Before leveling the press base, the condition of the grout and foundation and the tightness of anchor bolts should first be checked. If necessary, remove the grout; re-level and shim the base; re-tighten the anchor bolts; and re-grout. If the levelness continues to change due to foundation deterioration or settling, consult a geotechnical engineer concerning modern techniques of foundation repair, such as **pressure grouting** and **grout pilings**. Once correctly adjusted and stabilized, re-checking of the press base should not be required except at infrequent intervals unless there are unusual foundation problems.

It is also important to insure that tie rod nuts are tight and that the tie rods and nuts are not cracked. Any looseness will affect measurements.

1. Level the Press Base in all directions. Check the level lengthwise, then across the base, and then diagonally both ways (left front to right rear, right front to left rear). The desired variation from true level is maximum 0.0005 inches/foot (0.04 mm/meter). Re-level the base if it exceeds 0.0030 in/ft (0.25 mm/M) from true level.

The guide ways are the preferred reference points for leveling. In case of angled guideways, use the Adapter Blocks for Angled Guideways (Figure 2-5) to establish horizontal surfaces for use in leveling.

Measure 12 to 14 points along the length of each guideway. If using a laser level, measure along both the inside and outside of each way. First choose one way as a reference plane and then measure all other points against the reference.

2. Level and align the Main Cylinder. The platen or flange portion of the main cylinder must be perpendicular to the guideways and the centerline of the press base, and parallel to the front platen. To measure, place a precision square on the machined front surface of the platen, and check the horizontal leg of the square with the machinist's level. Maximum allowable variation from perpendicular: 0.0005 in/ft (0.04 mm/meter).

If using a 3-plane laser, measure the angle between the reference guide way and the main cylinder and front platen, in order to determine their squareness to the reference guide way.

Another important check: extend the main ram just far enough to accommodate the machinist's level on the ram surface (about 18"). At this point the main ram should be fully supported by the main ram bearing bushing. The main ram should be level to the same tolerance: 0.0005 in/ft (0.04 mm/meter). If the main cylinder's platen surface is perpendicular and the ram is not level, the main ram bearing bushing is likely worn and may require replacement. The guide shoes of the moveable crosshead should just be touching the guide ways in this position.

On some presses the perpendicularity of the main cylinder platen may be adjusted by jacking and shimming the rear cylinder support.

3. Check the levelness of the tie rods. Check the level in both directions -- along each tie-rod and across both the top and bottom sets of tie-rods at each end. The tie rods should be level to the same tolerances as the press base: 0.0005 in/ft (0.04 mm/meter).

4. Check that the Front Platen and Main Cylinder Platen are parallel. Distance between the two platens should be measured at each tie-rod, with the container at operating temperature. Measurement is made with the trammel rod (Figure 2-3), always measuring between machined surfaces. In some cases it may be easier to measure between the inside tie-rod nuts; in this case you will always measure the thickness of the nuts with a micrometer and add these dimensions to the trammel rod measurements.

Always support the trammel rods from the tie rods with "S" hooks to avoid deflection, and insulate the rods to avoid expansion due to heat from the container.

Maximum variation will depend on manufacturer's recommendation; in absence of this information, the maximum allowable variation between tie-rods should be ± 0.003 inches (0.075 mm). This measurement should be repeated under both no-load and loaded conditions.

Newer presses may have the tie rods encased in sleeves, which are machined to exact dimensions. In this case, the platens should always remain parallel, and it is not necessary to check the "tram."

5. Check the pre-stress of the tie-rods. Follow the press manufacturer's instructions for loosening the nuts and adjusting the prestress of tie rods. In the absence of such manufacturer's instructions, the following general procedure may be useful:

Prestressing of tie rods is usually accomplished by raising the press tonnage to 10% above the rating, using the main ram to stretch the rods, and then tightening the inside nuts and locking them to retain the prestress.

The inside nuts should remain tight, even under full load, and should not allow insertion of even a 0.001 inch feeler gauge (0.025 mm) between the nut and flange. Likewise when the load is relaxed there must be no clearance between the platen and outside nuts. With sleeved tie-rods, no space is permitted between the sleeve and platen. Any such space indicates a loss of pre-stress and requires re-torquing of nuts and rechecking of squareness.

Alignment of the Moving Press Components

The so-called “dynamic” press components are cycled many thousands of times in a typical month and so are subjected to wear, as well as to heating and mechanical shocks. However, while your press has grown older and wear has accumulated, your customers’ demands for profile tolerances and wall thicknesses have become more difficult. Alignment between container, die, and platen pressure ring are more critical than ever. Following are the recommended procedures:

1. Check the level and alignment of the main ram and ram stem. Check that the main ram remains level and aligned with the press centerline (in the plan view) throughout its travel. On most presses adjustment is made through the guide shoes of the moveable crosshead. It is recommended to check at least 3 points of the travel. Level may be checked on the main ram with the machinist’s level or the surveyor’s level. It may also be checked on the ram stem after determining that the ram stem is both straight and parallel with the ram, and that the stem retention devices are properly tight.

Alignment in the plan view (left/right) is checked by first establishing the press centerline with a piano wire and using a plumb bob at three points along the ram stem travel.

If using a laser level, attach a receiver to the ram and track it throughout its entire stroke. The stem can then be tracked in the same way.

2. Check the alignment between the front platen pressure ring, die stack/die changer, container, and ram stem. There are several different procedures and fixtures for you to choose from, for measuring the relative alignment of these elements. You will probably use a combination of the following:

A. Aligning moving components with laser. The laser can be used to find the center of the die stack in relation to the pressure ring opening. A clear die stack such as the alignment tool stack will make placement of the receiver units easier. In a similar manner the stem’s centerline may be checked relative to the pressure ring and tooling stack; check it at various positions for the stem. Finally, the centers for the front and rear of the container may be checked if cold – if hot the laser beam will be distorted and inaccurate! For this check the sender is placed in the container bore and the receiver on the stem.

B. Locating the die stack position by use of an Alignment Tool Stack: While it is theoretically possible to measure the die location from the surfaces of the die carrier or die changer pocket, in practice it is recommended to use an alignment tool stack (pages 2-11 and 2-12) for more accurate measurement of centering. **In every case, you should check both sides of the double die slide, or both die carriers if fitted with unistation or rotostation die changer.**

C. Locating reference centers with the Piano Wire method: You should have already established the correct alignment of the ram stem and front platen. Next a piano wire is placed in tension along the press centerline, according to Figures 2-6 and 2-7. The special Front Platen Centering Fixture and Ram Stem Anchor Plug are installed and used to apply tension to the piano wire and establish the center reference for checking alignment of the die stack/die changer and container.

D. Locating reference centers with the Precision Tube fixture: The Precision Tube Fixture shown in Figure 2-8 may be used to establish reference centers for alignment of the die stack/die changer and container. The wall thickness of the precision tube is selected to insure minimum normal sag even after it is machined and ground for straightness. For example, a 4-inch OD tube (100 mm) with wall thickness 0.250 inches (6 mm) will sag only about 0.001" (0.025 mm) in a length of 9 feet (2.75 meters).

The tube is fitted with end plugs that have locating centers as shown. Fixtures are shown for supporting and aligning the precision tube at the ram stem and front platen. Note that the centering fixture for the front platen is fitted with an adjustable stiff spring, which accommodates expansion of the tube due to heat from the container.

E. Locating reference centers with the Base Centerline system. This method creates two precisely located holes in the press base, which are then used for accurate placement of a special taut wire system for checking centerline distances (figure 2-9). (Some press bases may not be suitable for this method, depending on the design of the press base.)

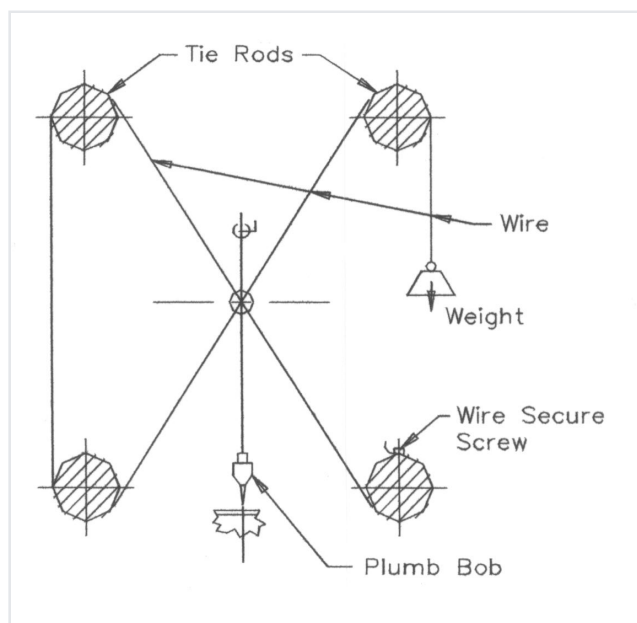


Figure 2-10: Locating the Centerline of the base

To establish the base centerline, the tie-rods are used as a reference and a taut piano wire is wrapped in criss-cross fashion as shown in Figure 2-10. Then a plumb bob line from the intersection of the crossed wires is used to locate centerline points on the press base. Two holes are drilled and reamed at these points: one

0.50 in (12 mm) and the other 0.75 in (19 mm). The two surfaces used for these holes should be approximately level with each other. Special wire holders (as shown in Figure 2-9) fit snugly into these holes to establish a taut wire centerline.

One wire holder is adjustable for height, the other one for wire tension. The wire is brought to true level, tolerance 0.0005 in/ft (0.04 mm/meter); level may be quickly determined by placing a straightedge across the wire holders and using the machinist's level. (The vertical distance "D" from the wire to the leveling surface should be machined the same on both wire holders.)

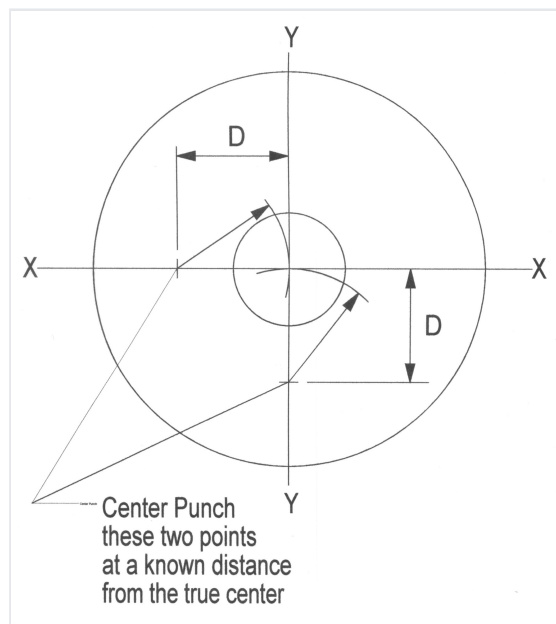


Figure 2-11: Locating the container centerlines

F. Checking clearance between Container and Ram Stem with taper gauges. The aluminum taper gages shown in Figure 2-4 are used as illustrated to check centering of the ram stem within the container opening. The gauges should be placed on the ram stem surface and against the container opening. The point of contact with the container opening, as compared with the inscribed marks, is checked at 4 points 90° apart around the ram stem. Clearance between ram stem and container should not vary more than 0.020" (0.5 mm) around the stem. This clearance should be checked at both ends of the container.

Note: similar taper gauges may be used with the Precision Tube Fixture system described above.

G. Reference Dimensions for the Container Centers. Because the actual openings of the container may contain nicks and irregularities, it is recommended to locate reference measurement points on the container faces. A center punch is used to locate reference marks at fixed distances from the actual center, on both the vertical and horizontal axes. Reference points should be marked on both the front and back container faces. Measuring from these points to the taut wire or precision tube described above is much easier and more accurate.

3. Adjusting the Alignment of the Container and Tooling Stack. The target alignment accuracy between the container and tooling stack in all directions is $\pm 0.020"$ (0.5 mm). Caution: when using taper seal dies, exact vertical alignment is desirable, but the container should never be below the die centerline, in order to avoid upward thrust loads to the die stack and die carrier.

Adjustment procedure varies according to press design, and there are many different systems. The die stack must be at operating temperature. Most commonly, the die stack is first adjusted to match the pressure ring. Lateral adjustment is made by moving the threaded stop of the die changer. (Unistation and rotostation changers use a single stop for both die carriers, so this adjustment is made easier and more accurate.) Adjusting the die position vertically is more difficult; while a few presses have built-in adjustment, on most it is necessary to vertically shim the guide ways or "gibs" of the die changer.

Next the container must be adjusted to align with the die stack and also the ram stem. Once again, the container and die stack must be at operating temperature. Container adjustment is made with the adjusting screws on the guide shoes. Presses with center guides (top or bottom) and "X" or angled guide ways pose the greatest problems in making accurate adjustments, due to difficult access and the indirect nature of angular adjustments. Consideration should be given to retrofitting the press with guides which permit "logical" vertical and horizontal adjustments. (See page 2-15 and also Chapter C: Modernizing Older Presses.)

4. Alignment of the Butt Shear. On smaller presses (below 1800 Tons), the shear adjustment should place the shear blade 0.020" to 0.025" (0.5 to 0.6 mm) from the hot die face. On large presses this clearance may increase to as much as 0.125" (3 mm). However, the dimensions of the die stack must first be standardized and the position precisely assured by the position and dimensions of the die carrier or die changer pocket (and clamp if available).

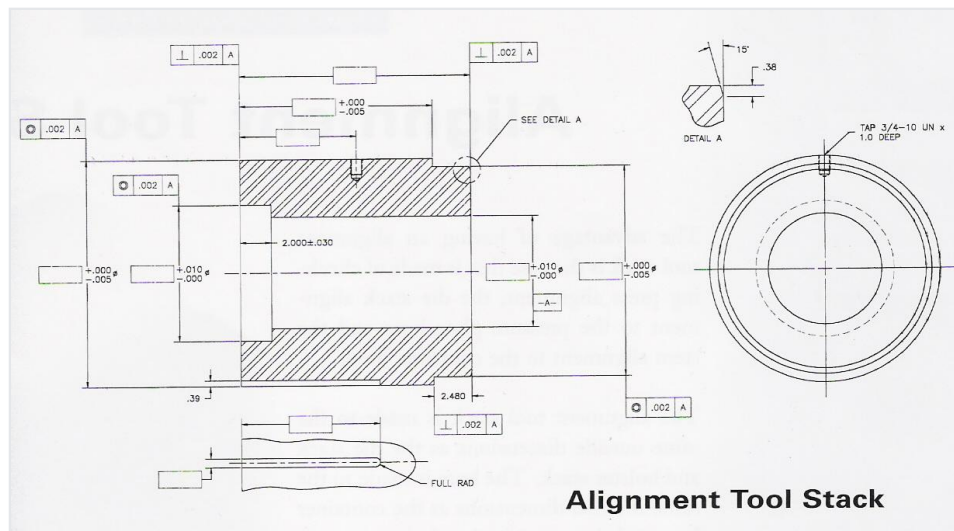
While many press operators operate with greater clearances, due to sloppy die dimensions and worn or loose parts, the result is a great risk of mechanical failures or collisions, and failure of the butt to separate from the blade properly.

The method of adjusting blade clearance varies according to the press design, but normally it is required to add or remove shims between the blade and its holder to achieve the necessary dimensions.

5. Alignment of the Billet Loader. The container, ram stem, and fixed dummy block must all be at operating temperature. Alignment accuracy of $\pm 0.020"$ is recommended. Preliminary measurements may be made by any of the alignment systems described previously, but should then be checked with an actual billet or full-size dummy billet, and with the container in the sealed position. The means of adjustment varies according to the design of the billet loader and press.

Alignment should take place with the loader raised to the loading position, then blocked in place with a heavy timber in case of power or control failure. Presses which still use loose dummy blocks should be checked with a loose block on the billet loader.

USE OF THE ALIGNMENT TOOL STACK¹



The advantage of having an alignment tool stack is the ease that is made of checking press alignment, the die stack alignment to the pressure plate bore and the stem alignment to the container bore.

The alignment tool stack is made to the same outside dimensions as the die stack and bolster stack. The bore is made to the same internal dimensions as the container bore and the pressure plate hole.

When the alignment tool stack is sitting in the die holder with the container sealed, you can look through the platen hole and check the alignment of the container to the die stack.

The stem should then be brought forward without the alignment tool stack, to the entrance of the container, and held so that the stem can be checked for alignment to the container bore. The stem should then be brought forward to the end of the stroke. It should be on center all the way through the container. If not, the stem is out of alignment.

Press Alignment

Most often the problem is not a single one, but a number of small ones which add up to a major problem.

¹ Pages 2-24 and 2-25 are taken from Castool Bulletin "Alignment Tool Stack."

Problems with press alignment can often start from the press foundation and bed, which can move over time from normal use. Foundation bolts and shims can become loose, allowing the press to shift.

Some presses are supplied with a pair of alignment blocks. In this case, the ways are on an angle and the alignment blocks can be placed on the ways with a straight edge and machinery level. This will soon tell the story (of course, more efficient lasers can be used if available).

Should the bed of a press be out of level, problems will multiply as you proceed with alignment.

The tie rods should be checked and maintained within .005" (.127 mm) in all directions.

The main ram (with level bed) should be moved out approximately 30" (750 mm) and a machinery level placed on top of the ram. The ram can then be leveled with shims under the main ram shoes. If the stem is not level, both the crosshead pressure plate and the stem should be checked.

With the alignment tool stack installed in the die slide, align the pressure platen hole and container bore to the alignment tool stack. If you have misalignment between the container and the alignment tool stack, check the die changer for height and the base of the die changer for level.

The alignment tool stack should then be removed from the die carrier and the stem moved forward and centered to the container bore (a taper wedge is useful for this purpose). Looking through the platen, the stem should then be moved slowly through the bore of the container; it should be in the center of the bore all the way through.

After the stem is aligned, align the billet loader so that the plates are approximately 0.020" (5mm) above the bottom of the container bore.

The face of the stem should be checked for mushrooming. If mushroomed, the stem must be stress relieved, checked for cracks and machined.

The extrusion cycle should also be checked. The container should only open 3/4" to 1" (20 to 25 mm) before the main ram starts to retract. This is usually accomplished by adjusting limit switches. This will reduce the damage caused to the alignment tool stack and container face during the ram return.

Many problems are caused by aluminum build up on the sealing face of the container or the die. This may be due to poor butt shear adjustment, bad loader alignment, or a butt lodging between the container and the die which forces the container to move. A tilt switch can be installed to stop serious damage to the stem and the loader if this occurs.

Another area which should be examined is the main ram bushing and the main ram packing. If there is wear in this area there will be signs of oil leakage and the stem will be out of parallel. A short term solution is to rotate the bushing 180°.

Quick Checks of Press Alignment

Following are two procedures which may be used for quickly checking alignment between the press container and die stack, for example, in the case where daily monitoring of alignment is desired.

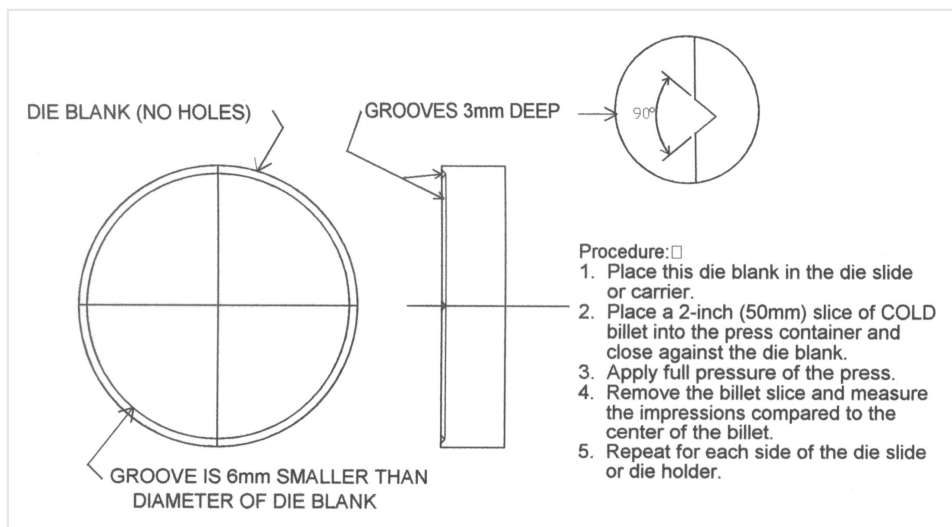


Figure 2-12: Scribed Dummy Die for Fast Check of Alignment

1. Checking alignment of Container with Die Stack by means of a Scribed Blank Die. A fast check of the most critical alignment -- between the die and container -- may be made with only a brief operating pause, by means of the Scribed Die Blank as shown in Figure 2-12. The special die is loaded into the die changer and used with a 2-inch thick (50 mm) billet slice, which may be hand loaded into the container (cold). After suitable press tonnage is applied to the blank, the upset billet slice is retrieved and set aside for measurement. Centering is easily measured at the peripheral ring and "cross-hairs". Each die carrier or die slide pocket should be checked in the same manner. Due to the quick nature of this test, it may be conducted daily, according to the sensitivity of production requirements to tooling alignment.

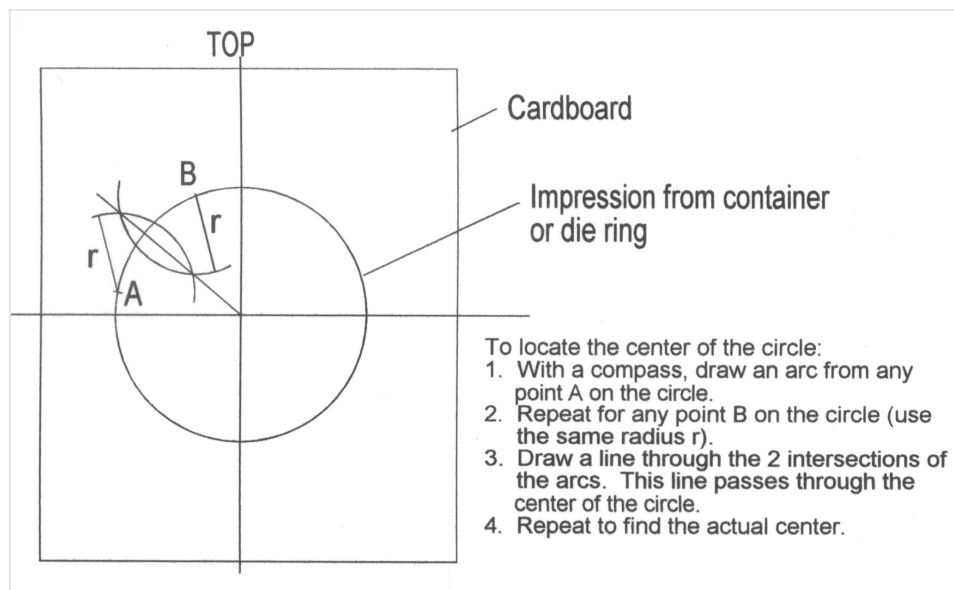


Figure 2-13: Comparing the centers of the container and die ring

2. Checking alignment between Container and Die Ring by means of a cardboard imprint. With this method, a sheet of cardboard is placed by hand between the container and die stack; mark the top position for the sake of orientation. Close the container onto the cardboard and then reopen it. The result should be circular impressions on each side of the cardboard, from the container opening and die ring. Next the cardboard is taken to the office, where the centers of both circles are located by geometry, using a compass (see Figure 2-13). By passing a pin (or compass point) through the cardboard at one of the centers, it is possible to measure the misalignment, if any, between the two circles.

Continuous Electronic Monitoring of Press Alignment

Various systems have been developed to continuously monitor press alignment, either to provide a read-out of alignment or to activate an alarm when pre-defined limits are exceeded. This is a difficult application due to space limitations and the generally hostile environment around the extrusion press. The heated air around the press container has adverse effects on laser and optical systems, causing the light rays to shimmer and bend. Airborne dirt and potential physical abuse also affect long-term reliability of such systems². Most of these monitor container alignment only. They often use a precision bar rigidly mounted to the container, and monitor its movement with precise electronic switches or encoders. Some examples:

- Some press manufacturers now install a fixture to the container and monitor its movement with a Balluff position encoder.
- Others use Linear Variable Differential Transformers (LVDT) to measure container position through contact with the guide ways. An accurate position is then available on-the press controller screen.

2. Freese, Howard W., *ibid*.

- Freese³ proposed a system of as many as eight LVDT devices mounted on air cylinders at 45-degree angles to the vertical. The cylinders are actuated periodically to bring the LVDT's in contact with the container holder. Sensor readings are converted to X and Y components and compared to reference data for the same points.

For further information, the reader is referred to the referenced paper.

The following comments on alignment of dynamic press components are adapted from the referenced paper by Mulder and Smith⁴:

Optical tooling uses powerful alignment telescopes to obtain precise reference lines and reference planes from which accurate measurements are made with optical micrometers, optical tooling tapes, optical tooling scales, and micrometer measuring rods⁵. This orthogonal measuring system was developed for the aircraft industry during the war but has now been rapidly superseded in many industries by faster modern technology. For press alignment, an alignment telescope is mounted in the egress hole of the front platen to establish an optical center line, and a target on the ram stem is sighted in three positions along its motion. This system provides its alignment check of the stem and of the main ram, assuming the stem is straight and parallel with the ram. The telescope line of sight is set using either the bore in the die pressure ring or the intersection of cross-wires in two places made by the intersection of a taut wire criss-cross configuration over the tie rods (tie-rod referenced centering, see figure 2-10).

Limitations are that the bore is often badly worn and not parallel, and the tie rods center reference may be from asymmetrically spaced rods or may not be on the center line.

Modifying the Press for Easier Adjustment of Alignment



Figure 2-14: Conversion of container guides to flat type (Photo courtesy of Lake Park Tool)

3. Ibid.

4. Mulder, Joseph E. V., Ibid.

5. Kissam, P. (1962) Optical Tooling, McGraw-Hill, NY. 1962



Figure 2-15: Conversion of X container guides to horizontal (Photo courtesy of OMAV)

Many older presses (and even some new ones) are fitted with “X” guiding systems, which have angled guide ways and can only be aligned by trial-and-error techniques. Ask the mechanic who must work with this type of guides and he will confirm: when you make an adjustment in one direction it causes an unintended movement in another direction. Correct adjustment involves a series of approximations, usually until he becomes frustrated and quits. Other designs use top or bottom center guides, which require that someone climb into the hot press to make adjustments; that is a dangerous and impractical job with the container at temperature, and if done cold the heat expansion must be “guess-timated.” More often than not, center guides are left unadjusted. The result is poor alignment, which affects dimensional tolerances of the profiles.

Many new presses now offer guide systems with “t” or horizontal ways, so that all adjustments are in either vertical or horizontal planes. As a result adjustments are more logical and can be made quickly by means of brated adjustment screws.

Typical conversions are shown in figures 2-14 and 2-15.

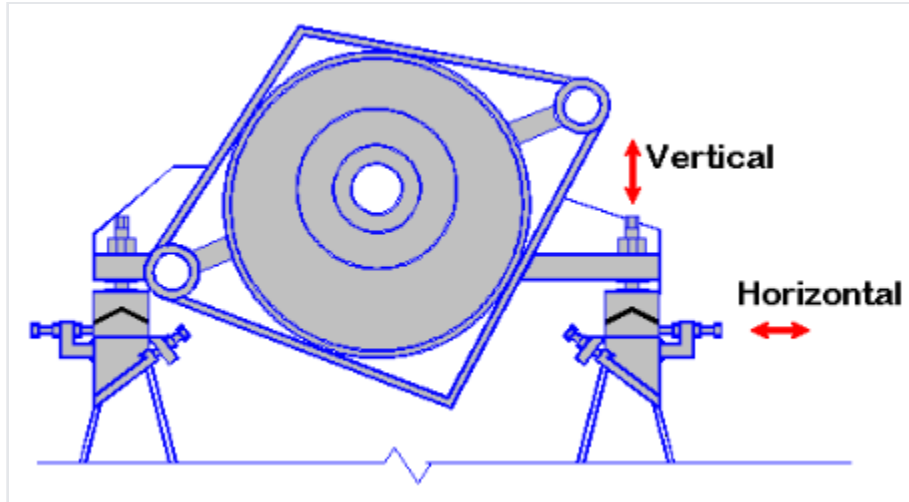


Figure 2-16: Conversion of container guides to V-type for easier adjustment



Figure 2-17: Container guides modified to V-type

Another design uses the same principle by installing “V” guides (Figures 2-16 & 2-17). As with flat guides, all adjustments are completely logical -- simple vertical and horizontal adjustments -- and are quick and accurate. All changes are made from outside the press frame and may be made with the container at full operating temperature. This system has been in operation for more than 20 years on numerous presses and has been trouble free.

An improved guiding system is often installed together with a new one-piece container housing, which also improves alignment and makes it easier to use fixed dummy blocks.

X-guides may be converted to flat or V-type by welding or bolting on specially-made fixtures.

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Laser Tracker Measurement Technology for the Alignment, Correction, Condition Monitoring, and Refurbishment of Extrusion Presses⁶

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ABSTRACT – Previously published methods of extrusion press alignment made use of traditional mechanics' tools such as precision levels, piano wire, micrometers, and various jigs and fixtures. Alignments were not made with the press under load, nor at operating temperature. More modern methods of measurement are desirable in order to improve accuracy and to take readings under actual operating conditions. Advances with surveying instruments began by using triangulation (intersection) with digital theodolites systems. In this paper, the latest methods using 3D Laser Tracking technology are presented. Additional benefits of this system have been identified, including: improved profile tolerances; significant production improvements; dummy block wear significantly reduced and total failures eliminated; longer container liner service life; noticeably less wear to ram and container guide-way bronze wear strips; and stem replacements minimized. Some observations are made regarding press establishment, press benchmarking, and the combined tolerances and error propagation effects for press frame alignment.

Background: Traditional Alignment Methods and Tools

Press alignment is important for smooth mechanical operation and avoidance of wear to press tooling and components. Improper alignment also affects the flow characteristics of aluminum through the ports of extrusion dies.

Traditionally, extrusion press alignment has been performed by use of mechanical tools and devices such as piano wire, precision levels, micrometers, and special jigs and fixtures (1). Alignments are necessarily performed with the press static and cold, not at full load or typical operating temperatures. Also, today it is not easy to find mechanics with the skills to perform precision mechanical alignments.

For many press operations, alignments using these methods and tools and under these conditions are adequate for the operations and products involved. However, extruders who require greater precision (to achieve higher-grade quality product or during critical press upgrade/refurbishment), and who wish to maximize the life of press components and tooling are often in search of alignment methods that use the latest measurement technology available today.

6. Mulder, Joseph, "Laser Tracker Measurement Technology for the Alignment, Correction, Condition Monitoring, and Refurbishment of Extrusion Presses," Proceedings of 11th International Aluminum Extrusion Technology Seminar, (2016), p.555-565.

Early Alignment with Technology:

Brief Review of Measurement Technology Using Surveying Equipment

Technology presented at the ET 2000 Seminar(2) introduced a methodology for extrusion press alignment using triangulation (intersection) with digital theodolites systems. This three-dimensional (3D) coordinate measurement system introduced the first published precise way to perform extrusion press alignment in true 3D geometry relationship using surveying equipment.

Modern portable 3D coordinate measurement systems directly applicable to extrusion press alignment today are:

- Triangulation (intersection) with digital theodolites systems (now dated and less efficient)
- Articulated Arm PCMM (Portable Coordinate Measuring Machine) uses contact probing where line-of-sight technology is unsuitable, or where there is difficult or restricted access. PCMM is unsuitable for full press alignment, but integrates well with Laser Tracker measurement.



Figure 1. Articulated Arm also known as Portable Coordinate Measuring Machine.

- 3D Laser Tracker systems
- There is no doubt that 3D Laser Trackers are the most appropriate and efficient measurement systems for full press alignment and many other press refurbishment/rebuild projects requiring precision measurement.
- Additional technology and features such as handheld probing, scanning, and machine control products have increased the efficiency and flexibility of laser trackers in their applications.
- There are several other portable 3D technologies that can be mentioned here to provide a more complete view. Many of these are based on laser radar scanning and photogrammetric principles using machine vision systems, high-speed cameras using integrated and structured light and automated metrology. They are more applicable in manufacturing inspection, control of mechanical parts, automated measurement applications, shop floor and production in-line assembly processes, and manufacturing multiple parts in repetitive work conditions. Data acquisition includes high-volume point

clouds from scanning systems and high-resolution digital images from close-range photogrammetric systems(3).

The focus here is Laser Tracker Measurement Technology for extrusion press alignment and the precision measurement associated with press establishment, adjustment, and the refurbishment/rebuild phases; however, comments on traditional/conventional measurement systems will also be made as appropriate.

This 3D Laser Tracker technology has been specially adapted to provide the specialist measurement service for the alignment of extrusion presses. The system and techniques provide a combined 3D inspection model by measurement of static and moving press components with the press under operational conditions (i.e., heated container, static, loaded under full extrusion pressure, and monitoring of dynamics). That means that thermal growth and load/pressure, stretch/distortion effects can also be measured, quantified, or taken into account.

Many extrusion plant managers who faithfully carried out traditional alignment methods were unable to determine the real problem until their press was measured in 3D as a full press alignment. Traditional and optical measurement processes will not pick up 3D misalignment problems such as platen skew/rotation, main ram misalignment to fixed platen, various press component concentricity issues, nor do they necessarily measure under operational conditions or during actual extrusion.

Ultimately, a Press needs to be Perfectly Aligned at and during Actual Extrusion

Note that the routine (in-house) maintenance alignment checks of the press centerline components or the tie-rod strain checks are highly dependent on the assumption that the whole press is correctly aligned (initial state of condition monitoring). Press centerline component alignment and concentricity checks including: the ram centerline (piston retracted, balanced and out positions); ram to crosshead to stem interface (stem bolster, stem clamp, stem pressure plate), and ram stem centerline must all be aligned/concentric with the press centerline. Then, the stem to container liner centerline to die stack (faces/cones) to pressure ring must be concentric and parallel.

Vertical alignments (slopes) are easily compared with machine levels. Vertical and horizontal offsets and horizontal deviations are not as simply determined with manual conventional methods. It has become more obvious that the 3D Laser Tracker alignment technique can significantly improve extrusion press efficiency, and is the superior method of correctly diagnosing and quantifying all misalignment problems. There are only a few measurement service providers worldwide that have applied 3D Laser Tracker technology specifically to extrusion press alignment. There are also some large maintenance engineering workshops and machine engineering companies with in-house laser tracker systems that they use for press alignment and precision measurement of press components when servicing the extrusion industry.

Note that measuring extrusion presses with this technology is not trivial, and requires very extensive knowledge and experience of both the measurement system and the extrusion press design and operational processes. This specialist measurement service for the alignment of extrusion presses is not something that can be readily duplicated, even if a laser tracker measurement system is available. Also, the

extremely harsh conditions and environment associated with measuring an operational, especially older press, to achieve overall 3D standard errors of 0.025mm (0.001in) is near to standard system limits. Constraints include restricted, congested, and difficult access to relevant press components, worn/unclean surfaces, surrounding instability, vibration, harsh fully operational extrusion conditions, and safety.

So why and when has this 3D Laser Tracker full press alignment service been utilized? The main reason why is because there are unresolved issues with product or equipment. Product inconsistencies and changes have a variety of causes ranging from press misalignment, to component and tooling condition/wear/fatigue, to type of product, to correct procedures not being adhered to. Often, many maintenance management strategies have been exhausted and suspected misalignment must be eliminated.

Press misalignment affects product, especially eccentric-wall tube, causing inconsistent profile and product outside tolerances. Press frame and press component alignment tolerances need to be even tighter when upgrading to achieve higher-grade quality product, and to achieve tighter product tolerance requirements. Press equipment issues are caused by wear and deteriorating press condition with an aging press; ongoing problems - extrusion plant management having a persistent history of difficulties with the press, and by press centerline tooling being well out of alignment. The geometric or dimensional aspects of an extrusion press are fundamental to proper press alignment, which is required for minimizing downtime and production wastage. Additional alignment requirements may be relevant when piercers/mandrels are involved, as they may affect the main ram alignment as well as contribute to tube wall eccentricity issues.

Three-Dimensional (3D) Laser Tracker



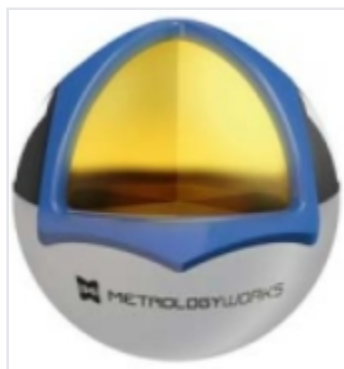
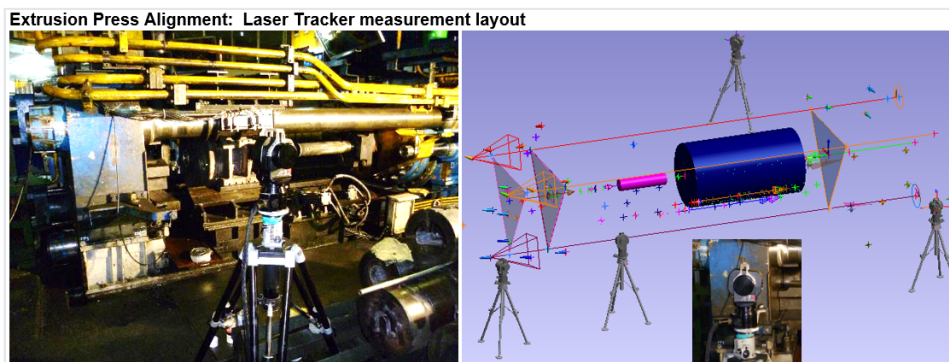


Figure 2. Laser Tracker and Retro-reflector target

Laser trackers have been used in the aerospace and automotive industries for over 20 years, and are now used regularly in many industrial settings where high-precision, large-scale industrial surveying is required for machine/component inspection, positioning, alignment, and dynamic monitoring. A Laser Tracker is essentially a portable co-ordinate measuring machine (CMM) that can measure large machines/components in 3D to better than 0.001in (0.025mm or 25microns). It uses a laser interferometer and/or high-precision absolute distance meter to measure distance within 10microns, and two precision angular encoders to measure the zenith and azimuth angles. The interfacing metrology software converts these polar coordinates to rectangular coordinates (X, Y, Z).

Hand-held spherical retro-reflectors are used to measure to individual points, or to scan whole surfaces. Reproducibility of a coordinate is $\pm 0.005\text{mm/m}$ ($\pm 0.005\text{thou/in}$) within a 35m (115ft) sphere from a single instrument position. By measuring to reference targets, multiple instrument locations can be accurately related to enable a large or complex extrusion press to be completely measured in a single 3D coordinate system. The high-speed capabilities of the system mean that 1000 points per second can be recorded at a tracking speed of up to 4 meters per second.



(b)

Figure 3. a) Laser Tracker setup alongside the Front Platen of a 3-column extrusion press; and b) All the critical components of the press are measured in a single 3D coordinate system measured from a few instrument stations around the press.

Application of 3D Laser Tracking to the Extrusion Press

A principal advantage of modern 3D laser tracker technology is the ability to establish and maintain a high degree of precision measurement with the press at actual operating conditions of temperature and no-load/extrusion-load. Typically, presses have been set up when new or after repairs and revisions, using conventional mechanical measurements that are taken without loading and at ambient temperature.

Press Benchmarking (Condition Monitoring)

On large machinery that is in service, it is usually not possible to measure and align all components in a single outage. Benchmarking of a machine with 3D laser tracker technology provides a snapshot of its dimensional and geometrical status.

A press benchmark assessment report provides an overall picture of misalignments, wear, and other operational issues. An improvement program is then developed to progressively bring the press towards ideal efficient operational geometry. Often, the remedial work and adjustments required can be carried out in a series of iterative improvement steps with conventional measuring tools during standard maintenance outages, or scheduled outages specifically for the remedial work.

Full press re-measurement after press adjustment is recommended, especially after significant iterative corrections, and after the press has bedded-in with a short period of production depending on what maintenance has been done. This provides verification of correct adjustment, identifies the net result of the incremental changes and operational changes, and re-establishes the benchmarking (initial state for condition monitoring). Once known, further improvements can be made with confidence and can be monitored with micrometers and dial gauges without having to have the press measured again for some time. Decisions to re-measure the press should be self-driven and based on repeat cycles dictated by the press's condition, its maintenance program/history, and its production characteristics. Various extruders have found full press alignment reports invaluable for progressive improvements, and have even been able to extend the repeat cycle for full press measurement from two to four years.

Benchmarking allows the end users to compare performance over time for predictive maintenance, and to compare the performance of the equipment after repair or rebuild as a condition report. Involvement of an independent extrusion press specialist (mechanical) is recommended to complement the alignment measurement, reporting, and press assessment. This provides added value to each project, with technical advice on the mechanical aspects for the various stages of professional extrusion press alignment services:

- Pre-measurement press inspection and preparation to ensure it is fit for measurement
- Press assessment to assist in interpreting the press alignment report by translating misalignments (**what** is misaligned and by **how much**) into actual press adjustments (**how** to mechanically adjust the specific press – sequence and locations of corrections and adjustment scheduling; machining, or replacement remedial work) and
- Supervision of this remedial work when necessary.

Press drawings are not essential for determining press misalignment or geometry, though a general layout may be useful for planning. Drawings are important post-measurement for the remedial/corrective phase to assess optimum adjustment locations, sequences, and procedures.

Full 3D Extrusion Press Alignment

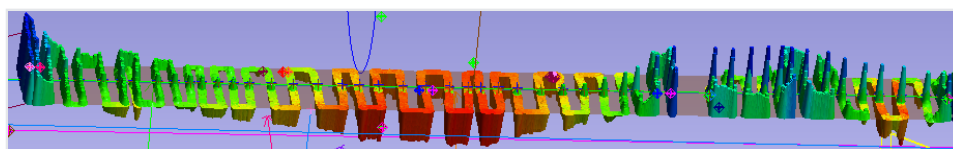
It is recommended to do a full 3D press alignment biennially, after every major component replacement or press overhaul, after catastrophic failure/events, after traditional alignment and press has bedded-in, or when all other maintenance strategies have not resolved issues. A full 3D press alignment is generally integral to establishing a dedicated alignment program as part of maintenance management. It provides press history records for ongoing decisions on maintenance, and facilitates balanced decision making before making an investment.

Press Frame Geometry and Alignment at Establishment

The correct establishment of a press is fundamental for trouble-free operation during its full life cycle. A press not well (re)established or fully aligned may not show defects or problems for several years, but then maintenance issues will increase continuously. Most new presses are installed by the supplier using traditional alignment methods for establishment. Procedures include replicating factory pre-assembled press machined reference points/faces. Many suppliers of OEM parts are now becoming more wary of having their work checked by a third party. Understandably, new or replacement component suppliers are wishing to supply, install, and align their machinery to cover their warranties and to capture all aspects of the sale. Supplier alignment methods may be traditionally based (one- or two-dimensional), rather than modern more accurate 3D measurement technology.

The Pressure Ring. This is the replaceable interface of actual extrusion with the press frame. When it is not parallel (worn, loose, or shifted) to the face of the front platen, this is equivalent to the front platen being misaligned (even if the rest of the press frame is dimensionally correct).

The Crosshead and Container Slides and Guides. These should be straight, parallel, and symmetrically spaced about the press centerline with the correct dimensions. Horizontal and vertical alignment of angled ways/slides and uneven wear characteristics are readily located and quantified with 3D alignment.



Slide Flatness/wear profile

Figure 4. Deviations of scanned points from best-fit Slide plane showing Flatness and wear profile.

Press Foundations, Bedplates and Full Machine Base

Our experience shows that the majority of beds are either fitted incorrectly at establishment or have moved and subsequently deteriorated, due to subsidence, differential settlement, damaged grout, etc.

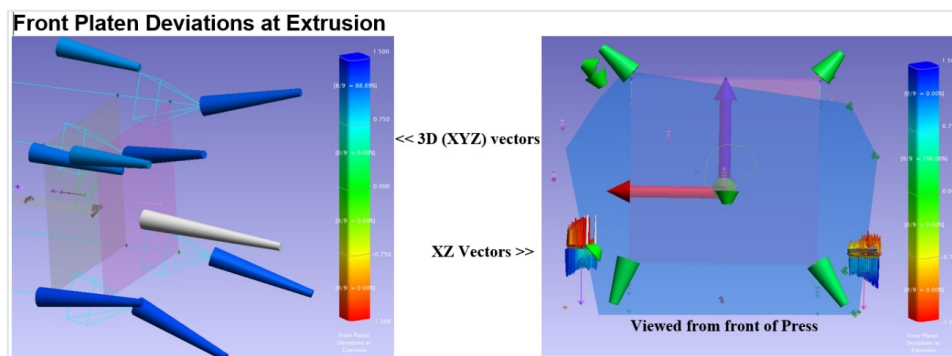
Press foundations ideally should be a single rigid block of concrete independent of the surrounding building floor/foundations, so that any ground movement/settlement/deformation will not have a differential effect on the base bedplates, and so the press frame stays intact and aligned. Foundations may be specified by the

machine vendor or manufacturer, and various design types are seen including block, box, wall/pit, framed, and even mezzanined. From a press alignment viewpoint, the full press base (whether full or partial-stepped) beneath the press frame must remain inflexible for all operational cycles and natural events throughout the press lifetime. Even if the foundation block tilts over time, the press remains aligned intact, though on a gradient. This situation is easily managed with 3D measurement systems, but will be more difficult with traditional measurement methods. The issues with a non-gravity press during routine alignment checks can simply be remedied with an appropriate wedge (longitudinal and transverse) for the machine level. Extruders often choose to reset the press to level during a major press overhaul/refurbishment.

Deflection and Dynamic Monitoring

Deflections of any part of the press frame can be measured dynamically in 3D when moving the cross head and the container, under various loads and during extrusion. These include static component foundation plates (especially during press assembly), back and front platens, pressure ring, front-insert piece, die stack, bolster, guides/ways/slides, and tie rods and their elongation.

Some presses and replacement tooling are being sourced from lower-cost countries. The platen frames of modern lighter presses cannot be assumed to be rigid bodies compared to older and larger extrusion presses, so during full press alignment measurement, they must be monitored fully (all sides of the press) during load and extrusion, to allow for distortion and differential deflection effects.



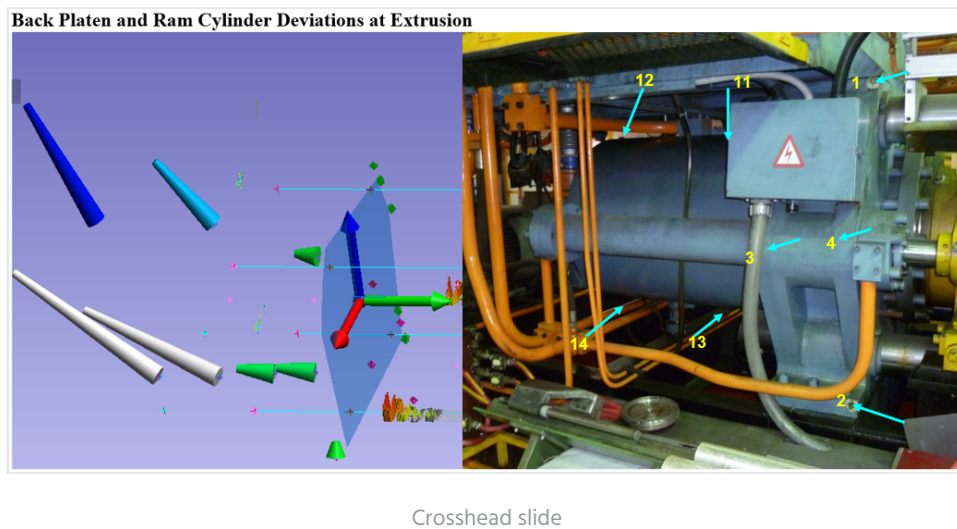
Container Slide

(b)

Figure 5. a) Front Platen point deviation 3D vectors from Static to Extrusion; and b) XY vectors from Static to Extrusion viewed from front of press.

Therefore, it is even more critical to align this type of press frame to tighter tolerances to prevent uneven deflection, and to schedule full 3D press alignment more frequently. Sensitivity to uneven tie rod elongation is amplified with the total press frame instability (base flexed with cross head movement) and a thinner, less rigid front platen.

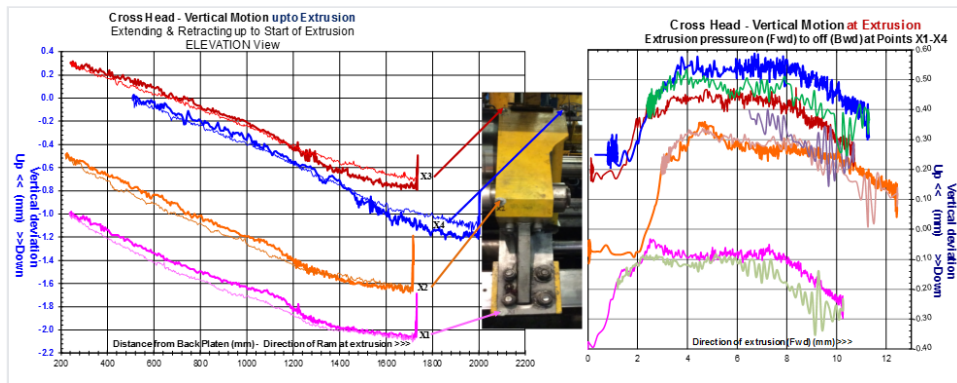
Those presses where the Ram Cylinder bolts into the fixed Back Platen housing should be monitored for independent movement of the Cylinder at extrusion.



(b)

Figure 6. a) Deviations at extrusion showing differential independent movement; and b) Monitored points on Back Platen and Ram Cylinder.

Component Monitoring. At various positions up to extrusion, and dynamic precision 3D measurement (continuous motion path profile) up to and during full extrusion, provide key diagnostic alignment information for these press centerline component combinations: ram-crosshead-stem-mandrel; and container-housing-liner.



(b)

Figure 7. a) Crosshead vertical motion up to extrusion; and b) Crosshead vertical motion during extrusion.

Major Component Replacement

In addition to the standard press alignment, 3D laser tracker technology also efficiently provides measurement assistance associated with:

- Main cylinder and ram replacement
- Full press dismantle and re-assembly
- Tie rod replacement, pre-tensioning and adjustment (including laminated and enclosed rods)
- Foundation leveling, re-establishment, re-grouting
- Platen and guide/way, tie rod monitoring.

During or after Press Disassembly, Re-Assembly associated with every Major Component Replacement or Press Overhaul. Metrology assistance and support with precision 3D Laser Tracker - Quality Control (QC) inspection and measurement for major revamp/overhaul/replacement tasks includes the following:

Reverse engineer components (in-situ, in-field measurements inspection) to produce manufacturing drawings of major press components for replacement.

- QC inspection as-found component (say back platen/main cylinder housing) of existing component at press disassembly, with correlated existing/modified foundation seats or plates. Other parts of the press could also be measured during this disassembly stage.
- QC inspection of new replacement (or repaired) component at pre-installation, for conformance to dimensions and comparison with as-found. The results of prudent QC inspection can mitigate serious remedial costs and downtime for non-fitting components, such as incorrect bolt hole positions.
- Virtual (mathematical) assembly before site installation/re-assembly for accurate shim information, and to set components accurately to level and to press centerline in 3D. This means every dimensional aspect can be verified and prepared prior to physical assembly. Final/actual geometry such as matched seating is critical during assembly, to eliminate soft-foot conditions (platen stresses over a long period), and when housing feet or sole plates are not flat or level or are non-parallel.
- Accurate positioning (build) of the back platen/main cylinder housing in real-time during press re-assembly.

Full 3D press alignment, correct pre-tensioning and adjustment (including enclosed rods), and press benchmarking.

Notes on Leveling and Alignment Tolerances and Technology

A note on existing/traditional tools for leveling foundations, bedplates, and press components: the general specification is to level these to better than 0.04mm/m; (0.04mm/m = 0.04 thou/inch = 0.0005in/ft = gradient/slope of 8.3 arc seconds). Precision engineers' spirit levels and machine/box levels have sensitivity ranging from 5 to 8 or 10 seconds of arc for each 2mm (0.079in) bubble division. These are more suitable for

localized plate flatness and level (with limited extension by straight-edge/bar transfer), and for checks on individual press components. The straightforward 180-degree end-to-end rotation of the machine level on a flat surface provides the accuracy to horizontal (gravity/zero) calibration and adjustment of the bubble vial if necessary.

High-precision electronic tilt sensors and clinometers/inclinometers achieve 0.001mm/m to 0.02mm/m (0.001 degree) single or dual axes, but most portable electronic tilt meters and protractors only achieve 0.01 degree (0.18mm/m) to 0.1 degree (1.75mm/m), and are not suitable.

Unless a press component can be assumed to be a rigid body, the 0.04mm/m (0.04thou/inch)(1) general specification ratio should be defined as $\leq 0.1\text{mm}$ (0.004in) point tolerance for foundation bedplates, machine base, ways, and any press frame or component with dimensions larger than 2.5m (8.2ft). (See note on error propagation below.)

A full press bed, for example 10m x 4m (33ft x 13ft), will require a surveyor's precise level (tilting, automatic, or digital), or a precision laser level (sweep) that can take readings (resolution) to 0.1mm or better, but preferably to 0.01mm (~0.0005in) so that individual plate level and flatness can be addressed. The level datum on these precision instruments is defined via the level vials (or the automatic compensator) that are generally accurate to 2 arc seconds (0.01mm/m). All optical instruments with rotatable lines-of-sight (LoS) used for leveling are subject to collimation error that occurs when the LoS is not truly level. Equal sight lengths will provide correct height differences, but the two-peg type test is the correct way to check and adjust the instrument to provide absolute (gravity/zero) calibration accuracy.

Individual foundation sole plates, press bedplate(s), and the faces of the matching press frame components should be flat and level with matching heights to avoid soft-foot-condition, warping, and longer-term stress loading effects. This involves setting combined base/sole plates in a single level plane or stepped height-planes for press base frames in sections, and evaluating correct shim thicknesses at each plate. The base section or overall base frame will then fit level and at the correct height relative to press centerline, with minimal distortion before and after it is fitted and grouted. If the sections of the base are not level after (re-)grouting, tie-down, and full assembly, then adjustments at individual locations may introduce soft-foot conditions. This can also affect the leveling blocks, which are machined to match the press ways and the matched seating required for major component replacement (see above).

Error Propagation and Tolerances

A note on error propagation or uncertainty analysis (overall geometric dimensioning and tolerancing): the accumulated effect of machining tolerances (especially older presses), specified tolerances for foundations, press frame, static components, and clearances (not including wear) of moving components, very quickly exceeds those for ideal press alignment; and, furthermore, tolerances may conflict with each other. Manufacturers' recommended press assembly specification tolerances may vary appreciably, especially if they are/were defined to assist a specific measuring technology or technique. Press frame specification for level, platen squareness, etc., of 0.04mm/m (0.04thou/in) when compared to that for tie-rods ($\pm 0.25\text{mm}$

between Tie-Rod CLs and $\pm 0.2\text{mm}$ Tie-Rod lengths), the maximum allowable variation between tie-rods should be $\pm 0.075\text{mm}$ (0.003in), and could already start to conflict at distance between tie rods of $\geq 1.875\text{m}$ (6ft). It is therefore essential to measure and establish a press well within tolerance, or to compare specified tolerances with the most critical frame specification that is to be achieved.

The Laser Tracker can measure to these press components in 3D coordinates to 0.025mm (0.001in) to provide absolute dimensions, heights, level, and flatness throughout the press with corrective adjustment in real-time (virtual digital dial gauge computer screen 3D display of X, Y, and Z coordinates reducing to zero target).

Tie Rod Averages and Non-Parallelism of Tie Rods

Why are tie rod average positions at the platens seldom centered correctly? (Or, why are tie rods not usually symmetrical or parallel to the press centerline?) The press centerline at the back platen, as defined by the intersection of the ram centerline with the plane of the fixed back platen, is generally found to be $\sim 0.6\text{mm}$ (0.024in) lower than the tie-rod average (analysis of many presses measured over several years), and this is considered due to the combined effect of clearance and wear of the main ram and bushings. Additionally, depending on machining tolerances, the tie-rod portholes may not have been symmetrically machined about the press centerline. The position of tie-rods within portholes of platens due to their clearances may contribute to tie-rod misalignment or non-symmetry about the press centerline. For example, if clearance is 0.015in on ϕ for the unthreaded part of the rod, (4) the rod can sit down, or to the side 0.19mm (0.008in); a worst-case accumulated effect is 0.381mm (0.015in) within and between platens. There are also cases where tie-rod nut seats at the platens were found to be spot-faced individually, not in a common plane, nor parallel. The accumulated combined effect of machining tolerances, clearance tolerances, positioning during press frame assembly or tie-rod replacement, and worn ram and housing cylinder bushings can easily explain this tie-rod anomaly. This can affect routine alignment checks and press alignment using piano cross-wire and optical/laser-in-centerline traditional methods. That is - the press centerline defined by the piano cross-wire will likely not match the true centers at both platens.

Preparing the Press for Measurement

Other than worn components that cannot be replaced immediately, the press is prepared by ensuring all static components are tightened, the tie-rods are correctly pre-stressed, and tooling sealing faces are clean, parallel, in good condition or where possible, new tooling installed --- stem, piercer/mandrel, container-liner, all die stack items, and pressure ring --- to obtain better accuracy of measurement. There is also the possibility of measuring used/worn out-of-spec die stack tooling to determine the differences and evaluate tooling issues. In any event, the press condition should be repeatable for moving components and reflect a fixed state from which it can be adjusted post-measurement by conventional manual methods for simple correction or real-time Laser Tracker for more complex misalignments.

Cost Savings from Full 3D Laser Tracker Press Alignment

The relative cost of a full 3D press alignment is economical, compared to cost savings after a press is correctly adjusted for optimum alignment. Benchmarking and information correlation of a variety of presses that have been measured indicate that production improvements on misaligned presses after adjustment are significant. Even presses running acceptably or well aligned by traditional standards have shown significant yield percentage gains. Generally, annual savings in the costs of disposables, not to mention maintenance down time are dramatic. "Improper alignment is one of the causes of inconsistent die performance; it causes premature failure of fixed dummy blocks and, in extreme cases, damage or breakage to stems, containers, and tie rods." (5)

The following cost savings can be readily evaluated by those associated with the financial aspects:

- Production improvements on some misaligned presses after adjustment were three-fold; daily throughput increased by 12 percent.
- Dummy block wear significantly reduced and total failures eliminated: replacements one to two weeks before, to eight weeks after correct alignment.
- Container liner service life: refurbishment or new replacement three to four months before, to 10 months after correct alignment.
- Ram and container bronze wear strips having noticeably less wear, negating annual machining or replacement.
- Stem replacements are also minimized.

The expensive part is fixing the press once the problem is identified.

CONCLUSIONS

Advanced Dimensional Solutions (ADS) supplies dimensional measurement and analysis services to industry using modern, three-dimensional (3D) measurement technology. Experience in providing extrusion press alignment services as a specialty for more than 18 years has been reviewed here to provide an update, beneficial information, insights to current practice, and to present the latest measurement technology available today for the alignment and major revisions of extrusion presses. Comments, recommendations, and findings for consideration for improvements have been prompted by combining the many questions, observations, and expertise from both metrologists (industrial surveyors) and the extruder specialists.

Laser Trackers are the most appropriate and efficient measurement systems for full press alignment and many other press refurbishment/rebuild projects requiring precision measurement. This modern technology is able to provide a combined 3D inspection model by measurement of static, moving, and loaded press components with the press under operational conditions. It should be employed when there are unresolved issues with the extrusion product or equipment. A properly established and aligned press, correctly pre-

stressed with a well-maintained pressure ring is fundamental. Combined specified tolerances can propagate rapidly, and it is essential to measure and establish a press well within tolerance or to compare specified tolerances with the most critical frame specification that is to be achieved.

Press frame and press component alignment tolerances need to be even tighter for lighter presses, or when upgrading to achieve higher-grade quality products, and to achieve tighter product tolerance requirements.

Press benchmarking with 3D laser tracker technology provides a snapshot of its dimensional and geometrical status with details of misalignments, wear, and other operational issues. The press is optimized by applying required remedial work and adjustments in a series of iterative improvement steps during standard maintenance outages or scheduled outages, specifically for the remedial work. Full press re-measurement after press adjustment provides verification of correct adjustment, identifies the net result of the incremental changes, and re-establishes the benchmarking.

Combining the specialties of measurement and alignment with mechanical extrusion consultant provides added value to each extrusion press alignment and many other press refurbishment/rebuild projects. The cost savings resulting from full 3D Laser Tracker press alignment can be significant.

ACKNOWLEDGMENTS

Thanks to Al Kennedy for his encouragement to prepare and complete this paper, his ready responses to any extrusion questions over the years, and his most valuable Extrusion Press Maintenance Manual.

Thanks also to Ron Sant, mechanical extrusion consultant, who has provided added value to each project with technical advice on the mechanical aspects for the various stages of extrusion press alignment services: pre-measurement press inspection and preparation; press assessment, and assistance in interpreting the press alignment report by translating misalignments to actual press adjustment locations; and the supervision of this remedial work when necessary.

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The following information was received from David Turnipseed and is reprinted here for convenience of Wean United press owners. Unfortunately the diagrams referenced are not included.

WEAN PRESS ALIGNMENT

This section is devoted to press alignment and tram level. Each group is essential to proper press operation.

- A. Stem
- B. Crosshead
- C. Main Ram and Tooling
- Tie Rods

A. Stem Alignment

The “squareness” of the stem (extrusion ram) with respect to the stem pressure plate, crosshead, and billet is very essential in order to prevent eccentric loading of the stem against the dummy block. A slight misalignment of the stem, in the center bore of the stem pressure plate, is magnified when the overall length of the stem is taken into consideration. A stem “out of square” in its “socket” by 0.025” could throw the tip out of square by as much as 1/8”. The sketch on the following page illustrates the various points to be checked when changing a stem. The stud nuts, diagonally opposite, should be tightened a little at a time in order to maintain uniform clearance between the stem holder and crosshead.

- 1• When changing the stem, uniform clearance must exist between crosshead and stem holder.
2. As stud nuts are tightened, be sure to check clearance at areas designated at points no. 1 thru no.6 inclusive.
3. Always be sure the nuts are tightened securely.

B. Crosshead Alignments

Proper guiding of the crosshead is required in order to keep the ram movement parallel with the tie rods and “square” with the tooling. The crosshead inside gibs have been set, at shop assembly, for proper running clearance and to prevent the ram from drifting when traversing the last portion of the extrusion stroke. After the press has been leveled and grouted at field erection, the inside gib clearances should be re-checked. Normally, the clearances will change; if so, the shims should be re-adjusted for proper running clearance.

The gibs are shimmed bronze wear plates. The adjustment is by means of shims instead of adjusting screws to prevent unauthorized personnel from making changes in the clearance when they are not familiar with the full importance of these clearances.

The gib mounting bolts should be kept tight at all times. Check these bolts once a week. The gib clearance should be checked once per month.

C. Main Ram and Tooling

After the press has been in operation for several months, normal wear of the crosshead bronze shoes will take place. As wear progresses, the ram, crosshead and stem will no longer move parallel with the tie rods and bed plate wear plates. As the stem drops, it will no longer be concentric with the container bore and may rub the “skull” in the container, causing inferior extrusions. The first tendency is to align the container with the stem so it will be concentric once again.

This procedure is incorrect because the billet centerline will be lowered and will not be concentric with the dies and tool stack. This leads to eccentric loads being applied to the tooling, thus causing poor metal flow and improper die deflections. Eccentric loads eventually result in breakage of components in the tool stack.

The proper procedure is to check the ram level, at the retracted position as well as advanced, to the “end of extrusion” position. The level of the bed plate should also be checked to determine the exact amount of “out of level” that actually exists. The crosshead wear plates should then be shimmed to bring the ram back to a level position. Once this is accomplished, the container elevation should then be adjusted to have the stem concentric with the bore of the container liner. The final phase of tooling alignment is to extrude billets and examine the butts to determine if the die is low. If the die is low, the die slide should be removed and the wear strips shimmed to have the die, container and stem in alignment. The container guides should also be checked to keep the container lined up laterally with the tooling and stem. These checks should be made every four (4) to six (6) months.

D. Tie Rods

Pre-stressing of tie rods is done for the purpose of preventing stress fluctuations to occur in critical areas of the tie rods during normal operation. These critical areas are the threaded portions of the rods. Without pre-stressing the stresses would fluctuate from zero to maximum every time the press is loaded to 3000 psi. Should this be permitted to continue, without pre-stress, metal fatigue would eventually set in and a tie rod failure would occur.

Pre-stressing is accomplished at shop assembly by loading the press to approximately 3450 to 3500 psi. and setting the inside tie rod nuts prior to releasing the pressure. The "locked in" stresses, between the inside and outside nuts, prevent any fluctuation of stresses in the threaded areas of the tie rods. The tie rod bodies are only subjected to pure tensile stresses.

The press tie rods are set at shop assembly; the press is "squared" to within approximately .005". The press should remain "square" for several months. However, a certain percentage of the pre-stress is lost due to the machined surfaces of the threads of the tie rods and nuts becoming "burnished in" during normal operation.

After six (6) months of operation, the press should be re-checked for squareness. The tie rod nuts should also be checked for loss of pre-stress, with the press at full load of 3000 psi. Should the inside surface of a nut separate from its contact surface with the platen, or cylinder housing, pre-stress is lost in that particular tie rod. When pre-stress is lost, the press should be re-aligned ("squared") and the rods pre-stressed again. It will be noted that after the press is re-pre-stressed, it will retain its alignment for a much longer period of time because the threads have been "burnished in" and have taken a permanent "set".

When the tie rods require to be re-pre-stressed, several items must be taken care of:

- a) The face of the main cylinder housing should be at right angles to the bed plate wear plates. You may have to block up under the main cylinder, if adjustment is required.
- b) Hydraulic system pressures will be adjusted temporarily, above maximum allowable operating pressure. The pumps must not be permitted to remain at elevated pressures for prolonged periods of time. Try to limit it to periods of time, not exceeding 10 to 12 seconds, and keep the pumps "short stroked".
- c) Oil temperatures should be kept at approximately 1200F, when the pumps are operating at elevated pressures.
- d) Necessary personnel and equipment must be on hand when the work begins.
- e) You will require two (2) sledge hammers, six (6) to eight (8) hot rolled steel pins to fit the holes in the tie rod nuts, a pin gauge bar with micrometer head, plus four (4) men.

With Port "B" of the pumps furnishing power for the "forward" or "extrude" portion of the circuit, the relief valves on Port "B" side of the pumps will have to be adjusted to permit pressurizing the system above the maximum operating pressure of 3000 psi. Note the position of each relief valve adjusting screw prior to

making any adjustments. Remove the screws from the pumps when the motors are not running. Take the lock-nuts off the screw and re-install the screws, turning them “in” approximately two (2) turns beyond the point where the locknuts were set for 3000 psi.

Place the control selector switch in the “manual” position; start the main motors; position the die slide with the sticker hole at the press centerline and slide selector switch at “neutral”. With the container closed against the slide, advance the main ram until the stem holder, or bumper, is in contact with the container. Note: For presses with a taper fit between stem and stem holder, the press tonnage must not be applied to the stem holder face. The load must be taken on the face of the stem. (Use a short cold billet, dummy block and solid tool stack.) Short stroke the pumps only enough to pressurize the system slowly. Set the relief valves for approximately 3350 psi. When adjusting the relief valves for higher pressures, always do so with the pumps in the “neutral” position, or when the system is at low pressure. Always keep the sticker by-pass button depressed while pressurizing. Don’t relieve pressure suddenly by releasing the by-pass button. Position the manual unit lever at zero and allow the pressure to bleed off until it drops to 1000 psi. before releasing the by-pass button.

Pressurize the system to 3300 psi. and “sledge-in” the inside tie rod nuts, only at the cylinder housing end of the rods. Do this as quickly as possible; keep the system pressure steady while setting the inside nuts.

Bleed off pressure in the system and prepare to work at the platen end of the press. Pressurize the system once again and loosen the inside nuts at the platen. When the inside nuts are loose, bleed off system pressure and retract the main ram slightly to permit the surge valve to open.

Pin gauge the press at zero pressure, and record the readings. If the readings show that the press is “square” within .005” or .006”, proceed with pin gauge readings at 1000 psi., 2000 psi. and 3000 psi. Should the press be “out of square”, in excess of .012”, do not “load” the press until you have re-adjusted it. Adjust the outside nut of the tie rod that requires to be adjusted. The outside nuts can only be adjusted under “no load”. When making adjustments, the following information will be helpful.

Place a mark on the surface of the platen, at the nut periphery, and measure on the outside diameter of the nut, the amount of adjustment to be made. One inch of rotation of the nut is equivalent to advancing the nut a few thousandths of an inch.

The following chart covers various press tonnages; use the value that applies to your press:

Rated Press Tonnage	Movement of Nut O.D. - inches	Linear Movement of Nut inches
1550 tons	1	.007
1675 tons	1	.007
2200 tons	1	.0064
2400 tons	1	.0055
2500 tons	1	.006

Rated Press Tonnage	Movement of Nut O.D. - inches	Linear Movement of Nut inches
2600 tons	1	.005
2750 tons	1	.005
3300 tons	1	.005
3500 tons	1	.005
3850 tons	1	.0046
5500 tons	1	.006

When the tie rod nuts have been adjusted and the press is “square”, at zero and at 3000 psi., proceed with the final phases of pre-stress.

Pressurize the system to 3300 - 3350 psi. and slug-in the inside nuts, at the platen. Release pressure in the system and pin gauge with pressure at zero. You may find that the press can be “out of square” after pre-stressing. This could happen when the nuts are being slugged-in and a fluctuation of system pressure has occurred.

When this happens, it will be necessary to make corrective adjustments. Pressurize the system to 3350 psi. and adjust the tie rod nut that requires it. Always remember that after pre-stressing, the tie rod that registers the longest length has been pre-stressed more than the other rods. • Its adjustment would require you to “back-off” the inside nut at the platen end of the press. Make such adjustments as required so the press will be within tolerances at “zero” as well as at 3000 psi. After final adjustment, etc., re-set the main pump relief valves.