Cambering I-Beams

What is the proper procedure for cambering an I-beam?

Follow these steps:

1. Sight along the edges of the flanges to see if the beam already has a camber. If camber exists, then plan on increasing the existing camber.
2. Place the beam on horses or other supports so that it is supported only on the ends. Place a third horse or support under the beam exactly at the beam's midpoint. The beam and its center support must not touch. Measure the distance between the bottom of the beam and the top of the center support and record this distance on the web of the beam above this point for later reference, Figure 4–26.

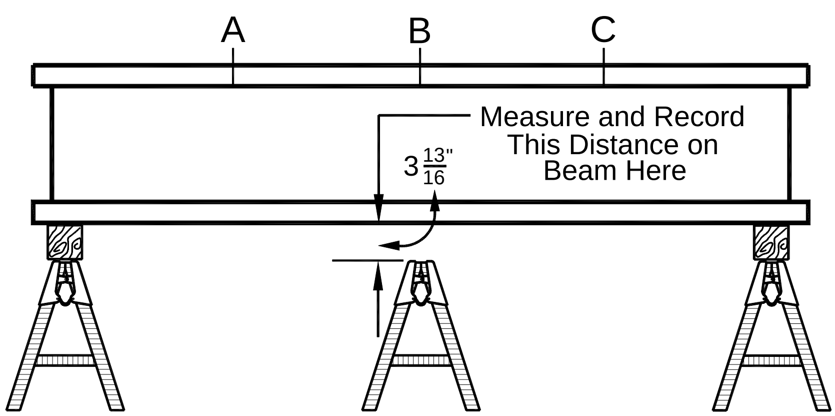


Figure 4–26. Cambering an I-beam.

3. Use a tape to divide the beam into quarters, and mark points A, B, and C with weldor's chalk, Figure 4–26.
4. At points A, B, and C as shown in Figure 4–27 (top), mark 10º pie-shaped sections running 7/8 of the way across the web and the matching areas on the top of the flange. Although 30º segments produce maximum bending in a single heating and cooling cycle, we begin with 10º segments so as not to over shoot the final bend. As we gain experience we can use wider segments.
5. In subdued light, heat the beam at point B to a dull red with an oxyfuel rosebud tip in the pattern shown in Figure 4–27 (bottom). Start heating at the bottom or point of the pie section. Consider using two torches, one on each side of the flange working opposite each other. When the

pie shape is heated, apply heat to the upper flange in an area matching the top width of the pie shaped-section. Cool the beam with water starting from the cooler, darker black areas around the heated areas and work into the red heat zones. When the beam is back at room temperature, measure the camber change at B. If more camber is needed, and it probably will be, mark the pie segment and top web area to be heated and, apply heat at points A and C in a similar manner.

6. Check camber at A, after heating and cooling at B and C. If more camber is required, apply heating and cooling at D and E. D is midway between A and B; E is midway between B and C.
7. If more camber is needed, repeat at additional intervals midway between previously heated zones. Avoid heating the same areas twice as this will not lead to a smooth, sweeping bend.

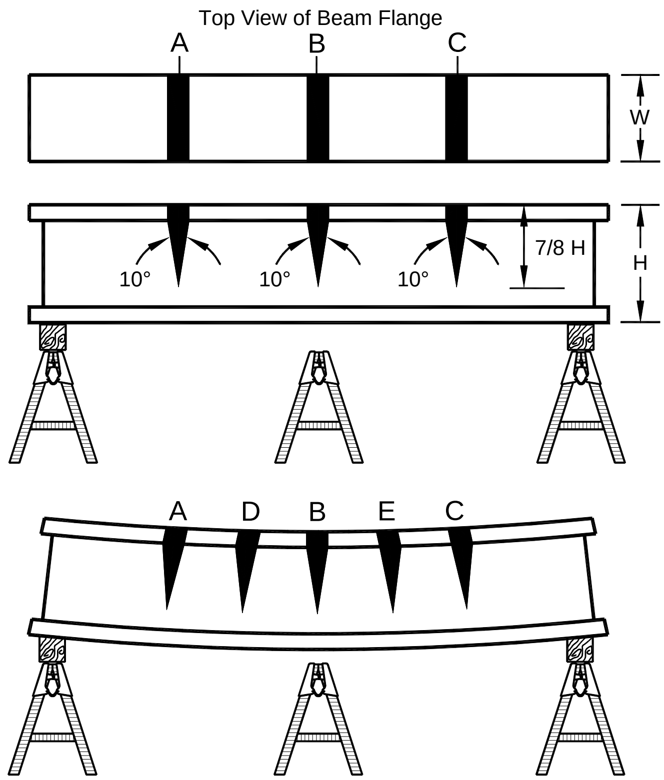


Figure 4–27. Cambering an I-beam.

Line Heating

How does *line heating* differ from other operations where heat is used to bend metal?

Line heating is flame bending performed on steel plate, rather than rolled shapes, pipe, tube, or sheet metal. While line heating can be used in a variety of steel fabrication activities, shipbuilding is its principal use. Steel hull plates vary in size but are typically 6 by 21 feet (2.3 by 6.5 meters). Hull plate can run from about 1/2 inch to several inches in thickness.

In the simplest instance, if oxyfuel torch heat is applied along a line in a plate, the plate will contract into a slight V-shape when it has cooled, Figure 4–28 (top). If a series of parallel and evenly spaced heat lines is applied, the plate curves evenly across its width, Figure 4–28 (center). Adding more heat lines closer together, further increases the bend in the plate, Figure 4–28 (bottom).

Unbalanced shrinkage forces between the heated and unheated sides cause angular distortion just as in other heat bending applications.

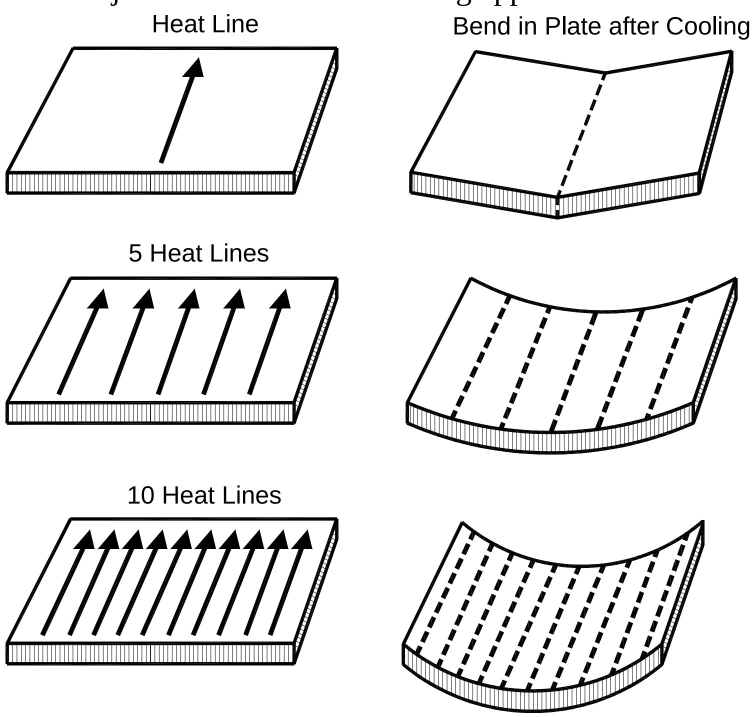


Figure 4–28. Effect of a single heat line on a steel plate (top), effect of multiple heat lines (center), and adding even more heat lines (bottom).

What is the typical spacing between heat lines?

See Table 4–2.

	Heat Line Spacing	
	Inches	**mm**
More plate curve	4	100
↓	6	150
↓	8	200
Less plate curve	10	250

Table 4–2. Typical heat line spacing.

In general, how much deflection on a plate will a single line heat produce under shipyard conditions with the proper equipment?
The range of deflection from one heat line runs between 3/4 and one degree for a single heating and cooling cycle.

How far should the torch flame be from the steel surface?
With the larger, multi-orifice oxyfuel torches used for line heating, a tip-to-plate spacing of between 3/4 and 1 inch (20 to 25 mm) will put the hottest part of the flame on the steel and create the maximum bending action.

How do travel speed and path shape influence how much deflection occurs?
There is an optimum line travel speed for maximum deflection; too slow or too fast torch travel will reduce deflection. Weaving serpentine lines, instead of straight-line travel, increases deflection in a 1-inch plate almost 20%.

How fast should the torch move along the heating line?
It should move rapidly enough that the metal temperature does not exceed 1200ºF. The exact speed depends on the torch, tip, fuel and oxygen pressures, but 1/2-inch (12 mm) steel plate should see a minimum torch speed of 15 inches/minute (400 mm). Thicker steel in the 1- to 2-inch (25-50 mm) range should not fall below 10 inches/minute (250 mm/min). These figures are approximate.

When only a small curvature adjustment is needed, line speed may be double the normal speed.

How is plate temperature measured and regulated?
Temperature regulating crayons work well to measure maximum metal temperature, but the experienced craftsmen tend to watch the color of the steel in subdued light to control temperature. Non-contact, optical pyrometers can also be used.

How are temperature-indicating crayons used to measure maximum metal temperature?
The oxyfuel heating torch is aimed in the direction of torch movement. The temperature-indicating crayon is marked on the steel on the line-heating path about 2 inches (50 mm) behind the torch. If the plate marking turns color from its initial one as shown in the manufacturer's tables within 2 seconds, the calibrated temperature exists on the plate. Tests have shown that at this 2-inch following distance, the steel's temperature falls about 270ºF (150ºC) from the under-torch temperature. To get the metal temperature under the torch, we must add back the 270º to the temperature of the crayon.

How deep should torch heat penetrate to cause the maximum bending?
Maximum bending takes place when the line heat penetration reaches the middle of the plate. However, this also causes maximum transverse shrinkage (across the plate, perpendicular to the heat lines), so the best compromise between shrinkage and bending is to have line heat penetrate to just short of the center of the plate.

What would happen if two torches were to apply the same heat to both sides of the plate?
Balanced contraction occurs. There is no bending, but there is shrinkage after cooling. By heating triangular areas on both plate sides at once, shrinkage forms the plate into a concave shape. More on this follows.

How does the maximum temperature on the heat line affect bending?
The higher the temperature, the more bending occurs. However, we want to limit the maximum temperature to avoid changing the properties of the steel and this turns out to be about 1200ºF (650ºC) for most ship plate steel.

A cooling water stream or a mist of water and compressed air is usually applied following the torch along the heat line. Why is this done?
There are several reasons:

- Cooling maximizes bending by confining the heat to the heat line, and maintaining the maximum temperature differential between the heated and the unheated areas.
- The water mist keeps the entire plate at a lower temperature and allows the heat bending cycle to be repeated quickly. However, if only a small bend is needed, cooling water or mist can be omitted.

How much cooling water is typically applied by hose and how far behind the torch should the water or cooling mist be applied?

Cooling water is applied about 5 inches (120 mm) behind the torch and at the rate of about 3/4 gal/min (3 l/min).

How closely can a skilled line heating craftsman match the templates?
Roughly ± 0.2 inches (± 5 mm).

If too much curve or bend is applied to a plate, how can this process be reduced or reversed?
Flip the plate over and apply line heat in paths parallel to the initial heat lines.

What other steps can increase bending during line heating?
Applying compression stress to the heated side of the plate can double angular deflection. This is a common practice in line heating. Wood and steel wedges pull the plate up on one side and cleats hold it down against the work surface on the other, Figure 4–29. Sometimes a crane applies stress to the work.

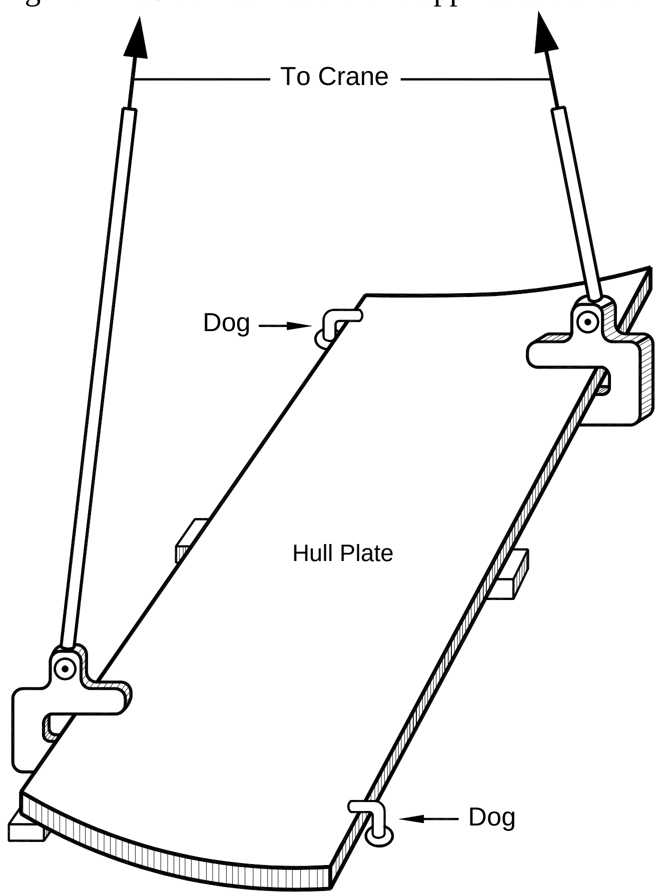


Figure 4–29. Using restraint to increase bending.

What line heating pattern makes a plate concave (dished)?

Use heat triangles, Figure 4–30. Heat triangles along the edges of the plate will shrink the edges, leaving the center of the plate un-shrunk, and so makes the plate convex.

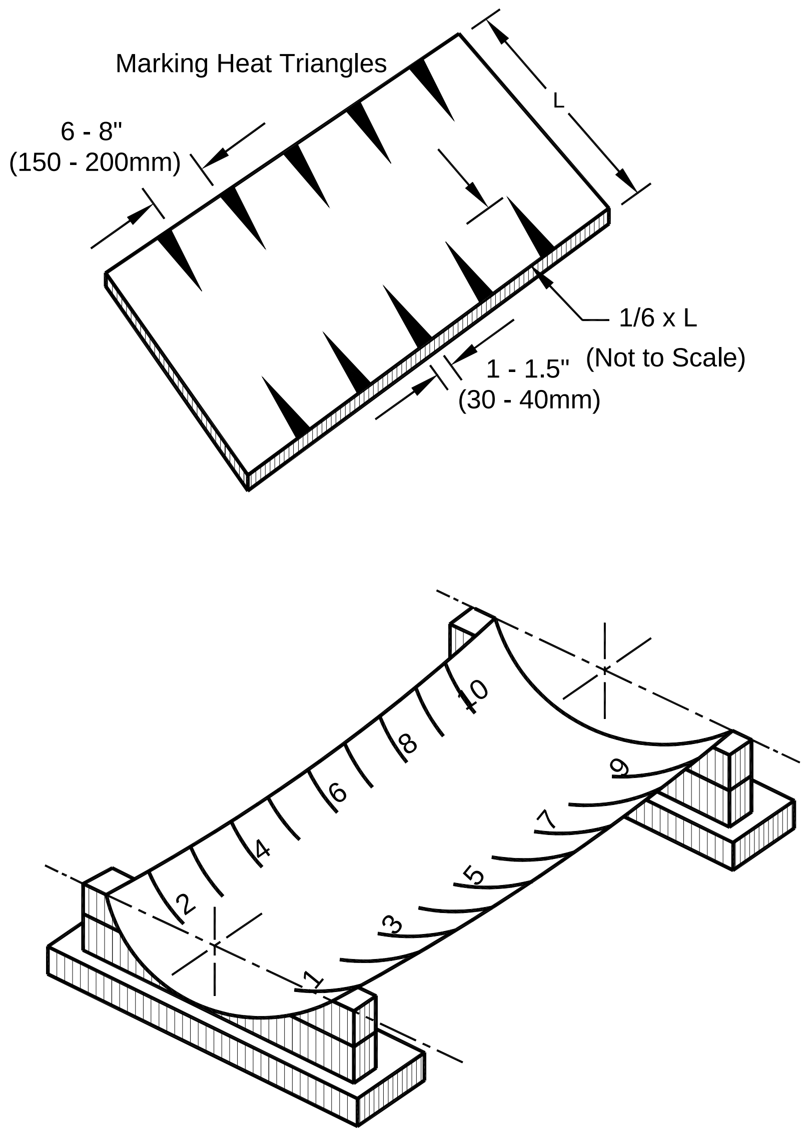


Figure 4–30. Using heat triangles to dish a plate.

What equipment is needed to perform line heating on large steel plates?

- Crane for handling the plates.
- 4” × 4” wood blocks to prop up corners of the plate.

- Assorted wood wedges.
- Steel wedges 6 inches (15 cm) long and 1.5 inches high (40 mm).
- Dogs to secure plates to the work platform.
- Large pry bar to move the workpiece and wedges.
- Sledge to tighten wedges under the work.
- Multi-orifice oxyacetylene or oxypropane torch with fuel and oxygen regulators, flow meters, and compressed gas sources.
- Temperature indicating crayons 700 to 1300ºF (400 to 700ºC).
- Assorted marking and measuring tools.
- Metal or wood templates to gauge plate curvature.
- Cooling water hose or compressed air-cooling water atomizer assembly.
- Safety equipment—safety glasses, tinted face shields, and gloves.

Why not just use bending rolls and avoid line heating?
Bending rolls form plate into a cylinder (or sections of a cylinder) with a *single*, constant radius. Line heating can produce bends in plates with *changing* radii. A gentle bend can transition to a severe bend and there may be several changes in curvature.

Line heating to a great degree can replace bending rolls, but not the other way around. When rolling capacity is limited, line heating can be used.

It is also possible to begin some bending jobs on rolls and then use line heating to add the final adjustments.

What templates are used to check that the work has the desired curves?
There are several different designs:

- Pattern templates cut from plywood.
- Reusable templates that can be formed to a given curve and lock the curve in place, Figure 4–31 and 4–32.

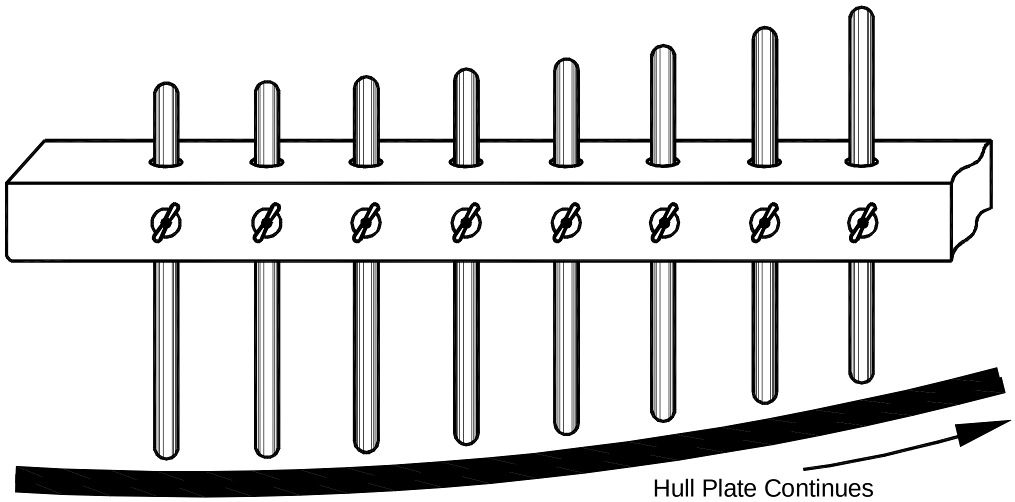
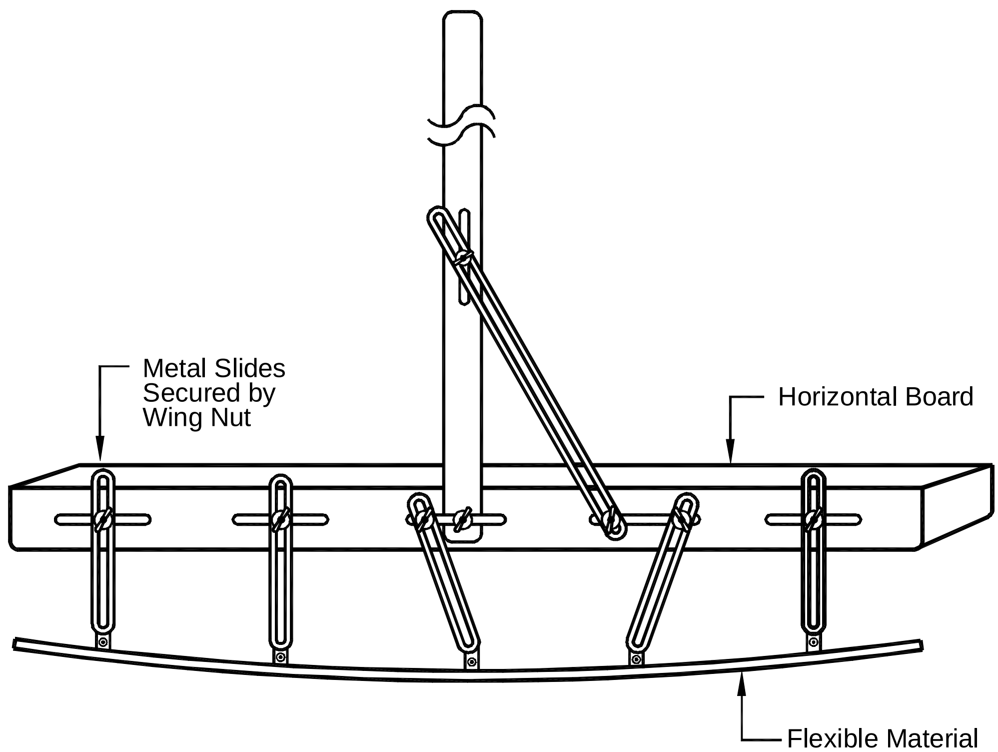


Figure 4–31. Templates used for checking line plate curves.



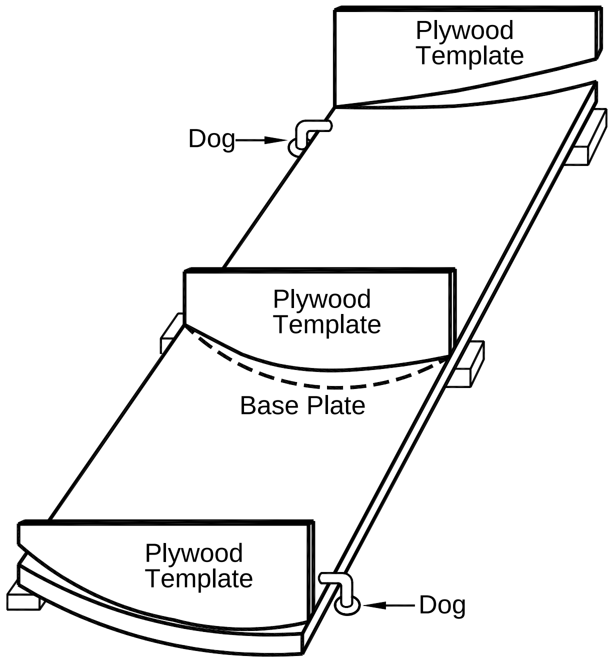


Figure 4–32. Templates used for checking line plate curves.

Author's Note: Line heating is based on well understood scientific and engineering principles, but the craftsmen who routinely use line heating to form ship hull plates are artists. Based on their experience, they examine a pattern for a complex plate and know where the heat lines should go and how fast to move the torch. Although it takes several years of experience to excel at this craft, using the basic concepts given here allows the beginner to make simple curves and shapes in steel plate.