
Blacksmith's Forge And Bellows

This Technical Bulletin shows an inexpensive way to make bellows, the air pump traditionally used by blacksmiths to make fires hotter. The design here will supply enough air to make a fire that is hot enough to melt steel. It can be built entirely from locally available scrap materials, with the possible exception of some nails and a few pieces of wood.

The Bulletin also gives general guidelines for building a forge, which is a blacksmith's special furnace. Specific forge construction plans are not included. However, the Bulletin does include instructions for using the forge and bellows.

The designs in this Bulletin were developed by Allen R. Inversin, who worked with VITA in Papua New Guinea during the 1970's. Mr. Inversin, a graduate of the Massachusetts Institute of Technology (MIT), previously worked with local technologies in Laos.

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VITA TECHNICAL BULLETINS

This Technical Bulletin is one of a series of publications that offer do-it-yourself technology information on a wide variety of subjects.

Technical Bulletins are idea generators, intended not so much to provide a definitive answer as to guide the user's thinking and planning. Premises are sound and testing results are provided, if available.

Users of the information are asked to send us their evaluations and comments based on their experiences. Results are incorporated into subsequent editions, thus providing additional guidelines for adaptation and use in a greater variety of conditions.

INTRODUCTION

The bellows pictured here is constructed from wood, old inner tubes from auto tires, lengths of steel pipe, and a number of nails and bolts. The most expensive tool required is a drill.

<FIGURE 1>

Although built from inexpensive materials, the bellows is quite efficient. It creates enough air to make a fire that is hot enough to melt steel. It maintains air in a reservoir so that the operator must pump the handle only once every 5-10 seconds.

None of the dimensions of the bellows is critical. Some of the dimensions of other bellows may differ because differently-sized inner tubes and wood may have been used. A few measurements are included in the plans. These are included only to give the builder a sense of the approximate sizes of certain parts.

Carefully read the instructions and list of materials before you begin construction. Any questions or comments about the construction or use of the forge and bellows should be sent to VITA.

MATERIALS NEEDED

- * A sheet(s) of wood that is at least 12mm thick. Plywood is the most convenient kind, if available. There should be enough wood to make four squares, each of which is no larger than 5cm X 5cm. The exact size of the squares will depend upon the size of the inner tubes used.
- * Two car inner tubes that have been discarded by service stations. The tubes should have no major punctures. Numbers are often printed on the inner tubes. If possible, select inner tubes with numbers ending in -13 or -14. Tubes with numbers ending in -12 or smaller might be too small to get enough air through the forge. Tubes with numbers ending in -15 or larger are hard to work with.
- * A third, large car inner tube, or part of one. This will be cut into pieces.
- * Four 10cm lengths of metal rod, 6mm in diameter. Pieces of hardwood or bamboo whittled to form dowels of the same size may be substituted.
- * Strips of wood 4-5cm wide X 5-6m long X 1-2cm thick.
- * Steel pipe, 2cm in diameter X 50-60cm long.
- * Scraps of galvanized steel.
- * 200 nails, 1-2cm long.
- * 36 nails, 4cm long.
- * Two 8cm bolts with nuts and washers (optional).

TOOLS

- * Hammer
- * Saw (to cut wood)
- * Tin snips
- * Wood chisel
- * Tape measure or ruler
- * Drill and bit (to drill holes slightly larger than the rods being used)
- * Auger bit for 5cm diameter hole (optional)
- * Metal file (optional)

INSTRUCTIONS

1. Cut a piece from the center of each of the two car inner tubes. The cut sides should be even. Each piece should be wide enough (about 5cm) to include both the air valve and the thicker rubber around the valve.

<FIGURE 2>

2. Measure the cut sides of each piece by holding the opening as shown. Stretch each opening by pulling firmly. Measure (x)cm. Each section has two open ends. One end will be somewhat larger than the other. You will have four measurements when you complete this step.

<FIGURE 3>

3. Cut four squares from the sheet of wood. One square should be cut to fit each inner tube opening. For an opening measuring (x)cm, the piece of wood should be a square measuring $(x)/2$ cm on each side. For example, the square cut to fit a 10cm opening should be 5cm on each side. Be sure to round off the corners so the rubber will not rip. The corners should be rounded as the arc of a circle whose center is 1 cm inside the edge of the square.

<FIGURE 4>

4. Arrange the four boards. The boards that fit the larger openings in each inner tube should be placed next to each other. Label the boards A, B, C, and D, as shown. Also label the inner tube openings to correspond to the wood pieces that will fit into them later.

<FIGURE 5>

5. Draw a line through the center of board A, as shown, from top to bottom. Center two holes close to each other on each side of board A. These holes can either be chiseled squares or drilled circles.

<FIGURE 6>

6. Cut two rectangular pieces of rubber from the third inner tube. The pieces should be cut so that they lie fairly flat, not curled, on the board. Each piece should be large enough to cover two of the holes in board A. Fasten one piece of rubber at one end only over the first pair of holes on board A, using tacks or nails. Position and fasten the other piece of rubber over the second pair of holes.

<FIGURE 7>

7. Draw a line from top to bottom through the center of board B, as shown. Make three holes next to each other, as shown. Each hole should be about the same size as those in board A.

<FIGURE 8>

8. Cut one piece of rubber to cover all three holes in board B. Position and fasten in the same manner as in Step 6.

<FIGURE 9>

9. Draw a line from top to bottom through the center of board C, as done with boards A and B. Make two or three holes in board C in about the same position as on board B. Do not cover these holes.

After finishing this step, boards A through D should look like this:

10. Make the horizontal support member E. Use the long strip of wood. Cut one piece that is 40cm longer than the largest wooden square. It should extend about 20cm on each side of the largest wooden square (square B or C).

<FIGURE 11>

11. Cut a few pieces of wood to make a box around the rubber-covered holes of board B. Support member E will form one side of the box. These pieces of wood should all be the same width and height. If possible, they should be planed to make them smooth so that the box will be airtight when completed. Make sure the box is large enough so that the rubber valve can move up and down freely inside it.

<FIGURE 12>

12. Make a hole in support member E, as shown. The steel pipe, which will carry air from the bellows to the forge, must fit tightly into this hole so that no air escapes. Make the hole smaller than needed. Then enlarge it as necessary. Nail (and glue, if possible) the box to board B, aligning the center lines of B and E.

<FIGURE 13>

13. Place board C over this box, matching the center lines of B, C, and E. Make sure the holes in board C are positioned over the box nailed to board B.

<FIGURE 14>

14. Cut off four pieces, each about 3cm long, from the end of the remaining long strip of wood. These pieces will make tabs to attach to squares A and D. Drill a hole through the center of each piece so that the 6mm metal rod fits into the hole. The rod may also be made from hardwood or sturdy bamboo.

<FIGURE 15>

15. Place two tabs each near the center of boards A and D. The distance between each pair is slightly more than the width of the wooden arms, F and G, which will fit between them. On board A, the tabs are placed opposite the side that has the rubber valve attached to it. Nail the tabs to the boards.

<FIGURE 16>

16. Cut a number of lengths of thin sheet metal that are a little narrower than the thickness of the square wooden board (for example, 10mm if the wood is 12mm thick). Remove with a file any sharp edges along these strips. 17. Stretch the correct inner tube opening over board B. Center the strip of metal along the board over the inner tube. Hammer in short nails at 3cm intervals along the strip. If the nails bend while going through the metal strip, sharpen a larger nail and use this as you go along to punch holes through the metal.

<FIGURE 17>

18. Fasten in the same manner the inner tube opening marked C over board C. 19. Fasten in the same manner boards A and D to the appropriate inner tube openings. Make sure that the tabs are facing out and are parallel to board E. 20. Make the vertical support member H. Fasten the horizontal support member E to H with either nails or two bolts, as shown. The pieces should be easily separated. The length of H can be as short as shown below, or can be extended into the ground. The shorter length makes the bellows easier to move. The longer length is sturdier. Note the two square wooden spacers in the drawing below. They should be thick enough so that there is room for arms F and G to move freely between the two vertical pieces.

21. Make handle F and upper arm G so that they appear as shown when the inner tubes are fully extended. These two arms should fit freely between the two vertical members of H and the two portions of the tabs. Insert rods through the tabs and arm pivot points so that the arms move freely.

<FIGURE 19>

The pivot points for arms F and G should be halfway between the extended and compressed positions of the tabs, as shown below.

<FIGURE 20>

CONSTRUCTION OF THE FORGE

A forge requires a cavity that contains the fire. It permits air to be blown in from underneath and does not burn or melt.

This cavity may most easily be made from clay. Make a depression in the middle of the clay. Place the air pipe from the bellows inside the clay so the end of the air pipe is in the depression. The air will blow from the bellows, through the pipe, and into the depression.

<FIGURE 21>

Rocks or dirt may be used, as shown, if clay is unavailable.

<FIGURE 22>

This cavity of clay, or of dirt and rocks, is supported either by a table or by a more solid structure. The more solid structure might be a wall made from cement, clay bricks, rocks, or timber. The wall is placed around a square area that is filled with rocks and dirt. The supporting structure may also be built from wooden posts, as shown.

<FIGURE 23>

The top surface of this support should be large enough to hold not only the fire, but also the pieces of heated steel. If the surface of the support is too small, the metal being heated must constantly be supported by one hand. This is a nuisance.

The most comfortable height for the fire is level with your hand when you are standing upright with your arm by your side.

Both the forge and bellows should be located under a shelter or roof to protect them from bad weather. Traditionally, a blacksmith works indoors or in a dark area because it is easier to observe the color of the steel when it is being heated. The color of the steel is very important during welding, hardening, tempering, and working in general. The color shows the steel temperature.

NOTES ON USING THE FORGE AND BELLOWS

1. Coal, coke, or charcoal(*) are often used as the fuel for a blacksmith's fire. These burn much cleaner and with a higher temperature than ordinary wood.
2. Make sure there is at least 3-4cm of charcoal between the pipe opening and the piece of metal being heated. Otherwise, the air going through the pipe will not have a chance to get hot. It will cool the metal rather than heating it. Also place some charcoal above the piece of metal. This increases the heat of the metal.

<FIGURE 24>

Charcoal burns fairly quickly. Do not stoke the fire unnecessarily, such as between heatings. Do not make the cavity larger than necessary.

3. There is no need to pump the bellows quickly. A full stroke every five to ten seconds should be sufficient. If you want more air to go through the fire to make it burn hotter and faster, place weights on the upper inner tube. Rocks can be used. The greater the weight, the more air is fed through the fire.

<FIGURE 25>

4. The rubber inner tube nearest the fire must be protected from sparks, which can burn the rubber. Some simple ways of doing this are:

* Put up a partition between the forge and bellows. * Drape a piece of burlap or cloth over the bellows.

(*) See Making Charcoal: The Retort Method, published by VITA.

The metal pipe will get hot if the forge is used for several hours. Don't let the upper inner tube rest against this pipe.

Theory of Operation

One of the most important parts of the bellows is the one-way valve. It lets air come in from one direction (a), but not the other (b).

<FIGURE 26>

When using the bellows, the upper tube is initially compressed and empty. The lower tube is extended and full of air (c).

Push the handle. The air from the lower tube is forced up through the upper valve into the forge (d). Extra air fills the upper tube (reservoir).

Compress all the air from the lower tube into the forge and reservoir. Then pull the lower tube down. Air enters from below to refill the tube. The air still in the reservoir, compressed by the weight of the upper board, continues to enter the forge (e).

<FIGURE 27>

The upper tube (reservoir) permits a constant flow of air through the fire in the forge. The bellows could be built without the upper tube, but the air would then flow through the fire only when the lower tube is compressed. No air would flow when this tube is expanded. Uneven heat would be produced.

<FIGURE 28>

<FIGURE 29>