The Construction of Vacuum Tables: Theory and Practice

Paul Robbert

"Aspects of a Disappearing Triangle" by Paul Robbert. 40" × 60". Vacuum formed handmade paper.

I became interested in vacuum forming techniques because of the flexibility that the system offered. It enabled me to expand the possibilities of my imagery, opening up a range of artistic choices which had not been previously possible. These possibilities include the option of working with larger paper, as well as creating high and low relief and a wide range of surface textures. The vacuum table, a set-up through which water is drawn out of wet paper lying on a table-top surface, also provides a means of working on imagery that economizes time and energy.

Up to this point, the nature of my work was governed largely by the more traditional means of sheet forming coupled with the use of the press. I wanted to work on a larger scale than before and the sizes offered by vacuum forming exceed the limitations (32" × 44") imposed on me by the seventy-five ton press that I had built in the early seventies.

I first learned about paper forming vacuum techniques in Jules Heller's *Hand Papermaking*. In particular I was intrigued by the description of what Peter and Pat Gentenaar-Torley were doing in Rijswijk in the Netherlands. Their pioneering work in vacuum forming techniques involved the use of a custom made concrete table, constructed by Peter and connected to a vacuum pump originally designed for water removal in concrete forming.

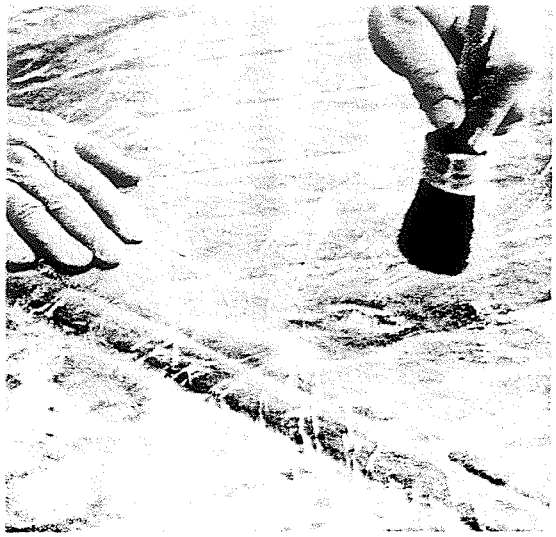
With limited information I set out to construct my first vacuum table. I employed the usual configuration of three units: a table, a tank, and a pump. The table was constructed of marine plywood, the holding tank was made from a converted propane tank, and the deep vac pump was obtained from a local refrigeration and air conditioning distributor. This system was quite successful, however it became apparent how important it is to avoid air leakage whenever deep vacuum pressures are involved. Failures of air tight sealing primarily occur at hose connections. I discovered that a well-designed system involves the use of minimum connections and small negative cavities within the table.

With further experimentation I came up with three approaches for the construction of vacuum tables. The main features of these three designs are the simplicity of construction and utilization of readily available hardware and materials. Each design has its advantages but all work equally well. Maintenance is minimal and repairs can be made easily. I have provided a description of each design after the following elaboration of basic principles and techniques.

Elaboration of the Principles

Vacuum forming techniques involve the exploitation of atmospheric pressure, which is generally 14.7 pounds per square inch. The concept is simple: by creating a vacuum on the underside of the paper, atmospheric pressure is brought to bear on the top side, resulting in both compaction and

Paul Robbert removing excess water from cast paper by use of a rolling pin.



Tamping with a brush insures good detail on the final art work.

the extraction of water. Although it is next to impossible to create an absolute vacuum (estimated to occur at 29.5 mercury inches), it is not uncommon to achieve 27 mercury inches of vacuum pressure during operation of the table. By comparison I found that a quality wet vac will create a vacuum of about 7 mercury inches. For most of my work 20 to 25 mercury inches is satisfactory pressure.

One of the advantages of vacuum extraction is its effectiveness in water removal from the newly formed stratum of pulp. I find that when forming flat sheets of paper the water removal is equivalent to that achieved with a twenty-ton press when pressing a post of 22″ × 30″ sheets. Compaction, however, is less. [1]

One way to compensate for the lack of compaction obtainable with a vacuum table is to apply additional pressure with the use of a roller, such as an ordinary rolling pin. Rolling will provide comparable compaction to a traditional paper press when used in conjunction with the vacuum forming of newly made flat sheets of paper.

In the case of three-dimensional work, additional pressure is applied by pressing with sponges and by pouncing with large stencil brushes where pressure is required in areas of detail. The function of compaction is important to ensure fiber to fiber contact and to promote hydrogen bonding, which will ultimately contribute to greater strength after drying.

The function of water removal through these methods is more than adequate in comparison to that achieved with a paper press. An advantage of vacuum extraction is that water is drawn down through the pulp stratum from the top surface to the bottom, resulting in mainly capillary water remaining in the paper. In contrast, a paper press forces water out laterally, radiating from the center to the outside edges of the sheet and felts. The importance of the presence of water is a given in papermaking, as it ensures fiber to fiber bonding. In casting paper I have experienced problems resulting from too much water being removed without adequate corresponding compaction, which leaves a weak structure.

Vacuum Extraction System

I have experimented with a variety of vacuum systems and found the traditional table, holding tank, and deep vac pump configuration to be the most satisfactory for my work.

The table construction I recommend consists of a marine plywood surface in which small ports are drilled 6 to 10 inches apart over the entire surface, allowing a 6 inch border without holes around all four sides. Each port connects with a common vacuum cavity which, in turn, connects to the holding tank by means of plastic tubing.One way to build this system is to sandwich two boards together, allowing the ports on the top surface to open into the negative space between the boards. This space is created by grooves fashioned with a router (figure 1) or by routed grooves in pine strips (figure 2). The space in Design III is made by the construction of a wood frame to form the cavity in conjunction with small, thin wood support spacers between the surfaces of plywood (figure 3).

The construction must be airtight and strong enough to withstand the high vacuum pressures applied during operation. In two designs, a single tube connects between the negative space in the table and the holding tank. The vacuum pump is attached to the holding tank, using the same tubing as above. Vacuum created in the tank by the pump draws both air and water through this tube from the table. The tank receives both air and water from the table, the water remains collected in the tank, and the air is pumped out through the pump.

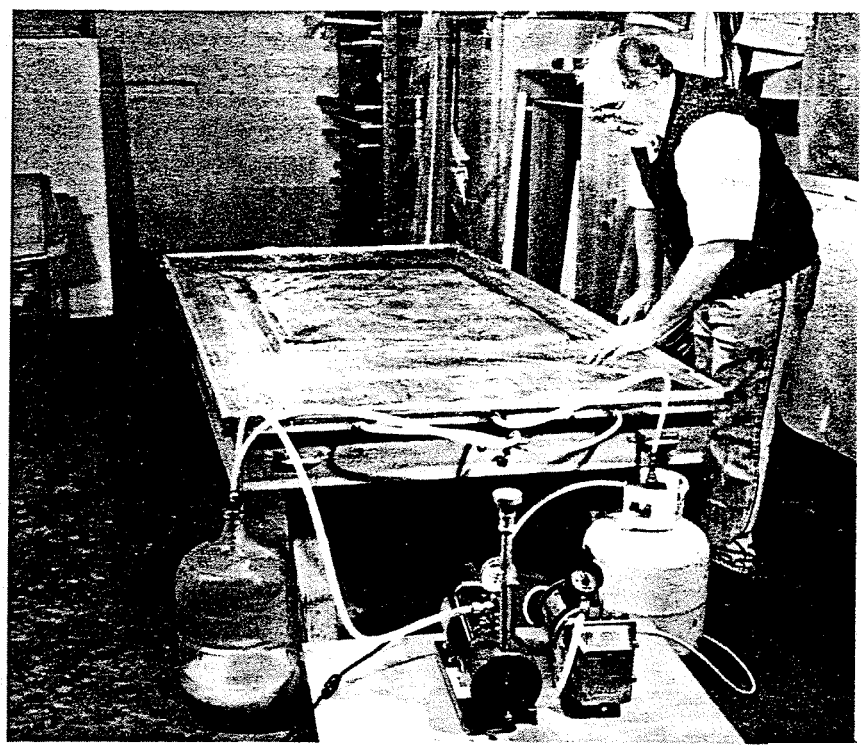
The holding tank must be sturdy enough to withstand the stresses associated with deep vacuum and large enough to accommodate the volume of water which will be extracted. A

conventional propane tank, converted, functions well for this purpose. The tank must be retrofitted with two tubes that connect to a single opening at the upper end of the tank. This can be achieved with standard plumbing parts installed at the top of the tank after the tank valve which comes with the tank has been removed. One tube connects the table to the tank and the other runs to the vacuum pump. A tap or plug is necessary to allow for emptying water from the tank.

There are many types of vacuum pump on the market to choose from, although some are prohibitively expensive. For all practical purposes two types are useful for papermaking. One is the oil vane pump commonly used for refrigeration and air conditioning servicing, and the other is an oilless pump which needs less maintenance. The latter is manufactured by the Dayton Company and is available at electric motor distributors. The pump should be capable of producing deep vacuum pressures of at least 27 mercury inches and must have the capacity of 3 or more cubic feet per minute to accommodate a table size of approximately 48″ × 48″. Larger tables require proportionally larger pumps, holding tanks, and related equipment. Attached to the pump is a gauge to measure the vacuum pressure level.

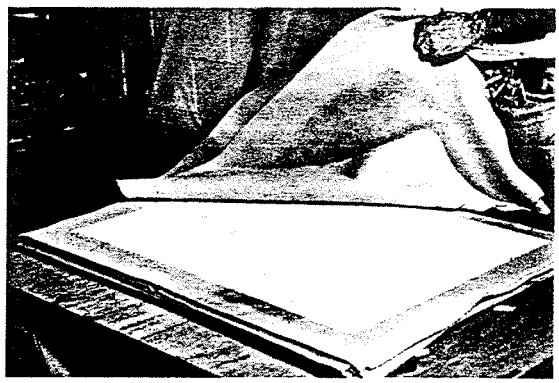
Traditional Sheet Pressing

The vacuum table can often be used successfully in place of the traditional paper press. Sheets formed in the traditional way can be couched directly on felts placed on the table. It is possible to build a small post of paper as well as couching single sheets, whether traditional or shaped. Although the major advantage of the vacuum table lies in the execution of unique works, I use this technique for the production of sheets that exceed the size limit of my press.



Vacuum apparatus removing water from a post of paper.

The procedure for traditional flat sheet formation is as follows. Two or more layers of plastic mesh (10-20 line screen) are placed on the surface of the table, leaving 3″ to 4″ of space on all sides of the table surface exposed. Plastic window screening works well. Next wet couching felts are placed directly on the mesh. Newly formed sheets are couched onto the felts as in traditional papermaking. I have found a post of 8 to 10 sheets to be manageable. The stack is then covered with a ⅛″ sheet of Plexiglass, slightly larger than the paper size. An additional felt is placed over the plastic for cushioning, covered by a sheet of thin plastic (0.3 mm). This plastic should be a few inches larger than the table and its contents. It is essential that the surface of the table be wet before applying the plastic sheet. I sometimes add formation aid around the outside edges of the table to achieve a better seal.



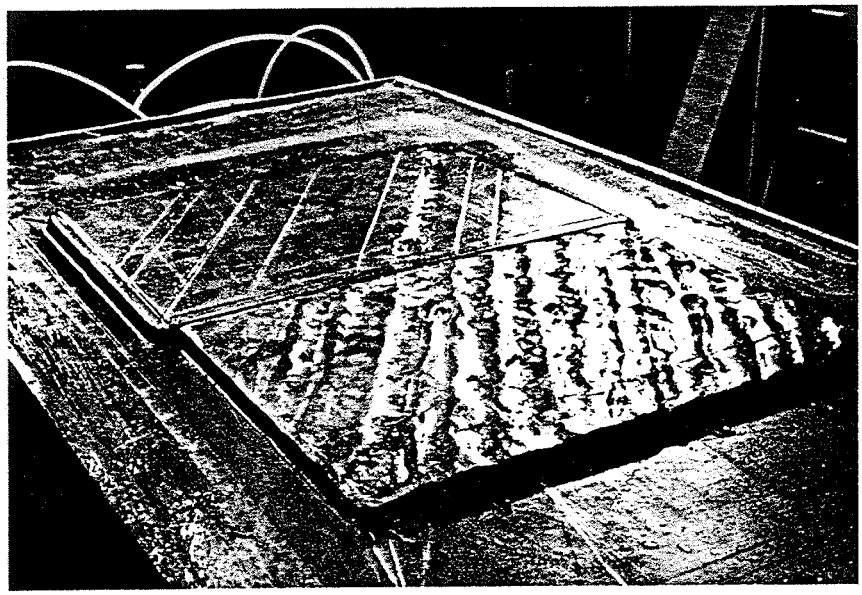
Post of papers which were "pressed" with a vacuum table.

The vacuum is then started, which removes the air under the plastic and causes it to constrict around the post. A damp sponge can be used to smooth the plastic down around the edges of the plastic to form a tight seal. Once a true vacuum begins, water will start to be extracted, along with any remaining air, and compression begins to occur on the post. At this point, after the entire surface of the thin plastic is moistened, a second and slightly heavier sheet of plastic (1.0 mm) is applied in order to create an additional seal.

When pressures of 10-15 mercury inches are achieved, additional light pressure can be applied by means of the roller. From this point on, rolling pressure should be increased corresponding to the increase in vacuum pressure. This procedure is continued until 20-25 mercury inches of vacuum are achieved and at this stage substantial rolling pressure is applied for maximum compaction. The pump should continue to run until free water is removed, after which the plastic can be removed, the pump turned off, and the paper then handled and dried in the traditional way. The time of operation depends on the equipment and the nature of the pulp used. Well-beaten pulp takes more time for water removal.

Unique Art Work

In the making of unique paper art work using pulp painting, embedding, and laminations, the vacuum table is very useful. I use the table as a drawing or easel board on which the work can remain in place from beginning to completion. At any point in the production of the work, light or deep vacuum pressure can be applied to draw off water.

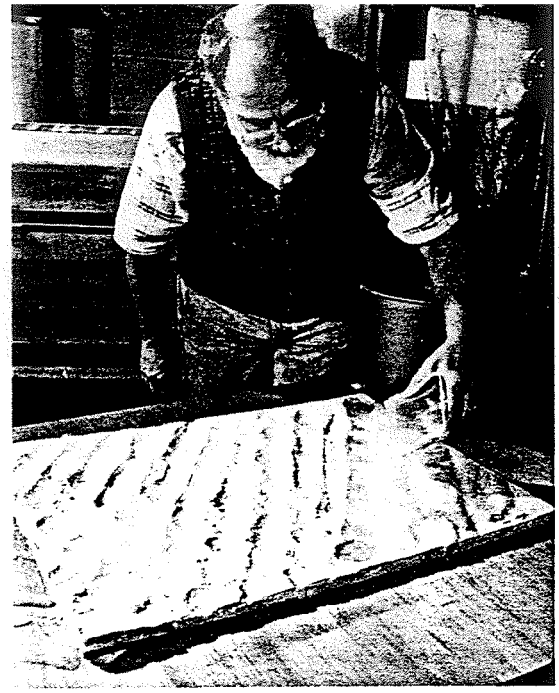


Vacuum pressure applied to art work to remove water.

Flat and limited relief shapes, including found objects, can be formed in the sheet by first arranging the forms or objects on the felt surface and couching a newly-formed sheet directly on top. The same pressing techniques as described above can be utilized excluding the use of ⅛" Plexiglass and replacing the use of the roller with a large sponge or pouncing with a stiff stencil brush. A relief technique that I often use involves cutting negative shapes and lines into a one inch thick Styrofoam sheet or insulation board. Water can be drawn through most Styrofoam and bead board. Closed cell-type insulation board works well if sanded and perforated through with needle holes about one inch apart. In addition to the various texture and low relief effects possible with this technique, another advantage is that the paper can dry directly on the Styrofoam sheet after the vacuum operation. The usual care must be taken during drying so that the paper does not prematurely separate from the board.

Three Dimensional Casting

The usual considerations in the construction of negative casting molds made from plaster or hydrostone should be used in conjunction with the vacuum table. Construction of the negative mold must be done keeping in mind the forces that are exerted during the vacuum forming process, which are capable of cracking molds that are not properly constructed or not well-supported on the table surface. Molds must be free of undercuts and negative spaces on the bottom. My technique is to drill minute drain ports in inconspicuous places through the low



Pouring pulp onto Styrofoam.

points in the mold to allow water to be drawn through during the vacuum process. I seal casting molds with clear plastic spray and apply canuba wax to function as a releasing agent in order to prevent the paper pulp, when dry, from sticking to the surface of the mold.

The casting mold can be located over the mesh on the vacuum table and all peripheral ports on the vacuum table surface are sealed with tape. Low shrinkage, lightly beaten pulp made from first cut linter is generally used for paper casting.

Pulp applications are no different from the usual paper casting techniques. An approach I use involves the formation of very wet sheets with a small paper mold which are then systematically flopped into the mold cavity. This is continued until an even layer of paper covers the entire mold surface. A thin sheet of Pelon is then placed over the entire mold followed by a thin sheet of plastic. The visible surface water can be drawn from the mold cavity with vacuum pressure which also forces the pulp to come in close contact with the mold surface. Water deep in the cavities is drawn through the drilled ports at the base of the mold. Additional applications of lightly beaten, low shrinkage pulp are applied to the mold until the desired thickness is achieved.

The same procedure as above is used for both compaction and extraction, with sponges and stencil brushes to compact the pulp in the cavity. The pulp is then allowed to dry in the mold. Care must be taken to ensure that drying is even in order to avoid potential distortion caused by uneven shrinkage. To achieve this, edges can be covered with aluminum foil or plastic. A combination of warm heat with surface air allows the molded paper to be dried in about twenty four hours, after which the paper casting is carefully coaxed from the mold.

A variation of the water extraction technique utilizes a plastic bag in which the entire mold with cast pulp is placed. The opening of the bag is securely taped closed around the tube that leads to the holding tank. Vacuum constricts the bag on all sides. The arrangement of felts or plastic mesh in the bag itself is important to allow the free flow of air and water from the bag to the vacuum tube during the extraction operation. This procedure works quite well for three-dimensional works of large size.

Table Design in Detail

Below are described designs for three varieties of vacuum table, with instructions on how to construct them. Each design possesses several important features worth comparing before deciding which is most suitable for the individual papermaker.

With all three designs an optional ¾″ strip of wood can be mounted with screws on the four top edges of the table to restrain water from dripping off the edge. Care should be taken to waterproof these strips as with the other areas of the table which will be exposed to water. Similarly, all surfaces on the table both inside and out must be thoroughly sealed with fiberglass resin or polyurethane varnish, since deep vacuum has the ability to draw air and moisture through wood. The connecting tubes used in these designs are made from ½″ O.D. polyethylene tubing which fits over ⅜″ copper tubing. The connections can be made airtight with the use of small hose clamps.

Vacuum Table Construction Design I

This design (figure 1) is substantial and will give many years of service if properly constructed. The table is made of two pieces of marine plywood glued together with marine glue. The top surface is ¼″ marine plywood in which ⅛″ countersunk port holes are drilled at equal distance from each other depending on the size of the table surface. Holes are typically 6 to 9 inches apart.

The base board is constructed of ¾″ marine plywood. Three eighths of an inch grooves are routed out that will connect to corresponding portholes on the top surface.

For final assembly, marine glue is brushed on both surfaces to be glued and clamped together tightly. Clamps should stay in place for at least twelve hours.

A ⅜ inch copper tube, 3″ in length, is glued in place with epoxy, with 1¼″ of tube exposed from the edge of the table as a vent. Sometimes exposed grooves on the edge of the table need to be drilled out with a ⅜″ drill to allow the tube to be inserted in the table. The tube needs to be secured firmly to the baseboard and sealed there tightly.

Vacuum Table Construction Design II

This design (figure 2) is a variation of Design I. In this case, 1″ by 3″ pine strips replace the base board of ¾″ plywood. This modification works well for the construction of a large table as it will be lighter in weight and less cumbersome to handle.

The design utilizes a ⅜″ plywood top surface with ⅛″ port holes drilled and countersunk at even intervals from 6″ to 9″ apart. The back side or bottom utilizes 1″ × 3″ pine strips that frame the outside edge and run directly underneath the rows of port holes in the plywood top surface. Prior to assembly, ⅜″ grooves are routed out on the pine strips located underneath the rows of

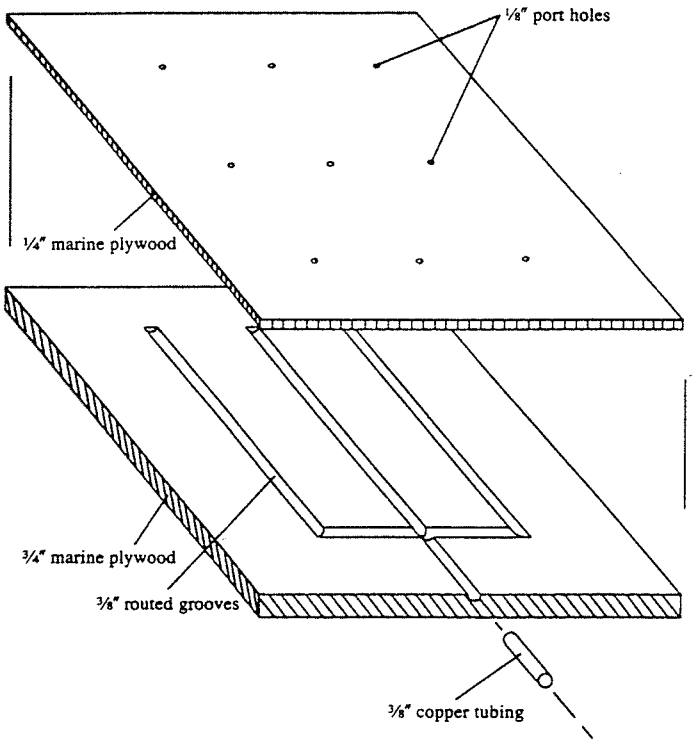


Figure 1

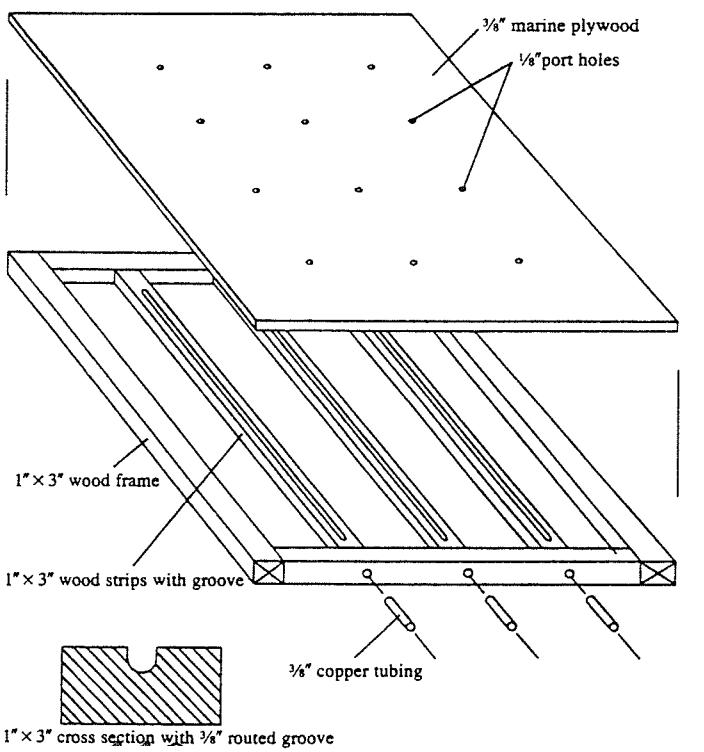


Figure 2

All diagrams by Paul Robbert

port holes. Care is necessary during construction to make sure that all joints fit tightly together.

The table can be assembled using quality marine glue. This glue works well as a water seal. The application of marine glue in the grooves, and all surfaces of the other pine strips to be attached to the bottom side of the top surface, needs to be done prior to assembly. One inch nails or small flat-head screws can be used to fasten the pine strips to the bottom of the top surface, eliminating the need for clamps. The glue should dry overnight.

Three eights of an inch copper vent tubes 3″ long, connecting to the outer edge of the table, are glued in place allowing connection from the inner grooves to the outside of the table. This is achieved by drilling ⅜″ holes from one edge of the table directly through the outer 1″ × 3″ strip into each 1″ × 3″ strip with routed grooves. In this design, separate Polyethylene tubes must be connected to these copper vent tubes and must be joined together with a configuration of ⅜″ copper tubing and ⅜″ copper T-fittings. On my 48″ × 72″ table I use two pumps in order to increase the air capacity. All surfaces need to be sanded smooth and coated with three applications of gloss polyurethane varnish.

Vacuum Table Construction Design III

This table (figure 3) is suitable for low vacuum work used with a wet vac, as well as deep vacuum operations. It is comprised of two pieces of ⅜″ plywood, exterior grade, which sandwich a 1″ × 2″ frame and 1″ × 1″ strips of wood for support, spaced approximately 3″ to 4″ apart. The supporting wood strips should be short enough to leave a space of 1″ on both ends, making the inside space contiguous.

The bottom should be constructed first and glued and nailed together. After construction, all inside interior spaces should be painted with at least three coats of polyurethane varnish. Care should be taken not to paint top surfaces of the 1″ × 2″ and 1″ × 1″ strips to be glued to the top surface later.

In the top, ⅛″ holes should be drilled from the top, spaced 3″ to 6″ apart, and located over the negative spaces between the 1″ × 1″ slats. Holes can be slightly countersunk for smoothness. The bottom surface should be painted with three coats of polyurethane after carefully masking out areas that will come into contact with the bottom section. After the polyurethane is dry, the top surface should be glued and nailed down to the bottom unit using ¾″ finishing nails spaced about 4″ apart; both the outside frame and the center wooden strips should be nailed. All outside surfaces should then be sanded and at least three coats of polyurethane should be applied.

A vac post block should be installed when a wet vac is intended to be used in place of a pump. A block of wood, 2″ × 6″ × 6″, needs a hole cut through the center, large enough for the wet vac hose to fit snugly. This block is mounted with wood screws on the bottom side of the table surface, into which a hole of the same size has been cut. Four screws should be located so that they will fasten through the ⅜″ plywood and into the inside strips, as shown in the drawing.

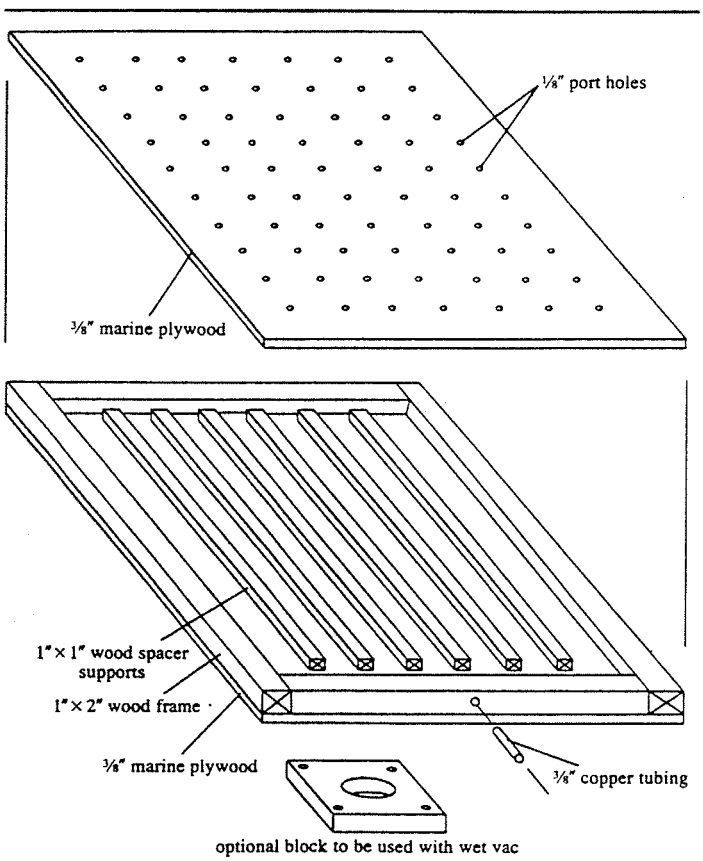


Figure 3

Notes:

1. A twenty ton press exerts 60.6 lbs of pressure per square inch on a sheet of 22″ × 30″ whereas a vacuum table provides 14.7 lbs per square inch on the same size sheet.

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