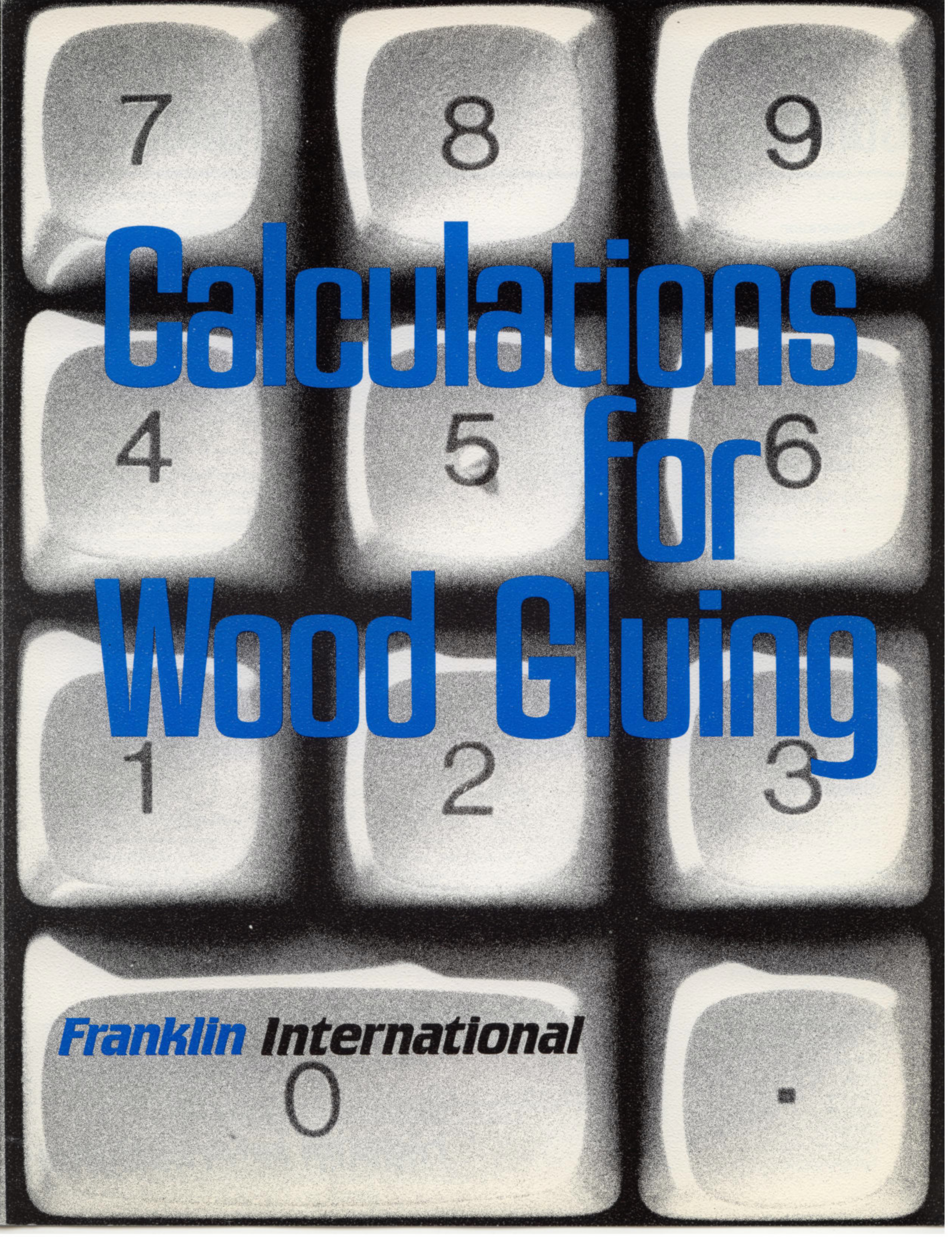
Calculations for Wood Gluing



Franklin International

Contents

Introduction

Many times an adhesive operation fails because the wrong values are used for the proper pressure, spread, etc. Usually there is some latitude in the proper numbers. To control quality, however, it is necessary that the numbers be kept at approximately the optimum.

At all times, it is desirable to record the times, pressures, spread, moisture content, etc. for each gluing operation, so that if any trouble develops, the cause can be quickly located.

This booklet has been prepared for your information and assistance by the Wood Adhesives Division of Franklin International. For additional product information contact: Franklin International, 2020 Bruck Street, Columbus, Ohio 43207.

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Joint Preparation

Circular Saws

Poor joint preparation makes the remainder of the gluing operation difficult to perform properly and increases the reject rate. The time and money spent to prepare joints well will be repaid quickly by improved product and reduced costs. Recommendations for the preparation of high density species glue joints on a straight line ripsaw (Figure 1) are:

1) The stock should be straight and flat.
2) The saw should be set to produce a straight line. (No end-to-end bowing, sometimes called "hollow joint").
3) At least one surface of the board should be planed flat and this face should be against the bed of the saw, to produce a square joint.
4) Saws must be sharpened frequently to produce a smooth cut.
5) The feed rate should not produce a chip load of more than 0.005" per tooth as this can give a rough joint and cause vibration of the blade which will cause deep scratch marks on the gluing surface. The following formula can be used to calculate chip load:

$$\frac{\textbf{Rate of feed (feet per minute)} \times 12}{\textbf{Number of teeth} \times \textbf{Blade speed, r.p.m.}} = \textbf{Chip Load}$$

Example:

Feed rate = 40 feet per minute
Number of teeth = 30
Speed of blade = 3,600 r.p.m.

$$\frac{40 \times 12}{30 \times 3600} = 0.0044$$

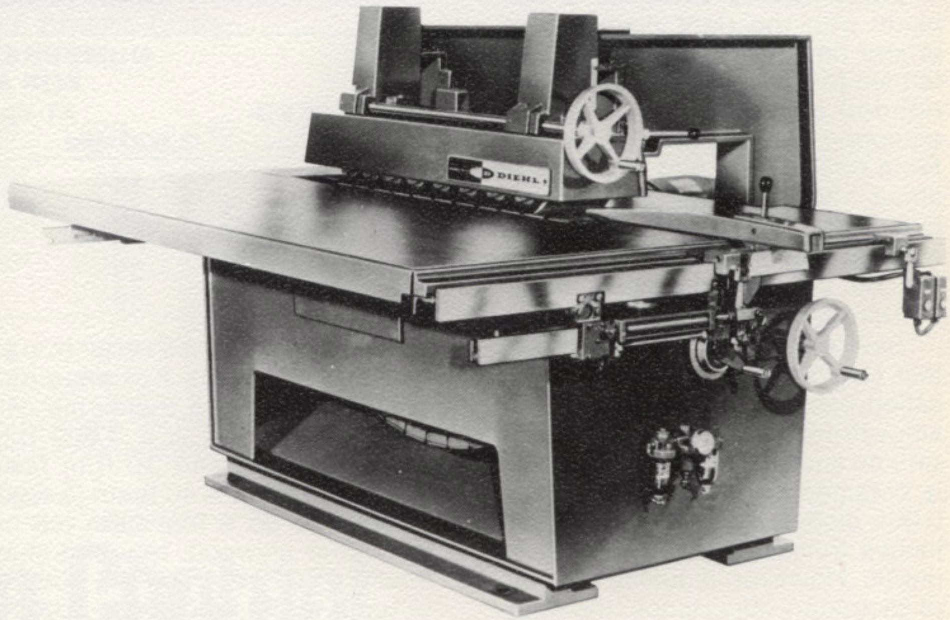


Figure 1: Straight line rip saw. (Photo courtesy of Diehl Machines Division, Wabash, Ind.)

According to John Ekwall[1], "A circular saw will achieve good cutting action only when the blade rotates fast enough to give the saw teeth proper speed as they move through the cut. Extensive experiments under varying conditions have shown rim speeds between 10,000 and 15,000 feet per minute to be best for cutting solid wood as well as plywood and plastic laminates.

"Solely from the cutting point of view, the higher the rim speed, the better and easier the cutting becomes. However, as the speed of the saw increases, so will the mechanical strain on the saw blade. Vibration, as well as blade distortion due to centrifugal force, put a limit on the speed. The wide range —5,000 f.p.m.—of saw speed recommended above is due to the great variation in condition of both machine and sawblade. Good bearings and a true-running saw spindle, along with a properly centered, well-balanced sawblade equipped with good saw collars will allow for fast rim speeds and cutting ease.

"It is generally preferable to use saws with small diameters since they give better blade stability and a narrower saw kerf. But the saw diameter must be such that it will yield the correct rim speed at the available spindle speed. Many saw catalogs include tables giving the relationship between spindle speed, saw diameter and rim speed. Such a table is shown below:

(1) John Ekwall, "Machining and Cost Reduction" FURNITURE DESIGN AND MANUFACTURING, February 1976, page 12.

SPINDLE SPEED	SAW DIAMETER (inches) FOR VARIOUS RIM SPEEDS		
rpm	10,000 fpm	12,500 fpm	15,000 fpm
3,600	11	13	16
5,000	8	10	11
7,200	5	7	8
10,000	4	5	6

(This table can be used for the selection of sawblades when the speed of the machine is known. It can also be used to determine desired spindle speed on belt-driven machines for saws of a given diameter.)

"After having selected a saw blade with the right diameter for proper rim speed, let's turn our attention to the number of saw teeth needed on the blade. A ripsaw equipped with 36 straight ripping teeth rotating at 3,600 rpm will cut about 130,000 chips per minute. Even when the feed rate is fast, one realizes that the size of the chips will be very small—measured in thousandths of an inch.

"Saw experiments have shown that chip size, or chipload as it is called, can be used as a measure of smoothness of the saw cut. A smooth and easily sandable surface is obtained by removing chips of 0.005 inches from wood or 0.002 inches from veneered surfaces or plastic. However, if quality of cut is of secondary importance, the chipload can be doubled.

"One thing to keep in mind when discussing chiploads is that while a tooth of a straight-tooth ripsaw will remove a chip the full width of the saw kerf, the tooth on a cross-cut saw will remove a chip only half the kerf width. Thus, two cutoff teeth are needed to do the job of a single rip tooth, and the same is true for a triple-chip ground saw. A tri-tooth saw requires three teeth to clean the kerf. Calculations dealing with chiploads, therefore, do not always consider single saw teeth but, rather, groups of teeth.

"With the above information in mind, a table can be set up giving the required number of saw teeth (or groups of teeth) for a predetermined chipload of 0.005 inch at various feed speeds.

FEED SPEED	NUMBER OF TOOTH GROUPS REQUIRED FOR A CHIPLOAD OF .005 INCH AT VARIOUS SPINDLE SPEEDS			
fpm	3,600 rpm	5,000 rpm	7,200 rpm	10,000 rpm
20	13	10	7	5
30	20	14	10	7
40	26	19	13	10
50	33	24	17	12
60	39	29	20	14

From this table, several things become apparent. For example, you can see that a triple-chip carbide saw running at a 3,600 rpm spindle speed and 30 fpm feed speed will require 40 teeth (2 x 20) in order to do a first-class job on wood. For plywood, required chipload is 0.002 inch, and the number of teeth would be 0.005 ÷ 0.002 x 40, or 100 teeth.

"You can also use this table to find out what feed speed to use for a given saw if a certain surface quality is required. For example, assume that you have a saw for splitting dust rails on the bottom head of your molder. The saw has 24 straight rip teeth and the spindle is running at 5,000 rpm. Referring to the table, you find the maximum feed speed for a good quality job will be 50 fpm.

"Any selection guide for sawblades must also take into account the position of the saw in relation to the wood to be cut. When the blade on a table saw is set low, in such a manner that the blade sticks up above the table only slightly more than the thickness of the wood being cut, the initial impact between the saw and the wood is made by the base of the saw teeth. Cutting wood in this manner takes a lot of power, both for feeding and for saw rotation.

"There is also some upward lifting action of the wood which can cause chatter unless the wood is firmly held against the table. While this saw position is not recommended for table saws, it is quite common on powerfed ripsaws where the saw arbor is located under the feed chain. The chips formed by these saws are long and slender and the cutting action quite smooth, provided the wood is held down firmly on the feed chain. Upward pressure on the wood can be reduced by using saws with large hook.

"If the saw is raised further above the saw table, the cutting approach angle of the saw teeth changes to hold the workpiece down on the table. Further, power for both feeding and cutting is lessened, as readily seen when feeding a piece of wood by hand on a table saw adjusted to this position. While this positioning and tooth approach angle is recommended for manually fed table saws, a ripsaw in this position gives shorter and thicker chips, and surface quality will suffer unless we use a saw with minimal hook.

"Still another approach angle is used on radial saws and powerfed ripsaws having their saw arbor above the feed chain. In these cases the saw teeth hit the wood in such a manner that the tip of the tooth receives the full impact of initial contact. This has a tendency to dull the saws fast, and it's here that a negative hook might be used in order to maintain sharpness. An important aspect of this cutting position is that very large stiffening collars can be used. This gives us an opportunity to use saw blades with a very thin kerf which, in turn, can result in considerable lumber-yield improvement and dollar savings.

"One further point on saw selection: When studying circular-saw selection principles, it would appear that every job in the factory will require a special saw with optimum tooth shape, diameter and pitch. Add to this the variety of available raw materials and you can visualize quite a collection of saws. Obviously you will want to standardize your saw supply; this is not only possible, but actually quite simple. Keep in mind that saw manufacturers are making their standard saws according to the fundamental sawing principles described here, and they can offer standard products well suited to our purposes. If you start out by standardizing saw-spindle speeds and spindle diameters, you're likely to end up with surprisingly few saw types, most of which will be interchangeable from machine to machine.

Jointers and Planers

John Ekwall[2] also contends that "through experience, woodworkers have found that hard and dense wood which is to be glued together should be machined with at least sixteen ridges per inch on the mating surfaces. If softer woods are glued, somewhat fewer ridges will do, as these woods compress more readily when clamping pressure is applied. Rough-planed lumber seldom has more than six or eight ridges per inch, but this is not objectionable since subsequent finish planing or wide-belt sanding will smooth the surface. On the other hand, hard-to-sand surfaces or those that are to be finished without sanding might require twenty ridges or more for a good-looking job.

"The number of ridges per inch depends on the feed speed of the machine, the rotational speed of the cutterhead and the number of knives actually performing the final cut. This relationship can be expressed by a mathematical formula —(r.p.m. ÷ speed in inches) x number of knives = ridges per inch—is used to construct the table below for a cutterhead rotating at 3,600 r.p.m.

FEED SPEED	NUMBER OF KNIVES			
fpm	1	2	3	4
20	15	30	45	60
30	10	20	30	40
40	8	15	22	30
50	6	12	18	24
60	5	10	15	20
80	4	7	11	15
100	3	6	9	12

Knife marks per inch at a cutterhead speed of 3,600 r.p.m.

(2) John Ekwall, "Sharpening Up on Cutterhead Knives" FURNITURE DESIGN AND MANUFACTURING, March 1976, page 21.

Adhesive Spread

There should be enough adhesive present in a bond to fill the gap between the two substrates. This is determined by a number of factors:

1) Adhesive penetration into the substrate. Excessive penetration is a cause of a starved joint. Sizing reduces penetration:
2) Thickness of gap between the two substrates. Gap between joints should be absolutely minimal.
3) Uniformity of gap between the two substrates. Enough glue should be spread to fill the maximum gap.
4) Ability of spreader to apply uniform spread at minimum thickness needed. A defective spreader is a glue and time waster.
5) Uniformity of clamping pressure. Lower glue spreads can be used if pressure is adequate and uniform.

Donald Jones[3] discusses factors affecting the spread obtained with roller spreaders. Several of the variables influencing adhesive spread rate are:

1) porosity and surface characteristics of the stock to be glued,
2) viscosity of the adhesive before and during application,
3) assembly time and
4) pressing conditions (amount of pressure, press temperature, and curing time).

Once the proper spread rate has been determined for a given operation, the ability to achieve the spread rate becomes dependent upon the control of certain mechanical and design variations within the roll spreader. Mechanical and design variations that influence spread rate are:

1) The distance between the doctor roll and applicator roll. This distance controls the amount of adhesive on the applicator roll which, in turn, controls the amount transferred to the stock.
2) The nip pressure on the stock. This pressure determines the amount of deflection of the roll grooving which affects the amount of groove area available to carry glue to the stock.
3) The construction, diameter and the surface treatment of the applicator roll.

Adhesive spread can be measured by three methods:

1) Wet film gauge. Results are in mils of wet film applied.
2) Weighing a piece of veneer before and after spreading with adhesive. Results are calculated to pounds of glue per thousand square feet and
3) Measuring the coverage of a given amount of adhesive. Results are in gallons per thousand square feet of glue line.

Wet Film Gauge

A Nordson wet film gauge (Figure 2) is a convenient way to measure wet film thickness. To use it accurately the film and substrate must have a smooth surface. A ridged glue film cannot be accurately measured. Likewise, an uneven substrate (such as foamed polystyrene–beadboard) cannot be accurately measured by this means.

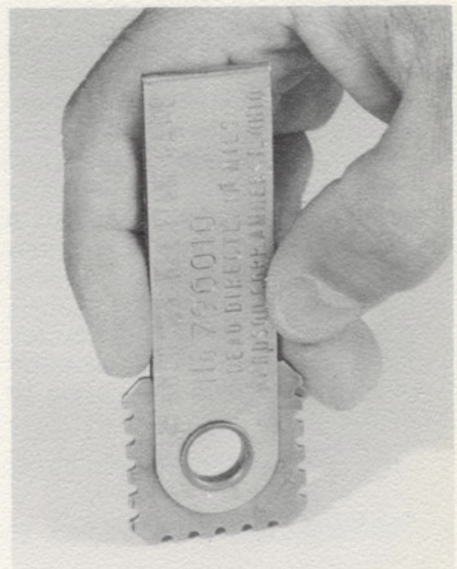


Figure 2: Nordson wet film gauge.

The film gauge readings, in mil wet film thickness, are convertible into pounds per thousand square feet by the formula:

$$\text{SPREAD} = \frac{\text{WET FILM THICKNESS (mils)}}{1.6^*} \times \text{WEIGHT PER GALLON (lbs.)}$$

As an example, spreading an eight mil wet film of an adhesive weighing 9 lbs. per gallon: SPREAD = 8/1.6 × 9 = 45 lbs. per 1000 sq. ft. Rearranging the formula to find the wet film thickness for a certain spread, it becomes:

$$\text{WET FILM THICKNESS (mils)} = \frac{1.6 \times \text{SPREAD (lbs. per 1000 sq. ft.)}}{\text{WEIGHT PER GALLON (pounds).}}$$

Using the above example: $\text{FILM THICKNESS} = \frac{1.6 \times 45}{9} = 8.0$

*A gallon of adhesive uniformly spread in a film one mil thick will cover 1,604 sq. ft.

(3) Donald T. Jones, "Developments in Roll Spreading Techniques" FOREST PRODUCTS JOURNAL, Volume 21, Number 6, page 25.

Veneer Method

(Figure 3—veneer on a balance)

A method for use with veneers is as follows based on a single glue line:

1) cut pieces of test veneer 12 inches by thirteen inches from material of the thickness and type to be passed through the spreader.
2) Weigh on a gram scale.
3) Pass through a double roll spreader adjusted to provide a uniform spread on the top and bottom roll.
4) Weigh the veneer and applied glue.
5) Substract weight #2 from weight #4.
6) The weight in grams on a twelve inch by thirteen inch piece, spread on both sides is approximately the same as the spread in pounds per thousand square feet of single glue line. Example:
   a) Veneer twelve inches by thirteen inches, weight = 80 grams,
   b) Veneer and glue, both sides = 110 grams and
   c) Spread = 30 grams.

The spread of thirty grams is equivalent to thirty pounds of glue spread per thousand square feet of single glue line surface.

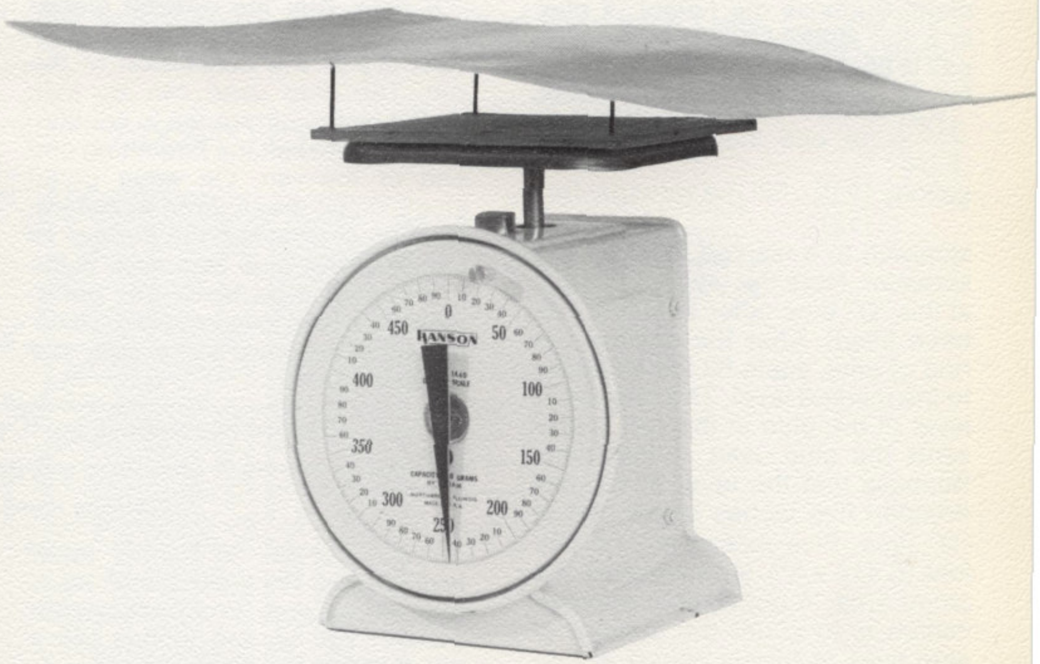


Figure 3: Veneer on a balance (wet spread).

COMPARISON OF SPREAD IN VARIOUS TERMS OF MEASUREMENT

Film Thickness in Mils	Lbs. of Glue per M sq. ft.	Gallons of Glue per M sq. ft.	Sq. Ft. of Coverage per Gal. of Glue
0	0	0	0
1	5.5	.6	1604
2	10.5	1.2	802
3	17.0	1.9	534
4	22.5	2.5	401
5	28.0	3.1	320
6	33.5	3.7	267
7	39.5	4.4	229
8	45	5.0	200
9	50.5	5.6	178
10	56.0	6.2	160

Based on an adhesive weighing 9 pounds per gallon.
For adhesives with weights differing from 9 pounds per gallon, a suitable correction factor will have to be applied.
Pounds of glue per thousand square feet has been rounded off to the nearest half pound.
If the glue weighs more than 9 lbs. per gallon (for example 9.3) multiply the gallons of glue per thousand square feet by 9.3 to find the pounds of glue per thousand square feet.
Example: 3 mils spread, 9 lb. glue equals 17 lbs. per thousand square feet. 3 mils spread of a 9.3 pound glue equals $1.9 \times 9.3 = 17.67$ lbs.

Coverage by Actual Glue Used

Several methods are available to measure the coverage obtained from a given amount of adhesive.

With a roller spreader (Figure 4) the following method is convenient. Suppose the height of glue in a full straight sided five gallon pail is twelve inches. Then one gallon is represented by 2.4 inches $\frac{(12'')}{(5\text{-gal.})}$ or one inch equals .416 gallons $\frac{(5.0)}{(12)}$. Fill the spreader (roll stopped) to a marked level on the spreader. Note the level in the pail at this "O" time (after spreader has been filled). After the desired period of time, again fill the spreader to the marked level. The change in level of the glue in the pail represents the glue used in that time. Suppose that the level of the pail dropped five inches below that at "O" time. Five inches is 2.08 gallons (0.416 x 5"). Now measure the glued area. A convenient approximation is to count the number of glue lines in fifteen panels at random. Divide the total number of counted glue lines by fifteen (the fifteen panels counted) to get the average glue lines per panel. Count the total panels glued. Multiply the average number of glue lines per panel by the length of the panel in inches being glued and also by the panel thickness (as glued) in inches. This gives the glue line area in square inches. Divide by 144 to convert the area into square feet. Divide the square footage by the glue used to get the consumption in gallons per square foot.

Since a bobtail spreader (Figure 5) can be run until completely dry, the glue used can be calculated as follows: Measure as before the number of inches per gallon. Use the full container as the height at "O" time. Run the desired pieces through, making sure the spreader runs dry at the conclusion of the run. The glue used can be estimated by the difference in container level between the beginning and end of the run. On edge glued stock, mileage is figured as before. On face or plywood, the number of panels x the glue line area x the number of glue lines per panel yields the total area covered. Dividing by 144 converts the area into square feet.

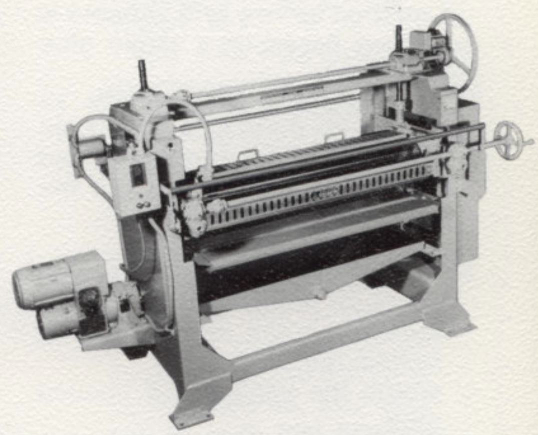


Figure 5: Bobtail spreader. (Photo courtesy of Black Brothers Company, Inc., Mendota, Ill.)

On 5-ply plywood coverage in sq. ft. per gal. =

$$\frac{\textbf{Number of panels} \times \textbf{glue lines per panel} \times \textbf{panel area in sq. inches}}{\textbf{Gallons used} \times \textbf{144}}$$

If the number of panels equal twenty, glue lines per panel equal four, panel area in square inches equal 1,728 square inches (48 x 36). Gallons used is 4.8.

$$\textbf{Coverage} = \frac{20 \times 4 \times 1728}{4.8 \times 144} = \textbf{200 square feet per gallon}$$

Square foot coverage per gallon can be converted into pounds per thousand square feet as follows:

$$\frac{\textbf{1,000} \times \textbf{weight per gallon of adhesive}}{\textbf{square foot coverage per gallon}} = \textbf{pounds per thousand square feet}$$

$$\frac{\textbf{Average glue lines per panel} \times \textbf{number of panels} \times \textbf{panel length in inches} \times \textbf{panel thickness in inches}}{\textbf{144} \times \textbf{gallons used}}$$

= Sq. ft. coverage per gal.

CALCULATION OF VOLUME: (Assuming uniform diameter of container)

$$\frac{\pi r^2 \times \text{HEIGHT}}{231^*} = \text{GALLONS}$$

In a 55-gallon drum, if **r** = 11⅛ inches (inside diameter = 22¼ inches) inside height of ahesive = 32.675.

$$\textbf{Volume in gallons} = \frac{3.1416 \times (11\tfrac{1}{8})^2 \times 32.675}{231^*} = \textbf{55 gallons}$$

$$\textbf{Volume in gallons} = \frac{3.1416 \times (5.5)^2 \times 12.15}{231^*} = \textbf{5 gallons}$$

*1 gallon = 231 cubic inches.

Adhesive Cost

The cost of the glue can be calculated from the glue spread and the price of a gallon of adhesive.

$$\text{Cost in cents per square foot} = \frac{\text{Glue cost per gallon in cents}}{\text{Spread (square feet per gallon)}}$$

For example: With a spread of 200 square feet per gallon and glue priced at $4.00 per gallon, the charge for the adhesive is 2.0¢ per square foot. Cost $= \frac{400}{200} =$ 2.0¢ per square foot.

Grooving of Spreader Rolls

For indicated spread rates on rigid stock, use the following composite grooving: (Figure 6)

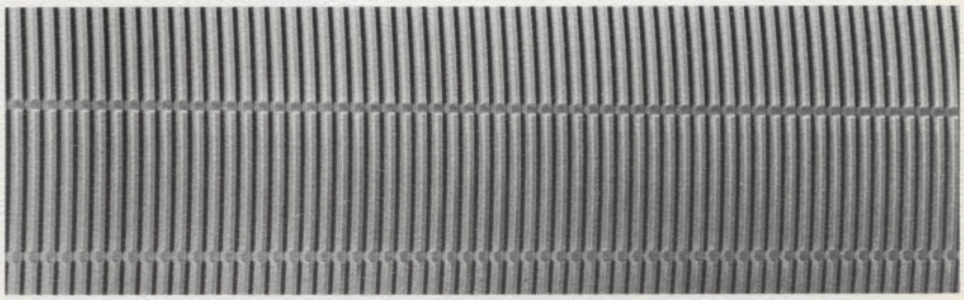


Figure 6: Composite grooving. (Photo courtesy of Black Brothers Company, Inc., Mendota, Ill.)

#/MSGL*	GROOVING	GROOVING NUMBER
20-30	20 x ½"	A-2172
25-35	18 x ½"	A-2050
30-40	16 x ½"	A-2158
35-45	14 x ½"	A-2137
40-50	12 x ½"	A-2178
45-60	10 x ½"	A-2130
55-70	8 x ½"	A-2118

For indicated spread rates on flexible stock, use the following buttress grooving.

#/MSGL*	GROOVING	GROOVING NUMBER
20-35	22	A-2038
25-40	20	A-2070
30-45	18	A-2071
35-50	16	A-2074

These figures are courtesy of the Black Brothers Company, Inc. of Mendota, Illinois.
Grooves should be kept clean. Glue is transferred from the grooves, not flat roll surfaces.
*Pounds per thousand square feet of glue line.

Felts for Spreader Rolls

Seamless wool felt sleeves (Figure 7) on roller spreaders provide for greater glue mileage and better coverage of adhesive on face or edge glued stock. The use of felts will allow the average operator to obtain only a bead squeeze-out on the clamped panel and yet spread the joint surfaces rapidly without skips.

Felts are specified by width of roll face times the circumference. 12" x 28" means a felt 12" wide by 28" in circumference. Circumference in inches = 3.1416 x diameter in inches. 28¼ inches in circumference = 3.1416 x 9" diameter.

A felt will shrink up to 20% when soaked in hot water. A 25" felt will shrink to about 20" circumference.

DIRECTIONS FOR USE: The dry felt should be slipped over the roller and carefully positioned. Submerging the felt in hot water will shrink it tightly on the roller.

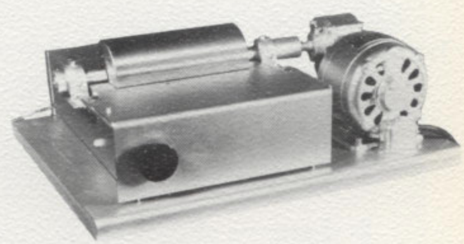


Figure 4: Roller spreader. (Photo courtesy of Black Brothers Company, Inc., Mendota, Ill.)

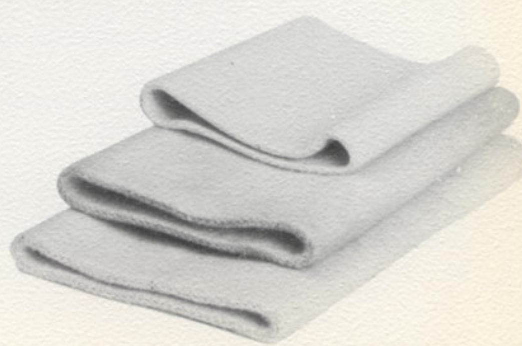


Figure 7: Wool felt sleeves for roller spreaders.

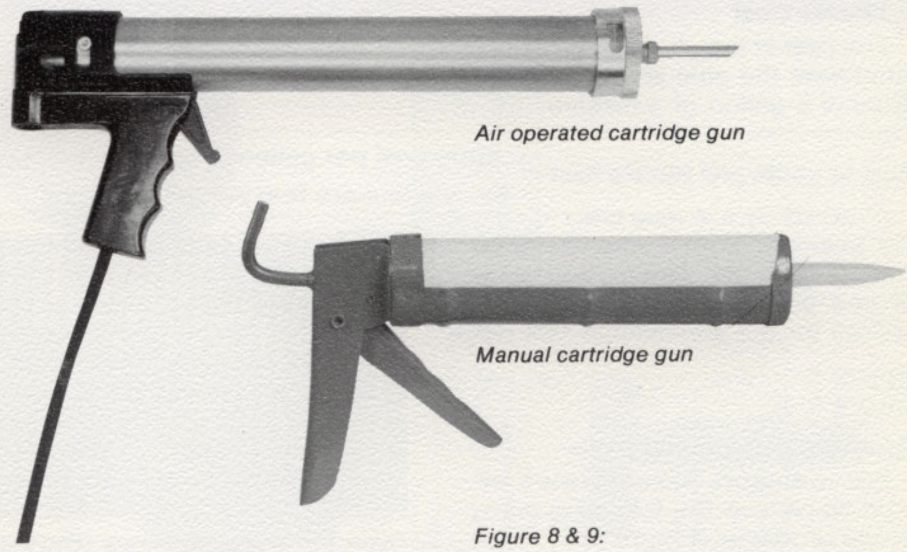
Extruded Bead Coverage

The coverage of adhesive when extruded either from a cartridge (Figures 8 & 9 manual and air operated cartridge guns) or pumped from bulk is related to the bead size.

Some common geometries are shown for beads applied to 4′ x 8′ panels when these are to be laminated to a flat surface with calculated coverage indicated.

Reference:

1 U.S. Gallon = 128 fluid ounces
1 U.S. Quart = 32 fluid ounces
1 "quart" size cartridge = 29 fluid ounces
1 "tenth-gallon" cartridge = 11 fluid ounces



Air operated cartridge gun

Manual cartridge gun

Figure 8 & 9:

TABLE OF VOLUME TO EXTRUDED BEAD LENGTH VS BEAD SIZE

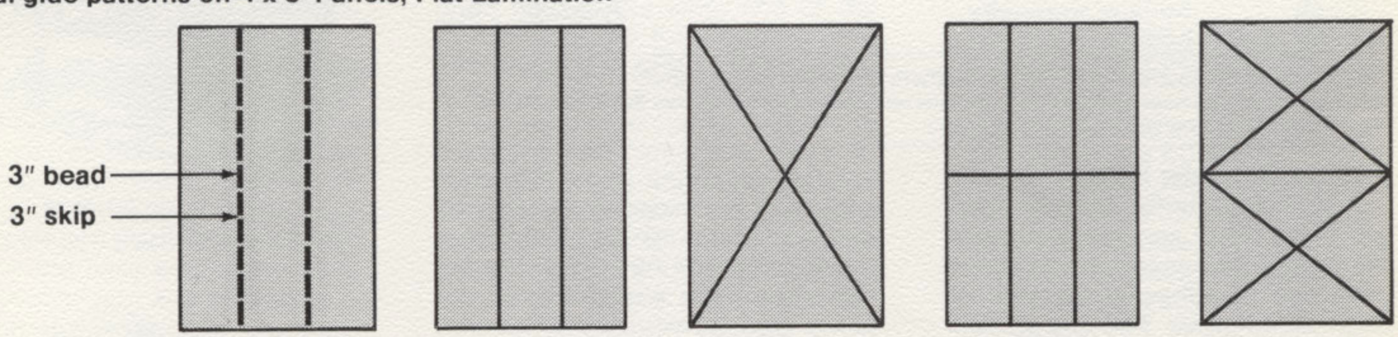
	Bead Size in Inches Diameter				
VOLUME	⅛′	3/16′	¼′	5/16′	⅜′
11-ounce cartridge	135′	60′	34′	21½′	15′
31-ounce cartridge	380′	169′	95′	61′	42′
1 gallon	1,569′	697′	392′	251′	174′
5-gallon pail	7,845′	3,485′	1,960′	1,255′	870′
52-gallon drum	81,588′	36,244′	20,384′	13,052′	9,048′

lineal feet of extruded adhesive (length)

In round figures, 1,000 feet of adhesive bead will require:

⅔ gallon at ⅛-inch diameter bead
2½ gallons at ¼-inch diameter bead
5¾ gallons at ⅜-inch diameter bead

Typical glue patterns on 4 x 8′ Panels, Flat Lamination



Bead Length in feet	**32′**	**40′**	**42′**	**44′**	**50½′**
(Each of the above patterns include a perimeter bead plus interior beads as indicated)					
⅛″ bead	2.6	3.3	3.4	3.6	4.1
¼″ bead	10.5	13.1	13.7	14.4	16.5
⅜″ bead	23.5	29.4	30.9	32.3	37.1

Pressing the Glue Joint

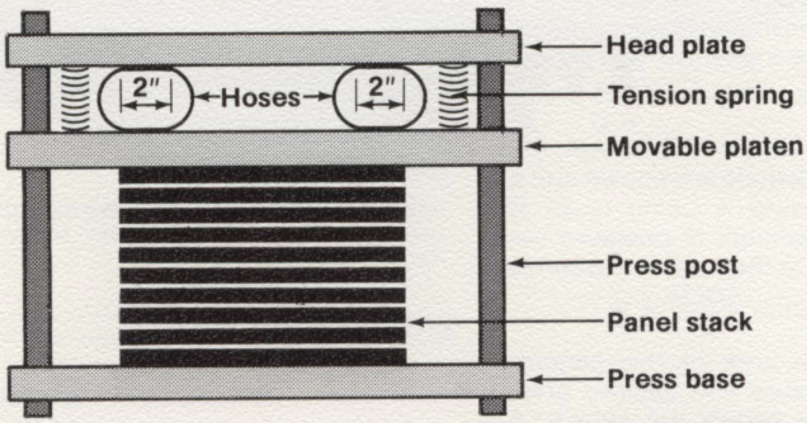
The thinnest glue line (as long as the adhesive is not completely squeezed out of the joint) is the strongest one. The important purpose of pressure is to bring the glue joint tightly together uniformly over the glue area. The pressure period is the time necessary to hold the joint in position until the bond is strong enough to keep the panel in the pressed position. It can be readily seen that pressure will depend on:

1) Wood species. High density woods will require more pressure to straighten them than weaker species. Excessive pressure with low density woods will crush the wood, weakening the joint.
2) Dimensions of wood parts. A board 3" wide by 4/4" thick will require more force to straighten it for edge gluing than for face gluing. This, in turn, would require more force than face gluing 1/28" veneer. Also 8/4 lumber will require more pressure than 4/4.
3) Deflection required to bring joint tightly together. In edge gluing a bow of 1/32" will require more pressure than a 1/64" bow to bring the pieces together snugly. Bowed pieces may result in excessive pressure at the initial contact points.
4) Glue viscosity is influenced by temperature, so that excessive pressure will cause too much glue to be squeezed out of the joint with radio frequency or steam press gluing.
5) Rigidity of the substrate. Excessive pressure on veneers or hardboard will encourage telegraphing of the substrate to be visible on the faces. Generally pressures of 100-300 p.s.i. on edge and face gluing and 25-100 p.s.i. on ply lamination are desirable.

Pressure Calculations for Air Hose or Bag Press

Air hose or bag presses may use one or more hoses that are inflated by air pressure. The pressure applied to the load will be the sum of the pressures applied to each hose.

The effective pressure area of the hose or bag is the flattened surface of the hose in contact with the moving platen of the press or jig. Well designed air hose presses will have an indicator showing the point at which maximum or rated pressure is obtained. The following sketch will roughly indicate the pressure system using air hoses:



The sketch shows a two hose press with movable platen and spring return.

The flattened area of each hose is two inches, so the pressure applied to the load will be 2 × 2 × the length of the hose × air pressure. Example:

The panel stack = 14" × 28"
The hose length = 40"
Air pressure = 80 pounds per square inch
B = pressure on the panels
C = 2 × 2 × 40 = 160 square inches = area of hoses
D = Gauge pressure = 80 p.s.i.
A = Panel area = 14 × 28 = 392

$$\frac{C \times D}{A} = B$$

$$\frac{160 \times 80}{392} = \frac{12800}{392} = 32.6 \text{ p.s.i.} = B$$

The above conditions will give a pressure of 32.6 pounds per square inch on the panels.

When the load is higher than the illustration, the hoses will be flatter and the same gauge pressure will produce greater panel pressure. When the load is not as high as shown, the hoses will be rounder with less flattened area, so the applied pressure will be lower. For this reason, some indication of the position of the movable platen must be known, to permit accurate pressure calculations.

Pressure Calculations for Hydraulic Presses (Figure 10)

- A = Area of panel in square inches (NOT the platen area)
- B = Desired pressure in pounds per square inch
- C = Area of hydraulic piston (or pistons)
- D = Gauge pressure

When the area of the panels, the area of the pistons and the desired pressure are known, D will be the gauge pressure needed. $\frac{A \times B}{C} = D$

When the area of the panels, the area of the pistons are known and a gauge pressure is being used, B will be the amount of pressure being applied to the panels in pounds per square inch. $\frac{C \times D}{A} = B$

When the area of the pistons, gauge pressure and desired pressure on the panels are known, A will be the maximum area that will give this pressure. $\frac{C \times D}{B} = A$

The area of the piston may be calculated as follows: B = diameter of the pistons in inches, squared x 0.7854. When more than one piston is involved, calculate the area of each piston and add them together. The total area in square inches can then be substituted for C in the above formulas.

Example: Hydraulic press has three pistons. Two pistons, 10 inches in diameter, one piston 12 inches in diameter.

10 × 10 × 0.7854 (one piston) × 2 = 157.08 square inches
12 × 12 × 0.7854 = 113.0976 square inches
Total area C = 270.1776 square inches (round off to 270.2)
Area of panels to be glued — 28″ × 45″ = 1,260 square inches = A
Desired pressure on panels, 125 pounds per square inch = B
Gauge pressure needed = pounds per square inch = D

$$D = \frac{A \times B}{C} = \frac{1260 \times 125}{270.2} = 582.9 \text{ p.s.i.} = D$$

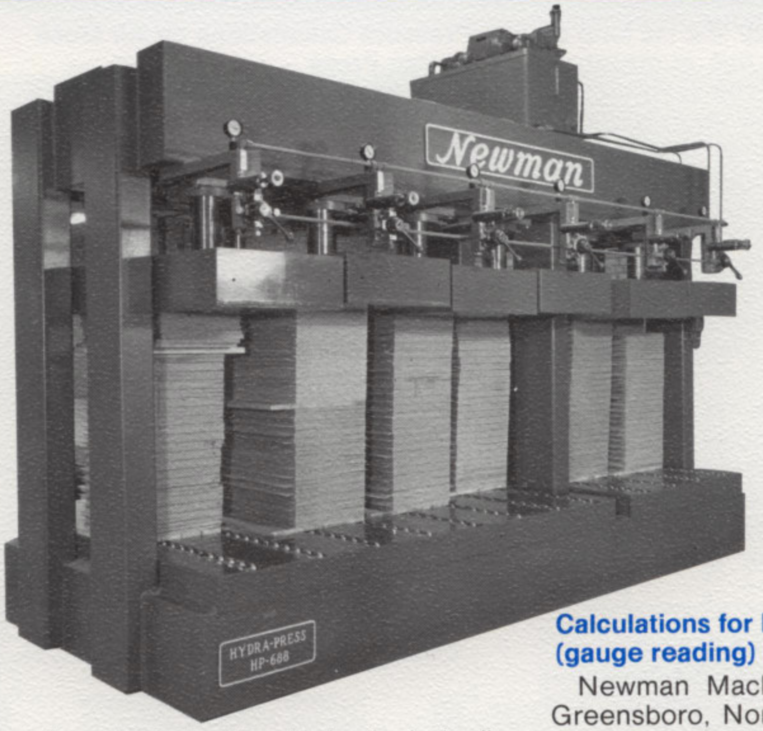


Figure 10: A 6-section side loading hydraulic press. (Photo courtesy of Newman Machine Co., Greensboro, N.C.)

Calculations for Line Pressure (gauge reading)

Newman Machine Company in Greensboro, North Carolina gives the following directions: It will be necessary to know the total square inches of gluing area, and the glue manufacturer's recommendations concerning gluing pressure in pounds per square inch. This information, inserted in the following formula, will give the reading that should show on the gauge when the top platen is exerting full pressure on the load.

Square inches of area in contact with glue × Manufacturer's recommended gluing pressure in pounds per square inch
———————————————— = gauge reading
50 × number of 8″ diameter cylinders on one top platen
or
28 × of 6″ diameter cylinders on one top platen

To obtain the square inches of area in contact with glue in hollow panels use only the sum total of the areas of the individual pieces of the frame. Example: If a hollow panel 12″ wide by 24″ long has a 2″ wide frame on all four sides it should be considered that there is the equivalent of two strips 2″ wide x 24″ long and two strips 2″ wide x 8″ long making up the frame. Total area in contact with glue, therefore, is 2 x 2 x 24 + 2 x 2 x 8 totaling 128 square inches.

Pressure Calculations for Air Pod Press

A number of pressing devices have been made using "air suspension" type rubber bags normally designed for use in heavy trucks etc. They have flat circular ends and accordion pleated sides. When they are filled with compressed air, they provide pressure similar to that shown for "air hose presses". The "air pods" are located between the head plate and the movable platen of the press and have the advantage over air hoses in that the spacing between the head plate and movable platen is not critical. The "air pod" retains the same pressure area, regardless of its degree of inflation.

Calculation of pressure is the same as that for hydraulic cylinder presses. The area of the circular end times the air pressure gives the total pounds of pressure generated by each "pod". (See calculations for hydraulic presses). Example:

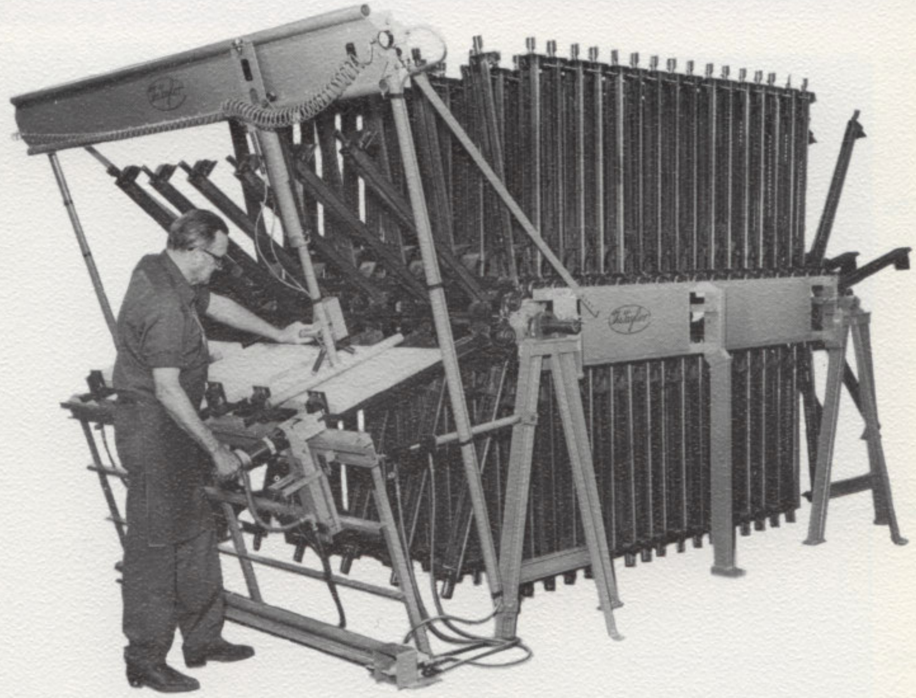


Figure 11: Air wrenches on a clamp carrier.

Air press having 4-8" diameter pods. Air pressure 60 psi. Panel aea 150 square inches.

$8 \times 8 \times .7854 \times 4 \times 60 =$ total pressure, 12063 pounds.

$\frac{12063}{150} =$ 80 psi. on the panel.

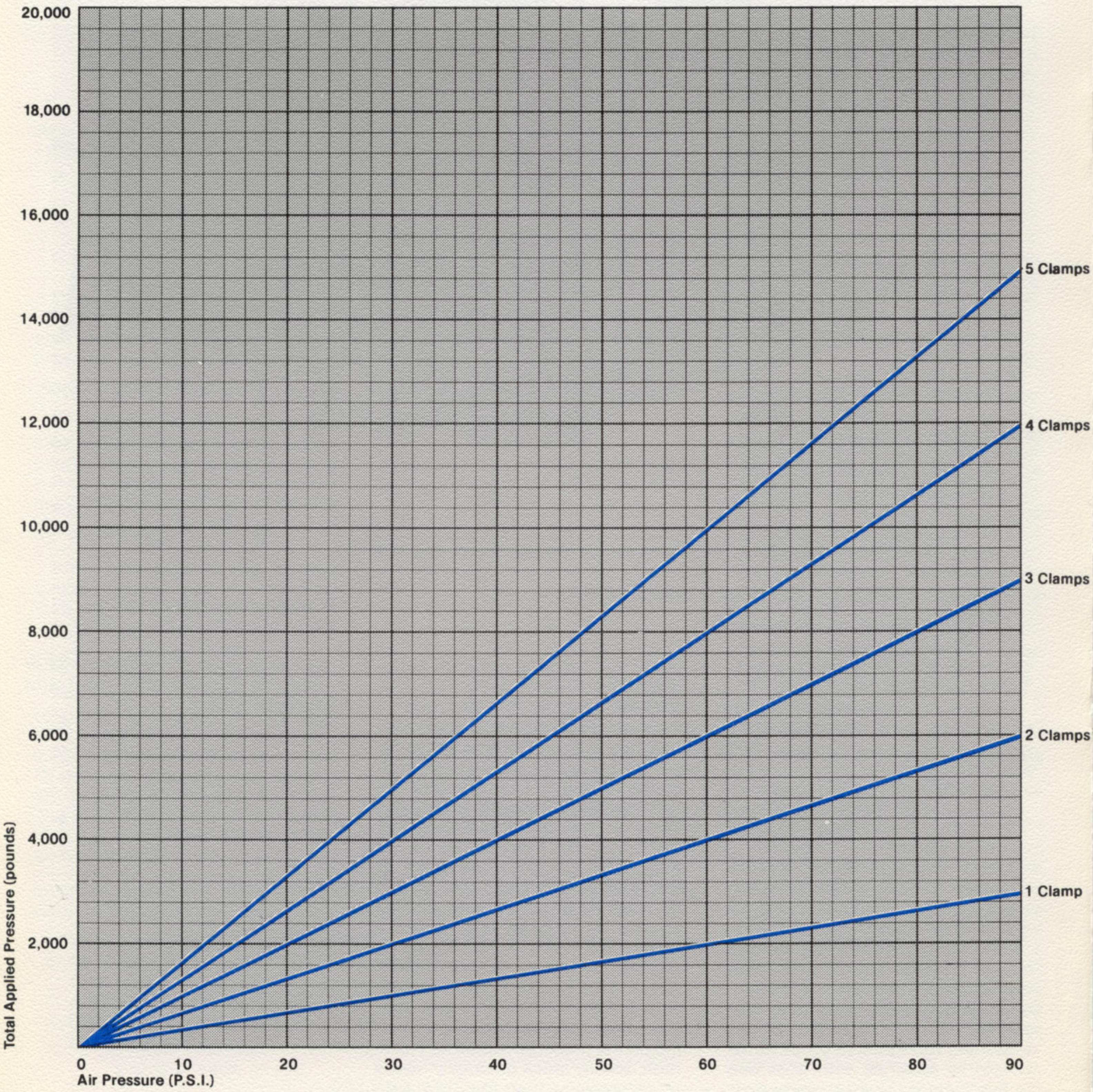
Use of Air Wrenches with James L. Taylor Clamp Carriers (Figure 11)

Uniform clamping pressures can be applied with the use of air wrenches on clamp carriers. Two wrench models are being supplied:

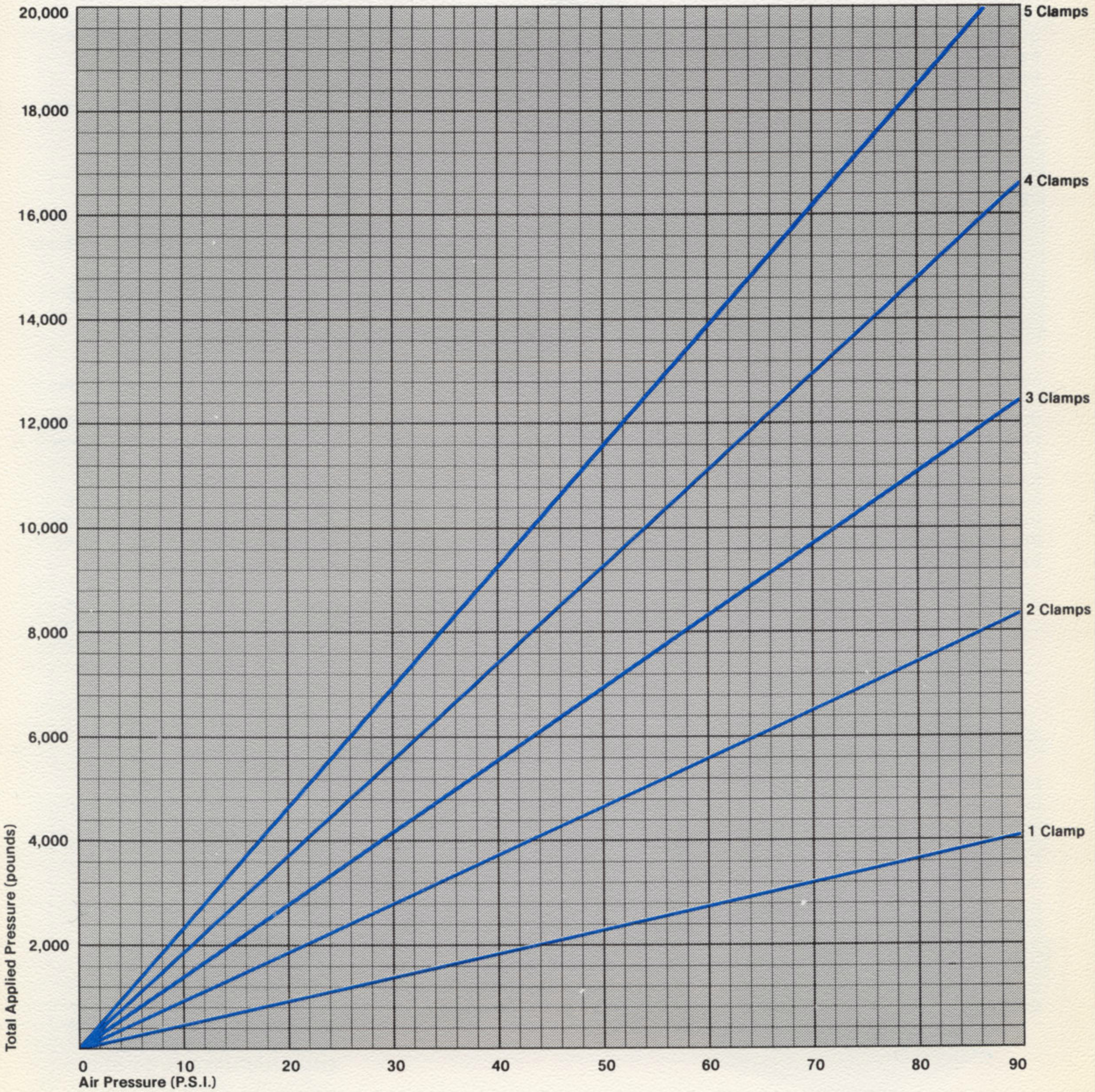
Model 3840-P provides approximately 3,000 pounds pressure per clamp, at a maximum air pressure of 90 p.s.i.

Model 3840-Q provides approximately 3,000 pounds pressure per clamp, at a maximum air pressure of 65 p.s.i.

The clamp threads must be kept free of dry glue and other foreign matter and they should be frequently lubricated to reduce wear and friction resistance. The graphs attached for each wrench show pressures obtained with from one to five clamps. The air pressure is shown at the top and bottom of the graph and the total pressure at the right and left margins. TO USE THE GRAPH: multiply the thickness of the stock to be glued by the length of the piece (glue line area) x the desired pounds per square inch gluing pressure. This will give the total pressure required. Find this value on the right or left margin of the graph and read across to the number of clamps being used, or the number of clamps that should be used. As a general rule, clamps should be located two or three inches from each end of the panel and about ten to twelve inches apart. The width of the boards, straightness of the joints and density of the species will have a bearing on the pressure required. Thick, high density stock obviously needs more pressure than thin, low density materials. Actual pressures can be checked by a compressometer inserted between the front and back clamp jaws.



TAYLOR CLAMP CARRIER WITH AIR WRENCH #3840-P



TAYLOR CLAMP CARRIER WITH AIR WRENCH #3840-Q

Compressometer

Many glue line failures of stock glued on clamp carriers can be traced to thick glue lines. They are frequently the result of inadequate pressure being applied.

Sometimes this is caused by too few clamps being used to provide the pressure needed and in other cases the "operator" is not applying sufficient force.

The use of air operated torque wrenches helps to minimize the "operator error", but worn or dirty threads and insufficient air pressure can prevent the desired clamping pressure from reaching the load.

An inexpensive device for measuring applied pressure can be made from a 2" diameter, 1" stroke, double acting hydraulic cylinder. A pressure gauge of approximately 1500 pounds capacity is suitable for measuring the pressure applied by clamp carrier clamps. The illustrated device can be used to check the actual pressure being applied by each clamp.

The drawing shows the parts needed for the Compressometer.

The pressure cylinder is a WABCO MF2-PH having a 2" bore and a 1" stroke.

The gauge is a HELICOID 430L, 0-1500 lb. range.

The hydraulic fluid is SAE #20 Motor Oil.

To assemble the unit, using the parts listed above; remove the plastic plugs from either end of the cylinder. Pull the stem out as far as it will go, then push it in about ⅛". Elevate the base end of the cylinder about 1" and add the motor oil through the hole near the base. When the oil has completely filled the base end of the cylinder, move the piston back and forth slightly to make certain all air bubbles have escaped.

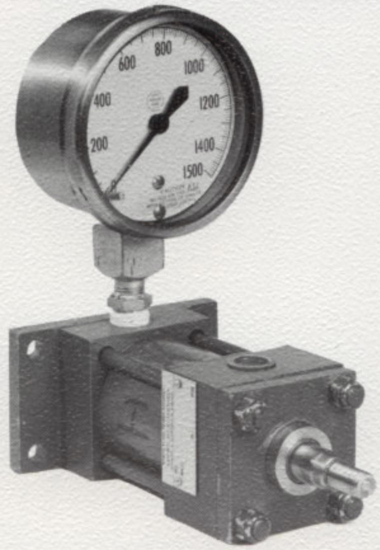
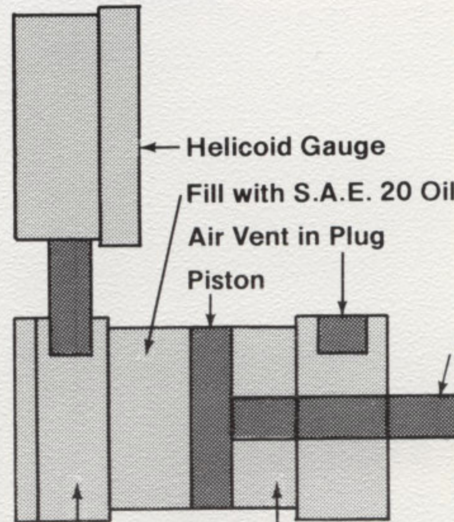


Figure 12: Compressometer.



With the cylinder in a horizontal position, push in the stem approximately ¼" to ⅜" and thread in the gauge. (The oil level should be filling the base end cylinder hole when the gauge is tightened, so air bubbles will not be trapped in the system). The gauge should be facing the stem end of the cylinder when properly tightened in place.

Make a couple of small holes in one of the plastic plugs, to act as an air vent and screw the plug into the open hole at the stem end of the cylinder. To use the Compressometer, place it in one of the clamps, with the stem in contact with the screw end of the clamp, then move the adjustable part of the clamp so it catches in a notch near the base end of the cylinder. It is generally desirable to place metal plates between the base and the back jaw of the clamp, as well as between the stem of the cylinder and the screw part of the clamp. This is particularly true when checking high jaw clamps, so there will be no chance of force being applied to the case of the gauge by the back jaw.

Tighten the screw of the clamp in a normal manner, either by hand or with a torque wrench. The gauge reading multiplied by 3.1416 (Pi) will give the TOTAL FORCE in pounds being applied by the clamp. As an example, a gauge reading of 1,000 would be 3,141.6 lbs.

The parts used in the Compressometer should be generally available from distributors of air and/or hydraulic equipment components. The main office address for each component is listed:

CYLINDER: Wabco Power Master Cylinder MF2-PH with 2" bore and 1" stroke.
WABCO Fluid Power Div.
Lexington, Ky. 40505

GAUGE: Helicoid 430L, 0-1500 psi. 304 SS, Type S case, 3½" dial, ¼" bottom connection.
HELICOID Gauge Division,
935 Connecticut Ave.
Bridgeport, Ct. 06602

(Approximate prices in Jan. 1978: Gauge $56.00, Cylinder $87.30)

Attached is a graph to assist in determining the number of clamps and pressure required for different constructions and species. TO USE THE GRAPH: follow the example.

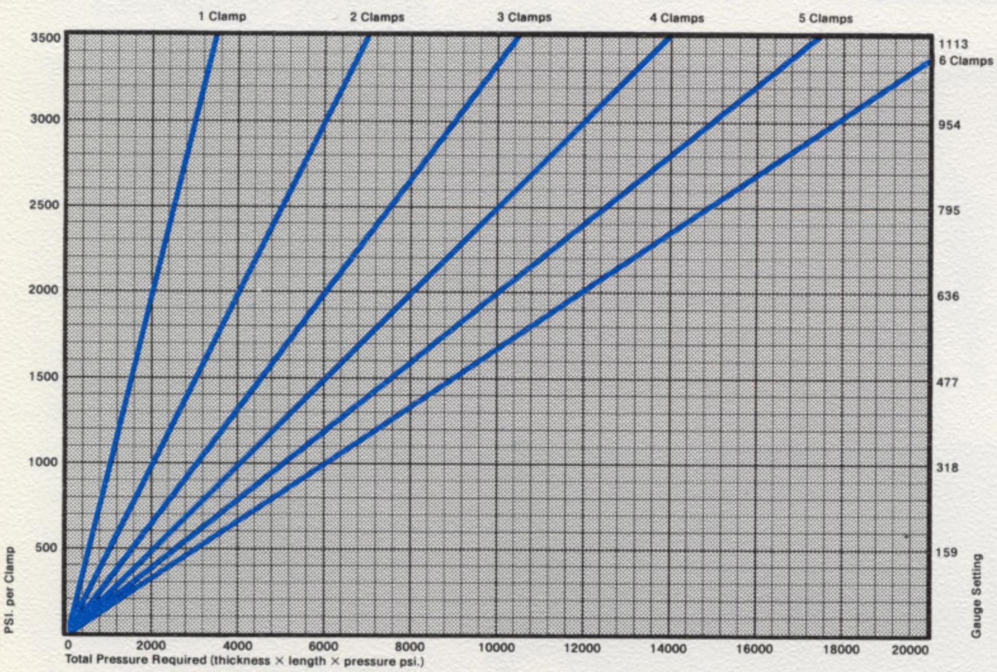
EXAMPLE:
Edge gluing soft maple top, ¼" × 40".
(Soft maple is considered a medium density species).
Desired pressure 150 pounds per square inch.

TOTAL PRESSURE = Thickness × Length × Pressure
6000 = ¼" (1) × 40 × 150

Clamps should be located approximately 1"-2" from ends of the panel with a 12" to 14" spacing between clamps. For this construction, 4 clamps would be indicated.

Along the bottom edge of the graph, find GOOD TOTAL PRESSURE. Read up to the 4 clamp diagonal line. Read to the left margin which shows 1500 pounds per clamp is needed. The right margin will show a gauge reading of 477 which will give this amount of pressure.

Good gluing practice dictates, when edge gluing random width stock, the wider boards should be located next to the jaws of the clamp, to properly distribute the pressure between clamps.



PRESSURE CHART TO BE USED WITH 2" DIA. CYLINDER COMPRESSOMETER

SUGGESTED PRESSURE RANGES FOR VARIOUS WOOD DENSITIES
Low: 100-150
Medium: 125-175
High: 175-250

N.B. The Compressometer and graph can also be used in reverse. Read the gauge pressure normally being applied to a given clamp. Find this value in the right margin of the graph. Read across to the number of clamps diagonal line. Drop down to the bottom edge of the graph and divide the **TOTAL PRESSURE** value by the area of the glue line (**thickness × length**). The resulting answer is the pressure being used, in pounds per square inch. The suggested pressure ranges shown are approximate, based on straight, well prepared glue lines.

COMPRESSOMETER USING 2" DIAMETER PISTON

Gauge Reading	Total	Gauge	Total
100	314.15	800	2513.27
150	471.23	850	2670.35
200	628.31	900	2827.43
250	785.39	950	2984.51
300	942.47	1000	3141.59
350	1099.55	1100	3455.76
400	1256.63	1150	3612.84
450	1413.71	1200	3769.92
500	1570.79	1250	3927.00
550	1727.87	1300	4084.08
600	i884.95	1350	4241.16
650	2042.03	1400	4398.24
700	2199.11	1450	4555.32
750	2356.19	1500	4712.40

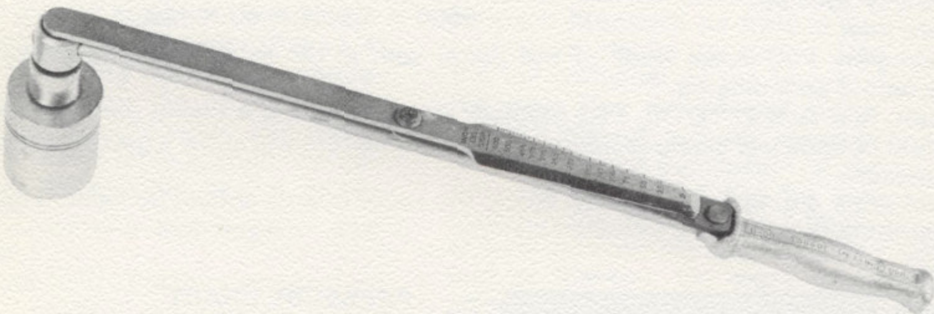


Figure 13: Hand torque wrench.

Torque Wrench

This is a device (Figure 13) for measuring applied pressure in inch pounds or foot pounds. It is used for comparing pressures being applied by screw type pressing apparatus such as clamp carrier clamps etc. In combination with the Compressometer, pressures can be calculated, and the proper "torque" applied by the carrier operator.

Ammeter

Some presses have been made that obtain their force from an electric motor connected to a gear train that turns two or more screws designed to bring clamping surfaces together. The more force applied, the higher current or amperage the motor will draw. This amperage reading can be converted to pounds of pressure.

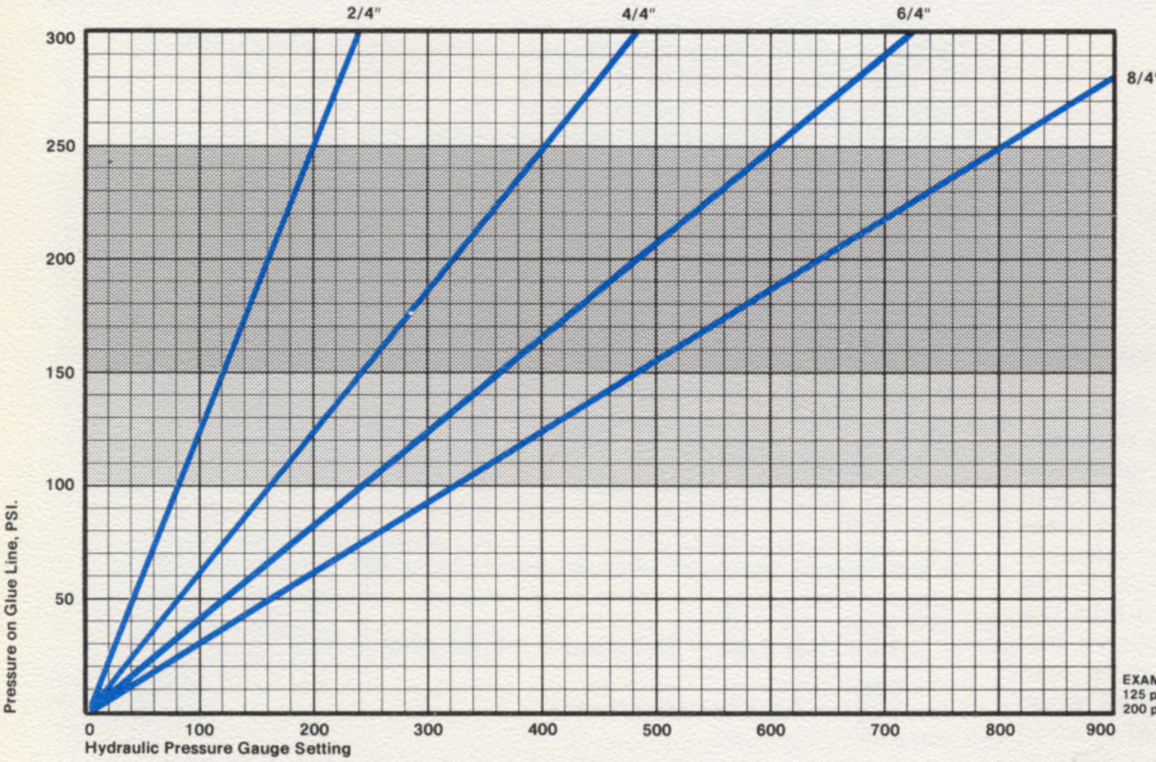
Figure 14: L&L radio frequency gluer. (Photo courtesy of L&L Machinery, North Wilkesboro, N.C.)

Pressure Guide for L and L Radio Frequency Edge Gluing

(Figure 14)

The attached pressure charts cover a number of pressure ranges and thicknesses for various density woods for two models of L & L gluers. Suggested pressure ranges are shaded for representative species. The lowest pressure for a given species group is usually best and should be used wherever possible. With high density species, the glue line pressure should not be greater than 250 p.s.i. If the stock is bowed, twisted, etc. so it will not pull up with that amount of pressure, then the stock should not be glued. The stresses "locked in" can cause grief at a later date with open glue lines or splits in the wood. The examples should be self-explanatory.

Choose the line representing the thickness of the material being glued, find the desired glue line pressure at the left margin and read the gauge pressure on the lower margin, below the point where the glue line pressure and the stock thickness intersect.



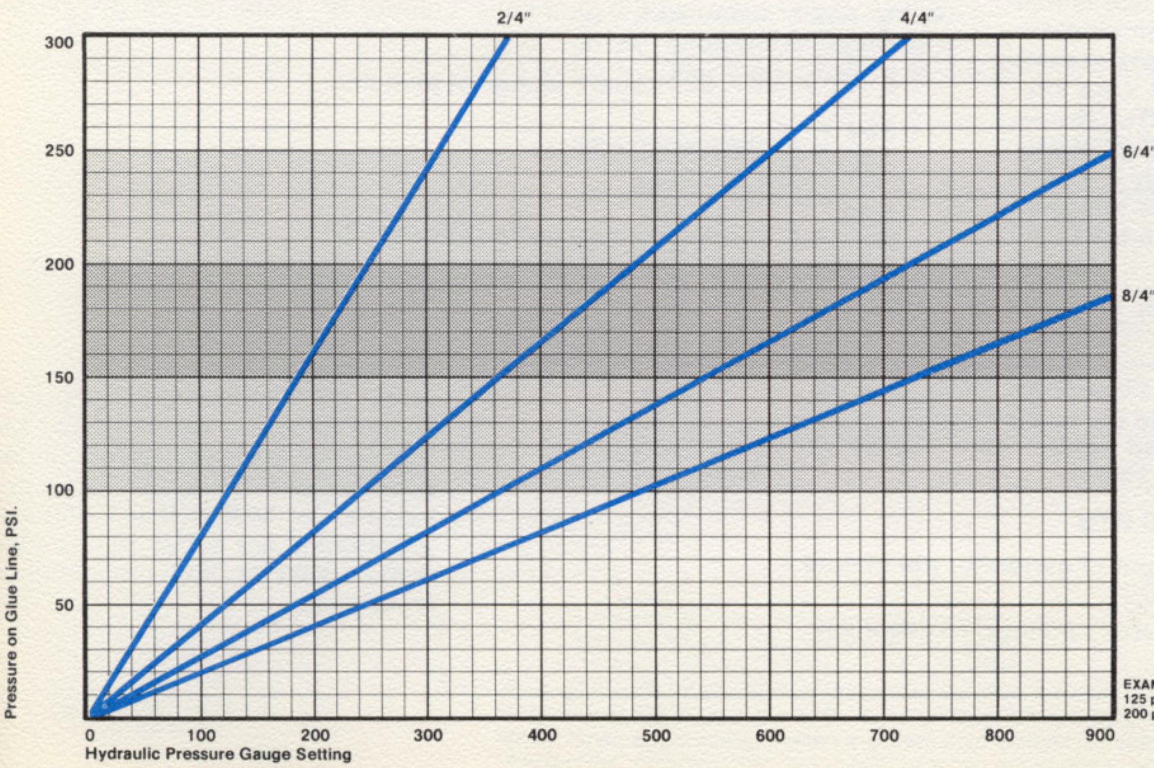
HIGH DENSITY
Birch, Beech,
Oak, Pecan,
Sugar Maple

MEDIUM DENSITY
Gum, Tupelo,
Soft Maple,
Cherry

LOW DENSITY
Poplar, White Pine
Spruce, Basswood

EXAMPLES:
125 psi. on 4/4" White Pine lumber = 200 Gauge Pressure
200 psi. on 6/4" Oak lumber = 485 Gauge Pressure

PRESSURE GUIDE L&L MACHINE CO.— Radio Frequency Edge Gluer— STANDARD GLU-ALL (4½" thickness capacity)



HIGH DENSITY
Birch, Beech,
Oak, Pecan,
Sugar Maple

MEDIUM DENSITY
Gum, Tupelo,
Soft Maple,
Cherry

LOW DENSITY
Poplar, White Pine
Spruce, Basswood

EXAMPLES:
125 psi. on 4/4" White Pine lumber = 300 Gauge Pressure
200 psi. on 6/4" Oak lumber = 720 Gauge Pressure

PRESSSURE GUIDE L&L MACHINE CO.— Radio Frequency Edge Gluer— GLU-ALL II (2" thickness capacity)

Press Time

Calculations for Radio Frequency Gluing

FLAT PANEL OR MOLDED PLYWOOD GLUING: All the materials being glued (wood and glue) are pressed with the glue lines parallel to the electrodes. The entire mass of wood and glue must be raised in temperature, usually to 200°F. The factors needed to calculate the curing cycle, for an adhesive that would normally cure at room temperature are: The weight of wood and glue; the specific heat of wood and glue; the required temperature rise and the output power of the radio frequency generator in kilowatts. The temperature rise is that needed to elevate the temperature of the load from room temperature to approximately 200°F. One kilowatt minute equals 56 BTU (British thermal unit). Wood and glue specific heat is approximately 0.45. Wt. of wood and glue x 0.45 x temperature rise, = BTU required. $\frac{\text{BTU}}{56}$ = kilowatt minutes needed to reach temp. Example:

Wood and glue weight 20 pounds.
Temperature of wood and glue 70°F.
Temperature rise required 200 − 70 = 130°F.
R.F. Generator output 15 Kw.

20 × 0.45 × 130 = 1170 BTU

15 × 56 = 840 BTU output of generator per minute

$$\frac{1170}{840} = 1.39 \text{ minutes cure (1 minute, 24 seconds)}$$

NOTE: With this type of gluing, after the heat has been turned off, pressure should be maintained for approximately 25% of the heating cycle. This will reduce the tendency for steam blister "blows" due to possible high moisture content areas in the panel. In the case of curved plywood, it allows the curve to take a "set" with reduced "springback" caused by the thermoplasticity of the hot moist wood.

Edge Gluing

The materials being glued are pressed with the glue lines perpendicular to the electrodes. It is theoretically possible to reduce this to a formula, but generally "rules of thumb" are better suited and easier to use. This method of radio frequency depends upon the "selective" heating of the glue lines as they are more conductive than wood of 6-8% moisture content.

Rule 1. For high density species—100 square inches per kilowatt per minute.

Rule 2. For low density species, 125 square inches per kilowatt per minute generator output.

Examples:

Hard maple panel with 12 glue lines. Lumber 6/4", panel length 40", generator output, 5 kilowatts.

12 × 1.5 × 40 = 720 square inches of glue line.

$$\frac{720}{100} = 7.2 \text{ kilowatt minutes}$$

$$\frac{7.2}{5} = 1.44 \text{ minutes cure cycle (1 minute, 26 seconds)}$$

Yellow poplar panel with 9 glue lines. Lumber 4/4", panel length 36", generator output 5 kilowatts.

9 × 1 × 36 = 324 square inches of glue line.

$$\frac{324}{125} = 2.59 \text{ kilowatt minutes}$$

$$\frac{2.59}{5} = 0.51 \text{ minutes cure cycle (31 seconds)}$$

Hot Pressing

The following table is only presented to give a starting point for trial on the particular system under consideration. This table was developed for MULTIBOND and the press times are somewhat shorter than needed for urea, resorcinol or melamines.

SUGGESTED HOT PRESS CYCLES
USING LUMBER OR PARTICLE BOARD CORE
PLATEN TEMPERATURE °F.

Distance To Deepest Glue Line	160	180	200	220	240	250
1/32"	1'40"	1'25"	1'10"	55"	50"	40"
1/16"	1'50"	1'35"	1'25"	1'10"	1'05"	1'
3/32"	2'30"	2'05"	1'50"	1'35"	1'25"	1'20"
1/8"	3'20"	2'50"	2'25"	2'05"	1'55"	1'45"
5/32"	4'	3'25"	3'	2'35"	2'25"	2'15"
3/16"	4'40"	4'	3'35"	3'10"	2'55"	2'40"
7/32"	5'25"	4'45"	4'15"	3'50"	3'35"	3'20"
1/4"	6'25"	5'30"	5'10"	4'40"	4'20"	4'

(For all veneer constructions the above time cycles may be reduced by 25%)
NOTE: Temperatures above 200°F. are not recommended for high pressure laminates by their manufacturers.
Only experience will define the minimum press time suitable.

Wood Moisture Content

Wood moisture content is accurately determined by oven dry weight.

$$\frac{\text{Green weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100 = \%\ \text{moisture content}$$

With green wood the moisture content of the wood can exceed 100%.

Conversion Charts

CONVERSION CHART OF THICKNESSES USED IN THE WOODWORKING INDUSTRY:

Fractions		Inch	Millimeters
1/64		.0156	.3967
1/32—2/64		.0313	.7938
	1/28	.0357	.9070
	1/24	.04166	1.0582
3/64		.0469	1.1902
	1/20	.0500	1.2700
	1/18	.0555	1.4110
1/16—2/32—4/64		.0625	1.5875
5/64		.0781	1.9837
	1/12	.08333	2.1165
	1/11	.0909	2.3088
3/32—6/64		.09375	2.3884
	1/10	.1000	2.540
7/64		.1093	2.7772
	1/9	.1110	2.8194
1/8—2/16—4/32—8/64		.1250	3.175
9/64		.1406	3.5706
5/32—10/64		.15625	3.9674

Fractions	Inch	Millimeters
1/6	.1666	4.2316
11/64	.1719	4.3641
3/16—6/32—12/64	.1875	4.7608
1/5	.2000	5.0800
13/64	.2031	5.1576
7/32—14/64	.21875	5.5543
15/64	.23437	5.9511
1/4—2/8—4/16—8/32—16/64	.2500	6.3478
17/64	.26562	6.7445
9/32—18/64	.28125	7.1413
19/64	.29687	7.5380
5/16—10/32—20/64	.3125	7.9348
21/64	.3281	8.3315
11/32—22/64	.34375	8.7282
23/64	.3593	9.1250
3/8—6/16—12/32—24/64	.3750	9.5217
25/64	.3906	9.9185
13/32—26/64	.40625	10.3152
27/64	.4218	10.7119
7/16—14/32—28/64	.4375	11.1087
29/64	.4531	11.5054
15/32—30/64	.46875	11.9022
31/64	.4843	12.2989
1/2—2/4—4/8—8/16—16/32—32/64	.5000	12.6957
33/64	.5156	13.0924
17/32—34/64	.53125	13.4891
35/64	.5469	13.8859
9/16—18/32—36/64	.5625	14.2826
37/64	.5731	14.6794
19/32—38/64	.59375	15.0761
39/64	.6093	15.4728
5/8—10/16—20/32—40/64	.625	15.8696
41/64	.6406	16.2663
21/32—42/64	.6563	16.6630
43/64	.6718	17.0598
11/16—22/32—44/64	.6875	17.4565
45/64	.7031	17.8533
23/32—46/64	.7188	18.2500
47/64	.7343	18.6468
3/4—6/8—12/16—24/32—48/64	.7500	19.0435
49/64	.7656	19.4402
25/32—50/64	.7813	19.8370
51/64	.7968	20.2337
13/16—26/32—52/64	.8125	20.6305
53/64	.8281	21.0272
27/32—54/64	.84375	21.4239
55/64	.8593	21.8207
7/8—14/16—28/32—56/64	.8750	22.2174
57/64	.8906	22.6142
29/32—58/64	.90625	23.0109
59/64	.9218	23.4076
15/16—30/32—60/64	.9375	23.8044
61/64	.9531	24.2011
31/32—62/64	.96875	24.5978
63/64	.9843	24.9946

CONVERSION FACTORS

U.S. System	Metric
LENGTH	
0.3937 inches	1 centimeter
39.37 inches or 3.280833 feet	1 meter
1 inch	2.54001 centimeters
1 foot	0.304801 meter
1 yard	0.914402 meter
AREA	
0.154999 square inches	1 square centimeter
10.76390 square feet	1 square meter
1 square inch	6.452 square centimeters
1 square foot	0.09290 square meter
1 square yard	0.8361 square meter
VOLUME	
0.0610 cubic inches	1 cubic centimeter
35.315 cubic feet	1 cubic meter
1.05671 quart or 0.264178 gallon	1 liter
1 cubic inch	16.387 cubic centimeters
1 cubic foot	0.02832 cubic meter
1 pint	0.473167 liter
1 quart	0.946333 liter
1 gallon	3.785332 liter
1 gallon	231 cu. in.

1 gallon (U.S.) of water at 15°C. (59°F.) weighs about 8.337 pounds or 3.782 kilograms.

U.S. System	Metric
WEIGHT	
0.00220462 pounds or 0.0352739 ounces	1 gram
2.2046 pounds or 35.273957 ounces	1 kilogram
1 ounce	28.349527 grams
1 pound	453.5924 grams or 0.4535924 kilogram
DENSITY	
0.03613 pounds per cubic inch	1 gram per cubic centimeter
1 pound per cubic foot	0.016018 grams per cubic centimeter or 16.018 kilograms per cubic meter
PRESSURE	
14.696 pounds per square inch (Normal atmosphere)	1033.2 grams per square centimeter
14.223 pounds per square inch	1 kilogram per square centimeter
1 pound per square foot	0.48824 grams per square centimeter or 4.8824 kilograms per square meter
1 pound per square inch	0.070307 kilograms per square centimeter or 703.07 kilograms per square meter

p.s.i. × 0.070307 = kg/cm²

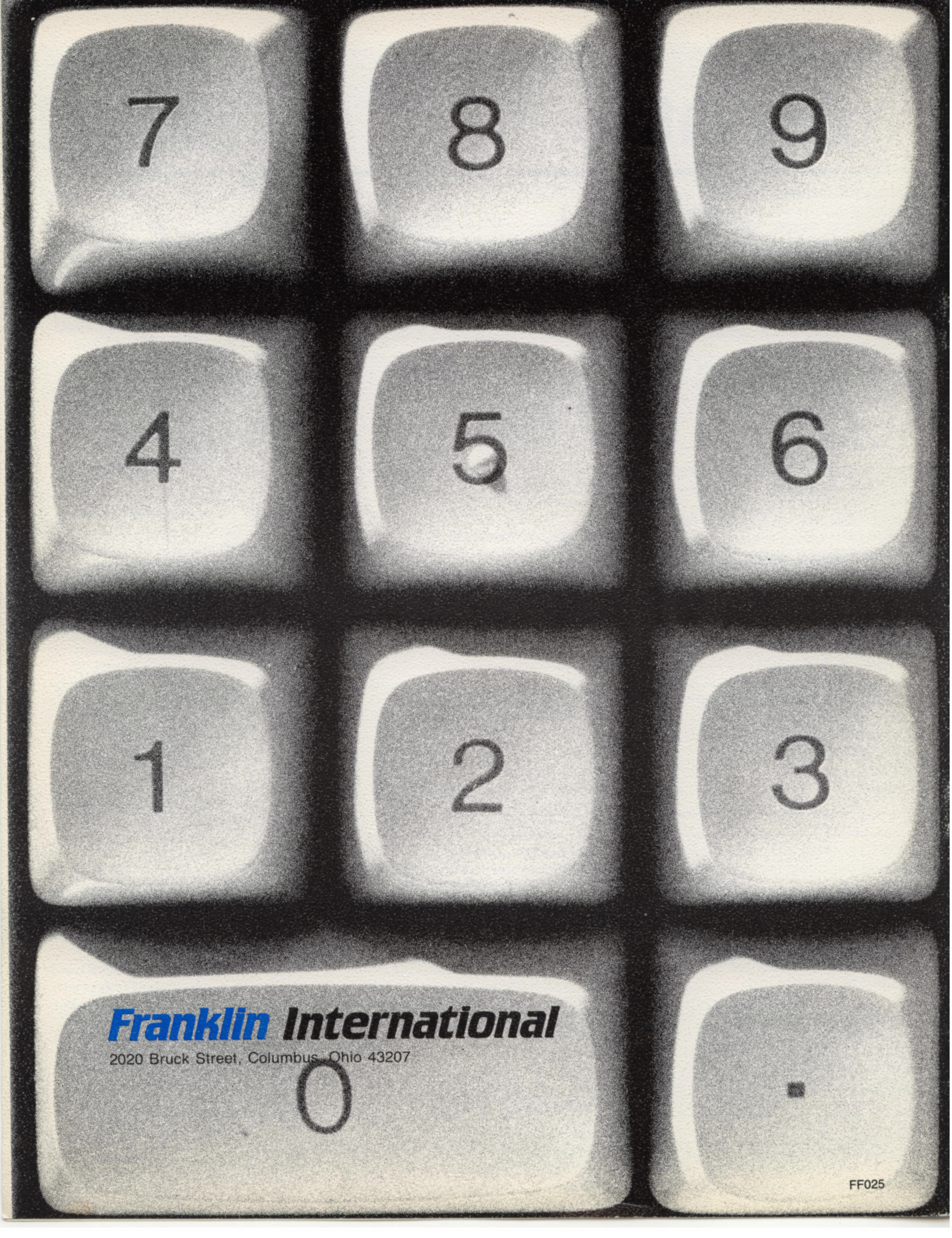
Kg/cm² × 14.223 = p.s.i.

CONVERSION OF TEMPERATURE

Temperature °C. to °F.	Temperature °C. × 1.8 + 32 = °F.
Temperature °F. to °C.	Temperature °F. − 32 ÷ 1.8 = °C.

1 B.T.U. is the amount of heat required to raise 1 lb. of water 1°F.

1 Kilowatt minute equals 56 B.T.U.'s per minute.


Franklin International
2020 Bruck Street, Columbus, Ohio 43207
FF025