CHAPTER 1

## AN INTRODUCTION TO THE TECHNIQUES OF FLAME STRAIGHTENING

Metal working institutions of all types must live with the fact that employees make mistakes. These errors often mean scrapped material or costly rework.

One effective method of salvaging spoiled work is 'Flame Straightening.' The operator, who is skilled in this field, is worth his weight in gold at times when the decision to either salvage a rejected component or scrap it hangs in the balance.

The basic fundamentals of Flame Straightening are familiar to many, but the techniques of applying these principles are limited only to those people who have actually experienced successes after countless trials and errors. A hot shot improperly applied or badly located will do more harm than good.

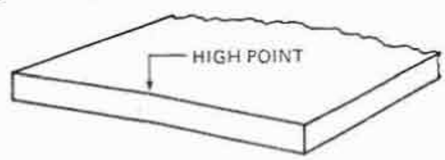
The process of Flame Straightening incorporates a welder's heating torch, the knowledge of where to locate the hot shot, and the skill of the operator who applies it. The hot shot is an evenly applied heat, cherry red in colour, directed along a line pre-determined by a knowledgeable individual.

The most commonly used fuels are acetylene or natural gas mixed with oxygen. The type of welder's heating torch or the fuel that is used is immaterial. The most important factor is the ability to quickly bring the surface of the object being heated to a cherry red condition, more favourably a bright cherry colour rather than dark.

Flame Straightening uses the principles of expansion and contraction to advantage, and this fact alone is the basis upon which all decisions are made as to where the heat should be most favourably applied. There are many exceptions to the rule, but generally speaking, the hot shot should always be applied at the high point of bend (Fig. 1-1). The length, width, form, and number of applications depends on the problem at hand and will be discussed later.

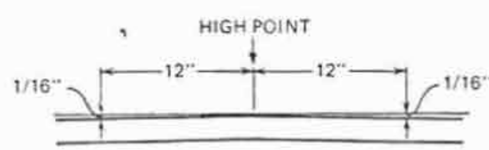
How much movement will be achieved as the result of a hot shot depends on many things: material type, thickness, torch tip size, operator skill, and the effectiveness of mechanical aids. All these conditions notwithstanding, in order to

*Fig. 1-1:*




*Generally, the high point is where the hot shot should be applied.*

*Fig. 1-2:*

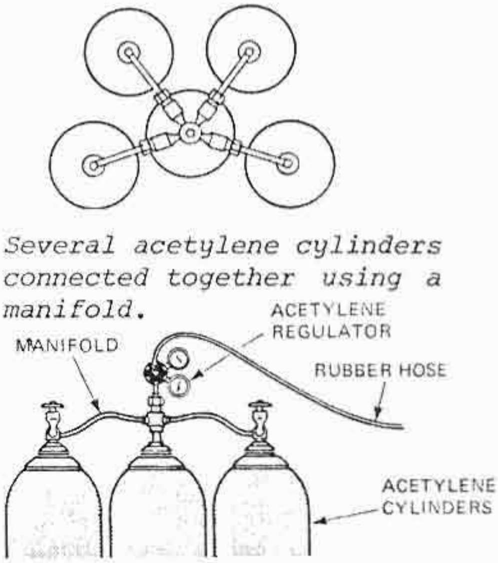



*To determine amount of bend, measure the distance at 12" each side of high point.*

make the most qualified educated guess, 1/16" for every foot of length would be the most acceptable generality (fig. 1-2).

It is assumed here that the reader is thoroughly familiar with the operation of a heating torch. If not, there are many books written on the subject and it can be learned quite easily and quickly. It is, however, felt necessary to offer the following advice in the interests of safety. Care must be taken at all times to avoid backfire. This can result in personal injury or damage to the equipment. The major cause of backfire is an inadequate acetylene supply. This is expecially worthy of consideration when working with large size heating tips, in which case it is necessary to connect to as many as five cylinders simultaneously through the use of a manifold (fig. 1-3). An inadequate acetylene supply is also caused by improper torch lighting. The safe method of lighting a torch is: 1. Open acetylene valve and ignite. 2. Increase acetylene supply. 3. Open oxygen valve to obtain the proper mixture.

*Fig. 1-3:*




*Several acetylene cylinders connected together using a manifold.*

*NOTE: Tip size up to and including #150 can use one cylinder safely.*

## What to Do When a Torch Backfires

Equally important as knowing how to use a torch is knowing what to do when there is a backfire. The following steps should be committed to memory:

1. As soon as the torch backfires, shut off the torch acetylene control valve immediately.
2. Keep oxygen control valve OPEN. This keeps the torch cool while you follow step 3.
3. Go quickly to the main valve on gas cylinder and close it. This will eliminate all the danger.
4. Disconnect torch and blow out to remove all carbon deposits before reusing. This can be done using compressed air.

Practice the aforementioned steps until they are known by heart. In the event a backfire does occur, the knowledge will give you absolute control over the situation.

## The Flame

The wrong flame could be harmful. Basically there are three types: an oxidizing, a carburizing, and a neutral (fig. 1-4). The oxidizing flame results when the fuel mixture has too much oxygen. This will melt the surface almost on contact and cause considerable damage if heating a machined face. Too much acetylene creates an undesirable carburizing flame, readily identified by the existance of a tail on the inner flame.

*Fig. 1-4:*

*Too much acetylene* *Too much oxygen*


*NEUTRAL FLAME*

*Approximate temperature 6300°F.*

*CARBURIZING FLAME*

*This flame leaves a coating of black sooty carbon.*

*OXIDIZING FLAME*

*This flame tends to melt the surface.*

The desired flame is neutral. Theoretically, this is two and a half parts oxygen to one part acetylene (2.5:1) with an approximate temperature of 6300°F. The neutral flame is easily recognized as a compatible mixture of both fuels. It neither oxidizes nor carburizes.

Selecting the proper tip size in relation to the work requirements is a simple matter. For heavy duty straightening, use the largest size available and for less demanding situations use the appropriate smaller sizes.

To give a general idea, a #100 to #150 size is adequate for all light to medium requirements. These sizes do not need excessive volumes of acetylene and are therefore quite suitable when using only one cylinder. Heavy duty straightening requires a #200 size or larger. The acetylene volume that these sizes command makes a manifold connected to several cylinders mandatory. Anything over three inches thick can be considered as heavy duty straightening.

Applying the Hot Shot (fig. 1-5)

First of all, ignite the torch and adjust to achieve a neutral flame. Start heating the selected area. Keep the point of the flame (inner flame) about 3/16" away from the surface, weaving it ever so slightly. Do not advance until the spot becomes CHERRY RED. At this point, progress slowly along the selected line, *Maintaining at all times the cherry red condition at the point of the flame and trailing by approximately two or more inches.*

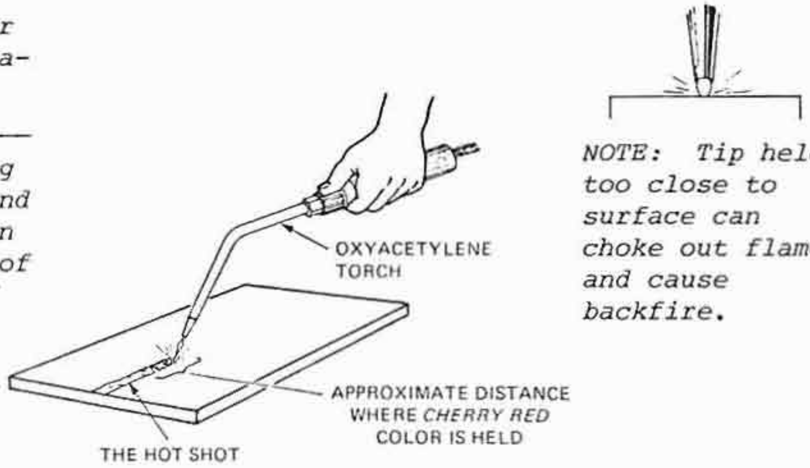
Continue heating in this manner along the complete length of the predetermined line. The hot shot must be continuous to get full benefit, so avoid stopping until the work is completed.

Holding the flame too close to the work results in damage to the surface. Holding it too long at the same place after the metal becomes cherry red is also damaging, as the colour will change to almost a bright white and consequently melt creating an ugly surface scar.

*Fig. 1-5:*

*Keep point of inner flame about 3/16" away from plate surface.*

*Flame Straightening works by heating and expanding a certain area, but because of the constraints of the unheated area, the heated area shrinks on cooling more than it has expanded.*

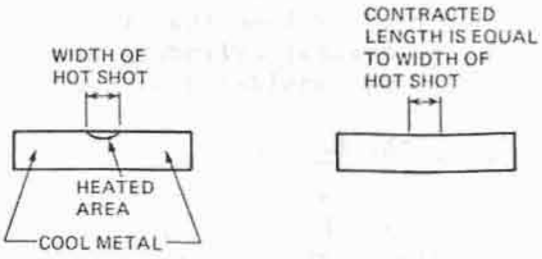



*NOTE: Tip held too close to surface can choke out flame and cause backfire.*

At first to familiarize oneself, it would be wise to try a few practice runs on available pieces of scrap metal.

Fig. 1-6 illustrates what happens to the metal when the hot shot is applied. Referring to item *x*, the rapid heating expands the area indicated with shaded lines; however, the cool surrounding areas prevent the expanded portion from spreading. Consequently on cooling, the expanded surface is forced to shrink or contract within its limits. This results in the condition relative to item *y*. Here we find that the contracted length is almost equal to the width of the hot shot and leads to the conclusion that the wider the hot shot, the more effective it will be. In order to obtain a degree of accuracy in determining the width of the hot shot, the following rule should always be adhered to: "Where the bend exceeds 1/16" at twelve inches (12") each side of the high point, the width of the hot shot should be equal to the thickness of the plate (fig. 1-7)."

*Fig. 1-6:*

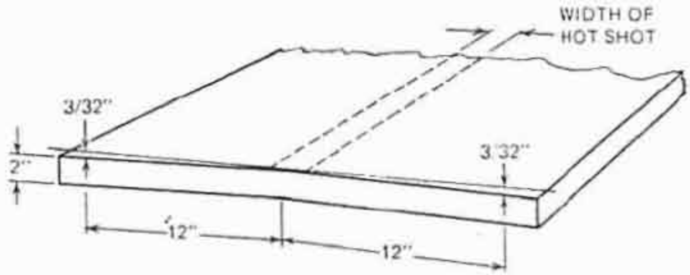



*ITEM* x *ITEM* y

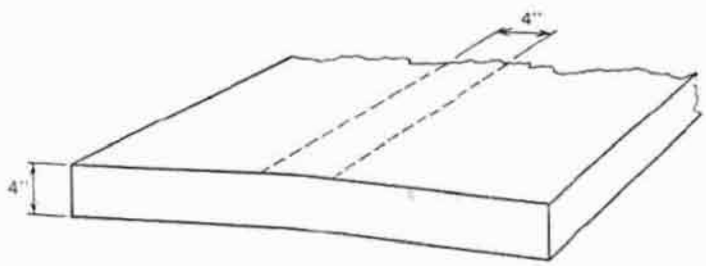
If the plate thickness exceeds four inches, it would be advantageous to use two torches simultaneously in order to obtain a deeper heat penetration and achieve a four inch wide cherry red condition quickly. If, on the other hand, the amount of bend is less than

1/16" at twelve inches each side of the high point, an appropriate lesser width hot shot would be in order.

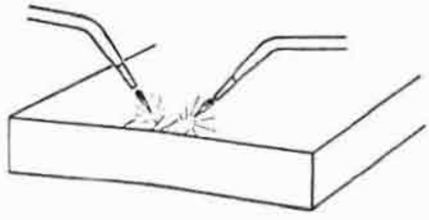
*Fig. 1-7:*



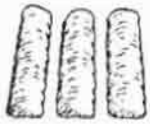

*Where the bend exceeds 1/16" at 12" each side of bend, the width of the hot shot should be equal to the thickness of the plate.*




*For heavy duty straightening, make 2 or 3 hot shots side by side or use two torches simultaneously.*



*A two-torch application.*



*Hot Shots side by side.*

# CHAPTER 2

## THE COOLING PROCESS

An accurate assessment of movement, resulting from the hot shot, cannot be made until after the work has returned to its normal temperature. Steel tends to hold the heat for hours and makes the thought of waiting it out very unattractive, especially to production managers.

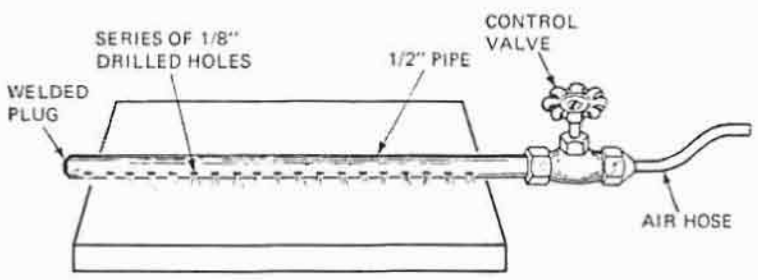
There are two ways of speeding up the cooling process. One is to use compressed air and the other to use cold water. Compressed air is generated and forced through plant piping systems as an energy source to drive pneumatic tools such as grinders, chipping guns, scalers, etc. The approximate pressure of an efficiently maintained system would be around 90 pounds per square inch (psi.). When applied to the heated area the air will be effective inasmuch as it will cool off the work quickly. There is a drawback, however.

Compressed air entering the atmosphere from a hose at the rate of 90 psi. is noisy, to say the least. When applied to a metal surface, the noise intensity increases to the point where it reaches deafening proportions. The decibel reading at this stage is well above the safety or tolerance levels dictated by government safety guidelines. Whenever the system is being used as a coolant the operator should have enough sense to protect his hearing by inserting plugs in his ears and advise anyone in the immediate work vicinity to do likewise.

### How to Make a Cooling Pipe

If job requirements are for multiple units needing flame straightening corrections, the operator can construct a simple but effective cooling pipe (fig. 2-1). This is made from a suitable length of 1/2" pipe having 1/8" holes spaced about 2" apart. A plug is welded at one end and the other is threaded to accommodate connecting to an air hose. Once installed the high noise level is reduced significantly because the air must supply a series of holes rather than only one. It also has the advantage of covering the entire length of the hot shot for an even cooling application.

*Fig. 2-1:*




*Cooling Pipe*

Cooling by water achieves faster results without the noise, but unless there is an adequate drainage system the area will become too messy for comfort. What some people do to try and control the situation is soak rags in a pail of water and apply these to the heated surface. this is not advisable because when water is applied to a very hot surface, the steam which develops could cause scalds to unprotected hands.

One very important detail hasn't been mentioned, and that is material type. The ordinary mild steel type can be heated and forcibly cooled with water or air without consequence. All other types must be put into a category whereby no flame straightening should be attempted without a written procedure from someone in authority such as a welding engineer or metallurgist. The reason for this is the molecular structure of various types of special steels. While they all look alike, some are soft and pliable like mild steel, but other specially heat-treated steels are so brittle that a heat application would do more harm than good.

When confronted with a flame straightening project the first thing an operator should ask is, "What type of steel is it?" If the material is other than mild steel he should also ask, "What procedure must I follow?"

These questions are for his own protection against adverse results should the steel be of a special nature. Flame straightening of special steels must never be approached blindly, each step must be spelled out by an authority, and followed to the letter by the operator. The reason for this is: cracks may develop in some steels when heated over 1000 degrees Fahrenheit; specially hardened forged steels can tolerate a reasonably high temperature, but rapid cooling by air or water will cause cracks to develop. Severe cracking often means expensive weld repair or the scrapping of the work.

One final point in this chapter, when fast cooling elements are permitted, *always apply the air or water directly to the hot shot.* Remember the theory, "Contraction takes place when heat expansion is confined within its limits." Therefore, applying the coolant to the heated area assures the curtailment of heat expansion and, hopefully, attains the desired results. Of course, rapid cooling should only commence upon the completion of the hot shot.

Average Flame Temperature with Different Gas-Combinations:

| | | |
|---|---|---|
| Oxygen-acetylene | approx. 5792°F | (3200°C) |
| Oxygen-propane | approx. 4532°F | (2500°C) |
| Oxygen-hydrogen | approx. 4298°F | (2370°C) |
| Oxygen-coal gas | approx. 3992°F | (2200°C) |
| air-acetylene | approx. 4456°F | (2485°C) |
| air-coal gas | approx. 3399°F | (1871°C) |
| air-propane | approx. 3182°F | (1750°C) |

# CHAPTER 3

## BENT PLATES

*Fig. 3-1:*


*Where the bend exceeds 1/16" at 12" each side of bend, the width of the hot shot should be equal to the thickness of the plate.*

For this simple type of flame straightening, the plate can be set up on a table, on trestles or stands, or it can sit on the floor astride two wooden blocks. The operator can use his discretion as to what is more practical or comfortable for him. The only important factor is having the high point of bend on top.

The next step is to decide on what course of action to take. The bend must be checked 12" each side of the high point to determine the amount of discrepency at these points. According to figure 3-1, it is 1/16". This suggests that only one hot shot may be needed. Measuring the plate thickness of 3" indicates that the hot shot should be 3" in width. The high point of bend runs through the centre of the plate, and that's where the hot shot must be applied. See figure 3-2 for examples of a shop procedure sheet.

By following all of the rules described in this book the success rate will be very high. There are times, though, when we will gain only half of what we hoped for, or very little. Success is contingent upon many things, among which; operator skill and material type are the most predominant.

If upon completion of the heating and cooling cycle, we find that we have accomplished only a partial straightening, then we must enter stage 2. At this time we take into consideration what we already did and what we gained as a result. From this we calculate the width of the subsequent hot shot. For example: if we gained half we would repeat the process exactly. If we gained less than half or more than half , the hot shot width would vary in proportion.

The location of the hot shot at this stage is also important. It must not be applied directly on top of it's predecessor, it should be applied alongside. Experience will tell you that once an area has been heated and allowed to contract, very little will be gained by going over that same area.

*Fig. 3-2:*

*WORK PROCESS SHEET*

*SUBJECT:* Bent Plate *CONTRACT #* 1234

*MATERIAL:* Mild Steel

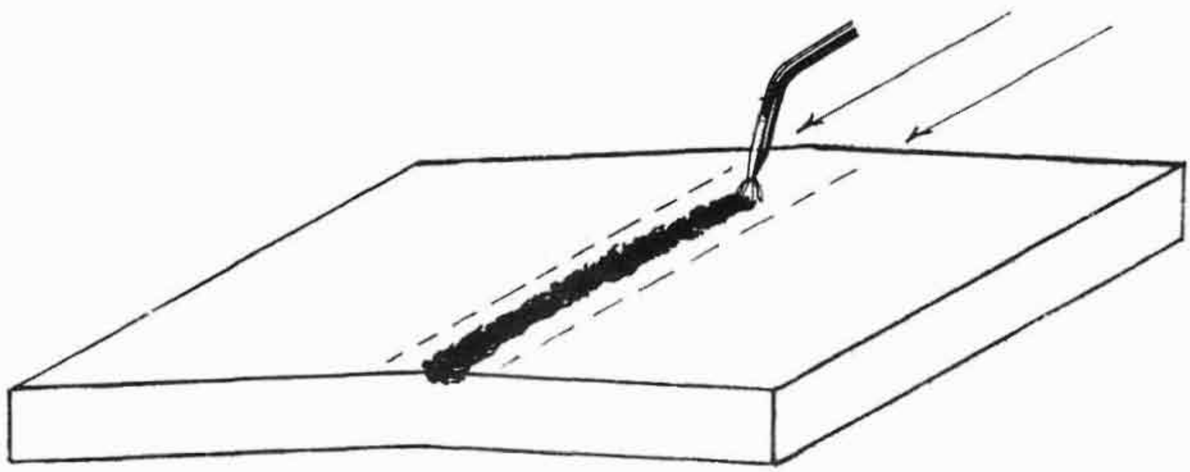
*REMARKS:* 3" thick plate 24" x 96" with 1/16" bend measured at 12" each side of high point. Attempt to salvage by flame straightening.

*WORKING PROCEDURE:*

*BY:* John Doe

1. *Set plate at convenient location with high point up.*
2. *Set up heating apparatus.*
3. *Using chalk, mark off location and width of hot shot. (Approx. 3" wide)*
4. *Apply hot shot.*
5. *Use compressed air or water for fast cooling.*
6. *Check for straightness. Make additional hot shot if necessary.*
7. *When finished, call inspection department to verify.*
8. *Move to next operation.*

*If needed, additional hot shots are to be made alongside the first one. (Not on top)*



*For the working process to flame straighten excessively bent thick heavy plates; see figure 9-3 (Chapter 9)*

Checking for Straightness

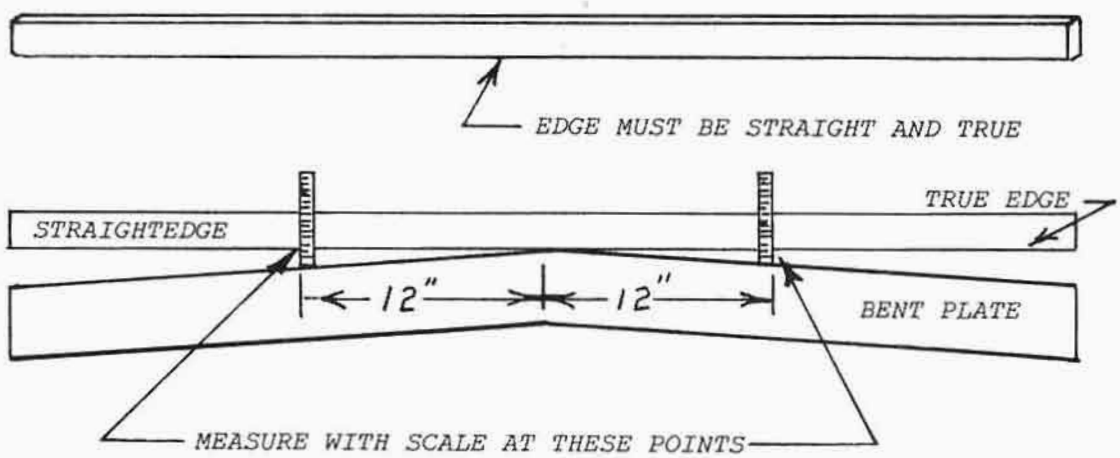
A straightedge is the most commonly used tool for checking straightness. It can be made either from wood or metal as long as one edge is straight and true. See fig. 3-3 for details.

Checking straightness with a surface gauge requires a table flat and true. Its base must always sit flat on the table as it is moved from one location to the other. Measuring the distance from the plate surface to the pointer at different locations gives the exact amount of bend. See fig. 3-4, next page.

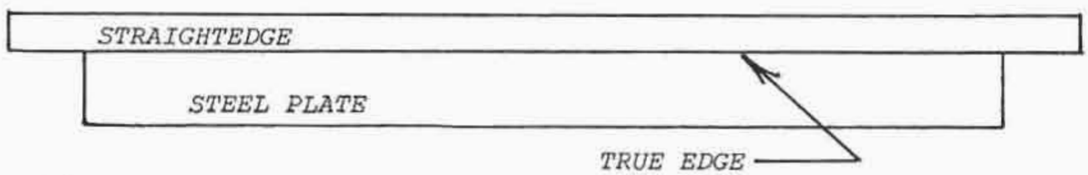
Another method of checking straightness is to set the plate on three equal spacers atop a flat and true table. Checking with a scale from the table to the top of the plate will give the exact discrepancy reading. See fig. 3-5, next page.

Using piano wire for checking is a method which can be used in the absence of a straightedge or when an accurate reading is important. With piano wire, two equal spacers are installed close to the plate edges. Weights are attached to the ends of the wire resulting in a taut condition which enables the discrepancies to be measured. See fig. 3-6, next page.

*FIG. 3-3:*




*TO CHECK WITH A STRAIGHTEDGE: 1. Measure off 12" each side of high point. 2. Hold Straightedge with true edge rocking on high point. 3. Measure discrepancy with scale at 12" each side. NOTE: Straightedge must be held in such a way that the discrepancy at each side reads the same.*




*When there is no daylight between the surface of the steel plate and the true edge of the straightedge, the work is straight.*

FIG. 3-4:

To check with surface gauge:
1. Keep base of gauge flat on table.
2. Set pointer at high point of bend.
3. Measure from surface of work to pointer at different locations.

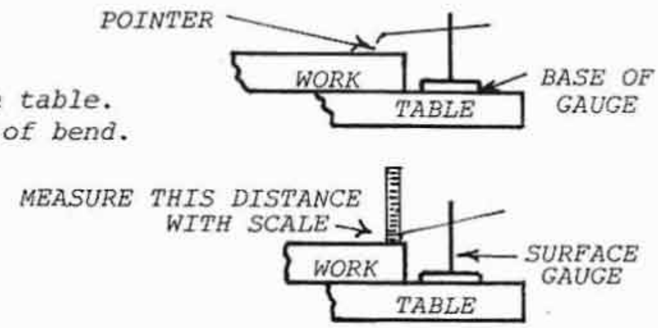



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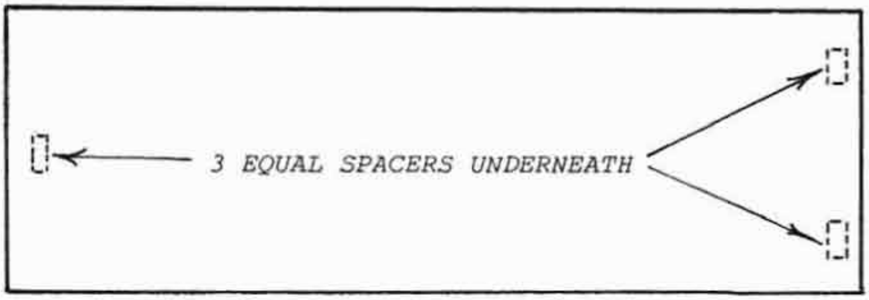
FIG. 3-5:




Using the flat table as a datum, measure at different locations to determine amount of bend.

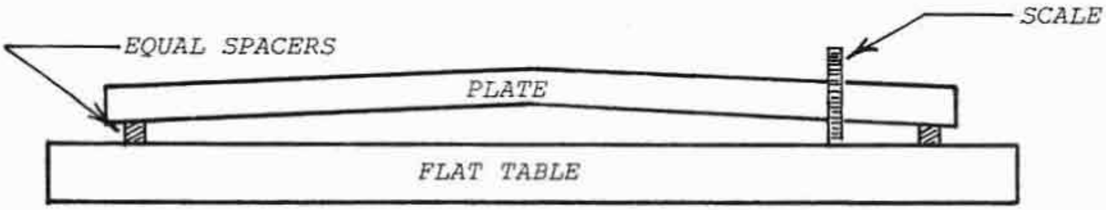



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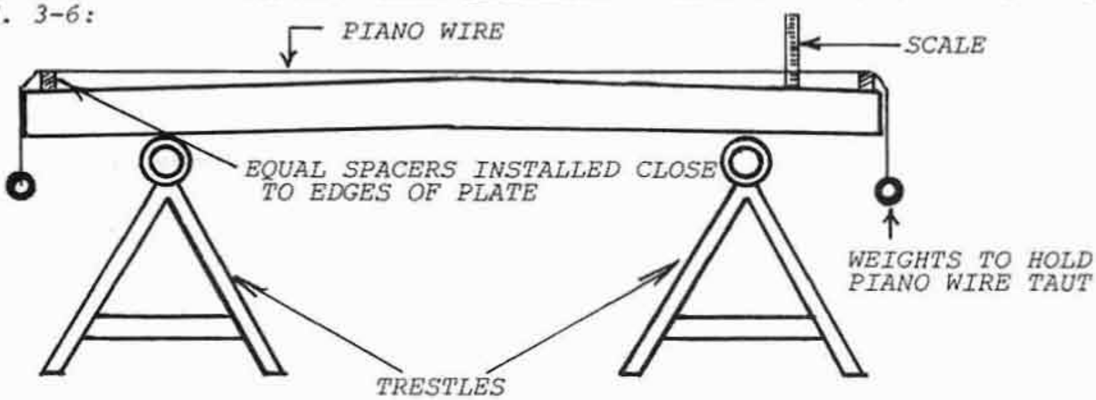
FIG. 3-6:




Determine the amount of bend by measuring from plate surface to piano wire, at different locations.
When the plate is straight, all measurements will be the same.

*Fig. 13-3:*

*WORK PROCESS SHEET*

*SUBJECT:* Welded Frame *CONTRACT #* 1245

*MATERIAL:* Steel Angles

*REMARKS:* Suggestion to making and holding a frame square during welding.

*WORKING PROCEDURE:*

*BY:* John Doe

1. *Tack weld A to B, one tack only.*
2. *Add turnbuckle and adjust until A and B are perfectly square.*
3. *Tack weld C to B, one tack only.*
4. *Add turnbuckle and adjust until perfectly square.*
5. *Tack weld D to A and C.*
6. *Reinforce tack welds.*
7. *Weld complete.*
8. *When finished, remove turnbuckles and grind residual tack welds.*