

1974

Sandwich Panel Construction

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Sandwich Panel Construction

Abstract

It was the purpose of this study to investigate and report on sandwich construction. Included within this study is

(1) the history of sandwich construction; (2) the reason for the development of sandwich construction; (3) the flexibility and versatility of this type of construction; (4) an evaluation of the strengths and weaknesses of various materials fused together; and (5) its probable use in the future. This study concludes with the construction of a shop project.

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SANDWICH PANEL CONSTRUCTION

A Research Paper for Presentation
to the Graduate Committee
of the Department of Industrial Arts
and Technology
University of Northern Iowa

In Partial Fulfillment of the Requirements for
the Non-Thesis Master of Arts Degree

by
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November 11, 1974

Approved by:
Ervin A. Dennis

Graduate Committee, Chairman

Dec. 6, 1974
Date

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CHAPTER I

INTRODUCTION

The writer of this report chose sandwich construction to investigate and report on in order to broaden his knowledge in this area. Numerous articles have been written on this subject expressing an ever increasing use and versatility of this type of construction in many industrial fields. Sandwich construction is not only suitable to stationary structures, it is also applicable to moving vehicles as well. Very little information is written about sandwich construction in school text books. Therefore, it seems advisable to incorporate a unit on sandwich construction into the wood area of a school shop.

I. THE PROBLEM

Statement of the problem. It was the purpose of this study to investigate and report on sandwich construction. Included within this study is (1) the history of sandwich construction; (2) the reason for the development of sandwich construction; (3) the flexibility and versatility of this type of construction; (4) an evaluation of the strengths and weaknesses of various materials fused together; and (5) its probable use in the future. This study concludes with the construction of a shop project.

Importance of the study. Sandwich construction was introduced to the public prior to World War II in an experimental plane. Today, however, the use of this type of construction has wide-spread application. It is being used in all transportation vehicles, whether they operate on land, in the sea, or in the air. Sandwich construction is used in all areas of construction and home furnishings. This method of construction has steadily increased since the 1940's and is presently recognized as an invaluable method of construction in our products today. All predictions quoted by leaders in the sandwich construction industry indicate that this method of construction will continue to increase in the future.

Since sandwich construction has gained vast prominence in industry, it is important to understand its implications in industry, its specific qualities which lend themselves well to a specific use, and the advantages and disadvantages of this type of construction.

Limitations of study. This study on sandwich construction is limited to information compiled from references in books and magazine articles from local libraries, from correspondence received from various agencies associated with sandwich construction, and from a visitation to a local industry that employs the method of sandwich construction.

II. DEFINITIONS OF TERMS USED

Sandwich construction. Sandwich construction refers generally to those types of composite construction consisting of two high-strength, thin facings, rigidly attached to either side of a low-density, shear-resistant and relatively thick core material. (Marshall, 1966, p. 586). (See figure 1, p. 3).

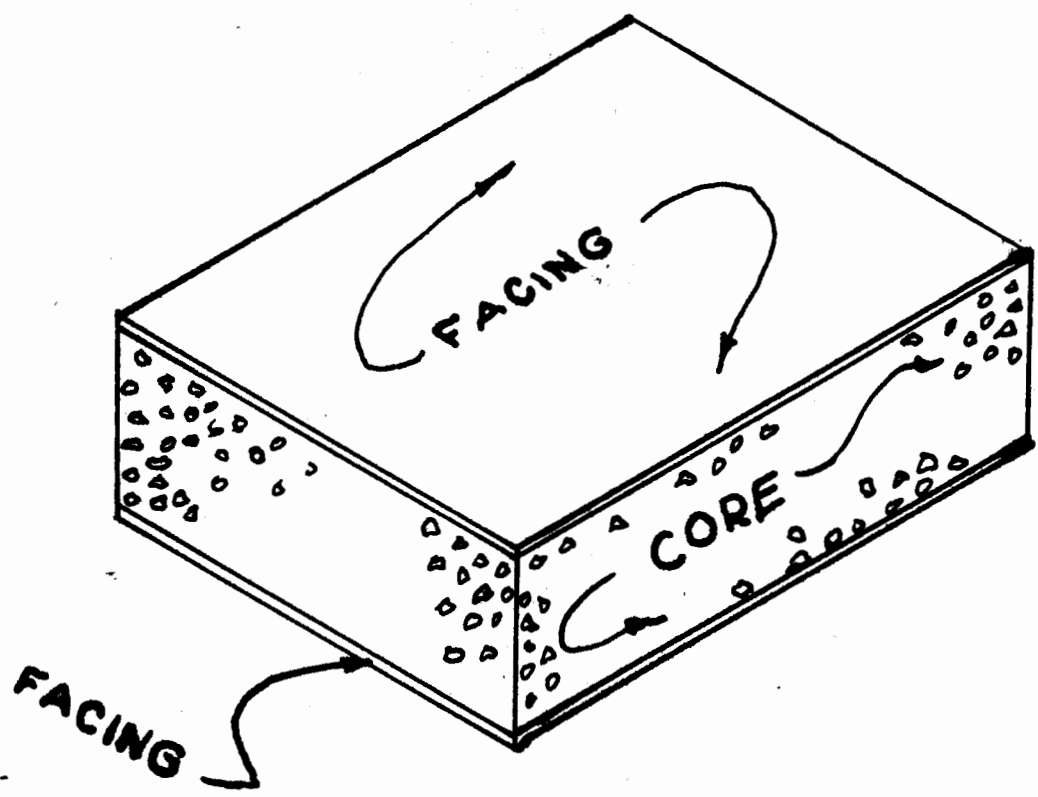


Figure 1
ISOMETRIC BLOCK

Facing. The thin outer member on a sandwich panel which is made of a high density strength material.

Skin. A term used interchangeably with facing, and meaning the same as facing.

Core. A low density, light-weight material located between facings in a sandwich construction panel.

Solid core. A solid, light-weight, low density material used in sandwich construction.

Honeycomb core. A cellulose designed core used in sandwich construction.

Fiberglas. Finely spun filaments of glass made into yarn that is woven into a fabric.

Section-modulus. Moment of resistance; a measure of the comparative strength of beams.

Moments. The tendency to cause rotation about a point or axis; the product of a force, mass, and volume, and its perpendicular distance from its axis.

Bending forces. An applied load which causes a member to bend or deflect.

Low density. A light-weight material.

High density. A heavy, high dense material used for the facing in sandwich construction.

Adhesive. A material that bonds the core and the face together.

Yield strength. Slightly above or beyond the elastic limits is that unit stress at which point the specimen begins to stretch without increasing in the load.

Rigid fiber board. A sheathing manufactured from fibers of wood, cane, or other vegetable matter.

Shear load. The separating and sliding of one part of one member past the adjoining part of the same member, in a direction parallel to their plans of contact. (Marshall, 1966, p. 588).

CHAPTER II

HISTORY

Sandwich construction entered into the industrial field in the early 1940's as an experimental material in the de Havilland Mosquito fighter-bomber. Aircraft designers were searching for a type of construction that was light in weight, and yet contained adequate strength to resist stresses and strains developed during flight. The skin of the sandwich panel was of spruce plywood, while its core contained balsa wood. Sandwich panels were used in the wings and fuselage and in the tail section. This experimental aircraft built with sandwich construction panels proved to be six times lighter in weight than a plane of similar size built of aluminum materials.

During and after World War II extensive theoretical and experimental research proved that weight could be reduced in sandwich construction by using a thin metal face having a higher strength than plywood. Thus in the sandwich skin designated as Metalite by the Chance-Vought Aircraft Corporation, the faces were of aluminum alloy and the core was of balsa. The thickness of the faces was 0.01 to 0.02 inch.

Other metals, such as stainless steel, were also proposed for the faces. However, metals have the disadvantage of being difficult to form, so that complex shapes are quite expensive to manufacture. This drawback can be eliminated if a textile is

used as the face material, since it can be cut and glued to the required shape without difficulty.

The textile used had the trade name Fiberglas. On a weight basis, Fiberglas textile could carry just as much load as aluminum-alloy sheet. (Collier's Encyclopedia, Volume 1, p. 253).

The following years after World War II a plastic ultra-light weight spongy substance entered the industrial market as an excellent core material, namely cellular cellulose acetate, polystyrene, and polyvinyl. Also during this time synthetic glues and glueing techniques were developed which permitted the bonding of materials as different as wood and metal.

Architects, building engineers, and industrial product manufacturers did not introduce structural application of sandwich panels until early in 1950. The basic system for manufacturing structural sandwich structures followed the same procedure as aircraft manufactures employed. (Lewis, 1963, p. 46).

Architects were hesitant in using sandwich construction in their building designs since very little research on plastics in this industry had been done at this time. They were concerned whether sandwich construction could withstand the loading applied upon them. They were also concerned whether the adhesives were of sufficient strength to permanently bond the face and core while heavily stressed. (Lewis, 1963, p. 48).

In recent years a considerable amount of research has been employed in building construction using sandwich practices. Monsanto Chemical Company has an experimental house on exhibit at Disneyland Park, Anaheim, California, called the "Plastic Home of the Future" which was opened to the public in 1957. Periodic inspections of this home for structural weaknesses and material deterioration have provided significant evidence that sandwich construction is a sound method for building.

In the future one can expect that plastics and metals will be combined using the recently developed improved adhesives into a new series of prefabricated sandwich panels that may be used structurally, and that will have high thermal insulation values.

The use of sandwich panels in aircraft will become greater in the future. There is not a plane flying today that is not partially constructed by this method of construction. All of the space ships are also built by this method, and who knows, our future space stations may be built in the same way.

(Collier's Encyclopedia, Volume 1, p. 254).

CHAPTER III

TECHNICAL INFORMATION

There are two different kinds of core materials used in the manufacturing of sandwich panels. The first type of material used is a solid core which is a light, low density material that is in sheet form. A second type of core material used is honey comb which looks much like dividers in an egg crate.

Throughout this report the writer refers only to the solid core type of sandwich panels.

I. USABILITY OF SANDWICH PANELS

Sandwich construction is used in the manufacturing of the following products;

1. Aircraft --- fuselage sections, wings, flooring, doors, rotor blades, and ailerons.
2. Semi-trucks --- floor bed, side walls, and top.
3. Boats and ships --- hulls and interior partitions.
4. Mobile units --- house trailers, travel trailers, campers, and motor homes; used for side walls, flooring and roofing.
5. Buildings --- bearing walls, roof panels, interior and exterior partition walls, curtain walls, flush doors, beam girders, and toilet partitions.
6. Commercial desks and furniture.

II. ADVANTAGES OF SANDWICH CONSTRUCTION

The many advantages of sandwich construction explain why manufacturers today are using this type of construction more and more. Some of the advantages of this type of construction are listed below;

1. High strength-to-weight ratio
2. Resistance to heat transfer and vibration
3. Use of nearly any structural materials.
4. High speed production
5. Ease of fabrication
6. Electromagnetic shielding
7. Noise suppressing quality.

III. FACING MATERIAL

The facing material is a thin, high strength panel which is fused to the core material with an adhesive designed for a specific purpose.

The high density facing of a sandwich panel corresponds to the flanges of an I-beam. The object being to place a high-density, high-strength material as far from the neutral axis as possible to increase the section modulus without adding much weight. When a sandwich panel is loaded like a beam, the facing resists the moments due to bending forces. (Marshall, 1966, p. 586). (See figures 2 and 3, p. 11).

Forces acting on flange and facing of sandwich panel are similar. They both resist the moments due to bending forces.

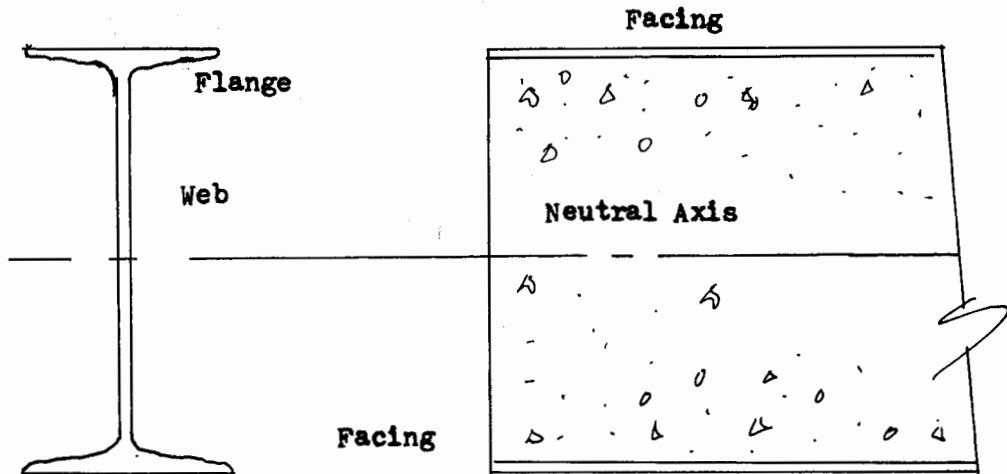
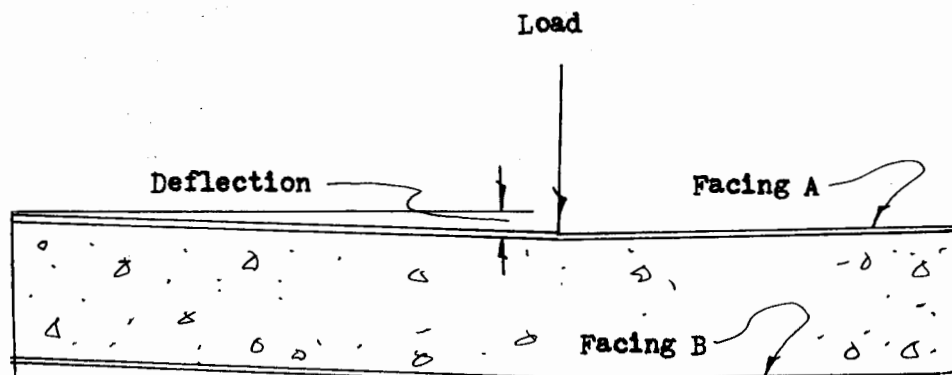


Figure 2

FACING AND I-BEAM RESISTS BENDING MOMENTS



As load is applied, facing "A" goes into compression and facing "B" goes into tension.

Figure 3

BEAM UNDER LOAD

The facing material may consist of many different kinds of high-density, high-strength materials. These facings may be of the same material or a combination of different materials according to the particular job for which they are intended to serve.

Listed below are different materials that can be used for facings:

1. Stainless steel.
2. Aluminum alloy.
3. Mild steel.
4. Porcelain enameled steel.
5. Gypsum board.
6. Plywood.
7. Reinforced plastic laminates.

IV. CORE MATERIALS

The core material in sandwich construction is a low-density, light weight material sandwiched between a thin facing material of high density. The core in a sandwich panel is comparable to the I-beam web which supports the flanges and allows them to act as a unit. The web of the I-beam and the core of the sandwich panel carry the beam stress. The core is different from the I-beam since it maintains a continuous area support for the facing, allowing them to carry stresses up to or above the yield strength without crippling and buckling. (Marshall, 1966, p. 586). (See figure 3. and 4, p. 13).

Both web of I-beam and core in sandwich construction fail
in shear.

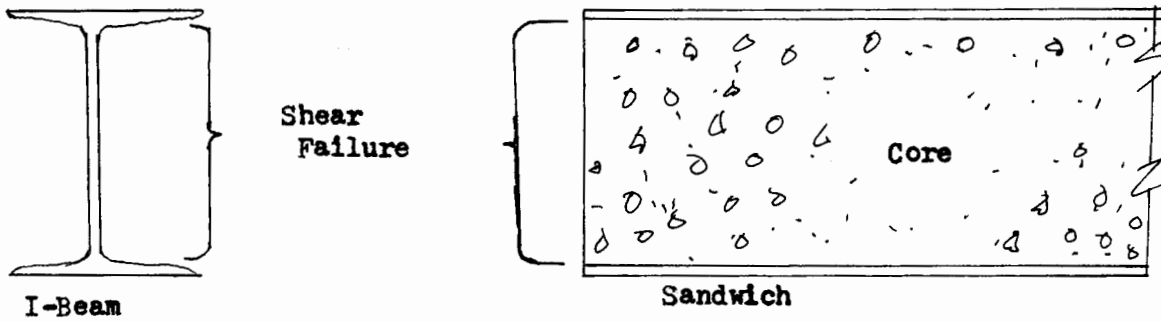


Figure 4

FLANGE AND CORE FAIL IN SHEAR

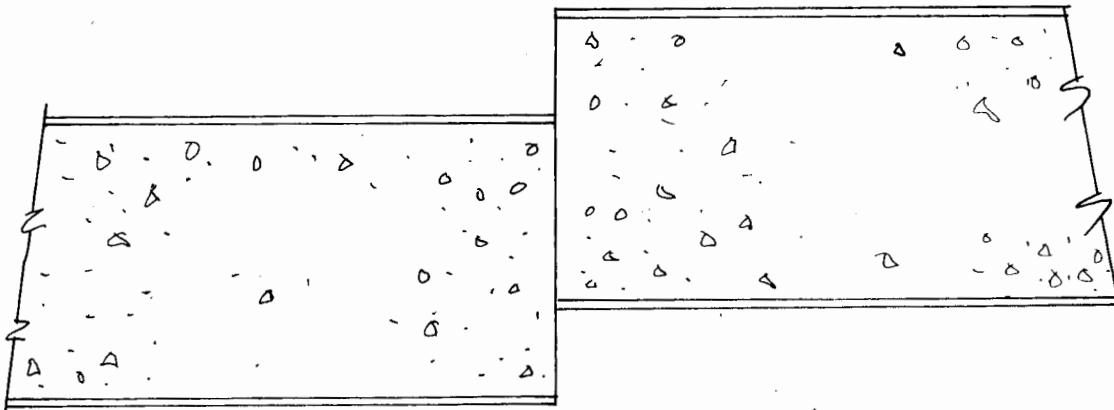


Figure 5

SANDWICH PANEL IN VERTICAL SHEAR

The core may consist of many different materials, each designed for a specific purpose or job. Several different materials that can be used for the core are;

1. Rigid fiber board.
2. Cellular cellulose acetate.
3. Polystyrene.
4. Polyvinly.
5. Expanded urethane foam.

V. ADHESIVE MATERIAL

The adhesive material in sandwich construction is the bonding agent between the facings and the core. The adhesive which bonds the core to the facing must be capable of transmitting shear loads between these components, thus making the entire structure an integral unit. (Marshall, 1966, p. 587).

When a sandwich panel is loaded as a beam, the core and bonding adhesive resist the shear loads while the facings resist the moments due to bending forces, and hence carry the beam bending as tensile and compression loads. When loaded as a column, the facing alone resists the column forces, while the core stabilizes the thin facings to prevent buckling, wrinkling, or crippling. (Marshall, 1966, p. 588). (See figure 6, p. 15).

The function of the adhesive material is to transmit the shear load between the facing and core. The vertical panel facing resists column forces while the core stabilizes the thin facing to prevent buckling and crippling.

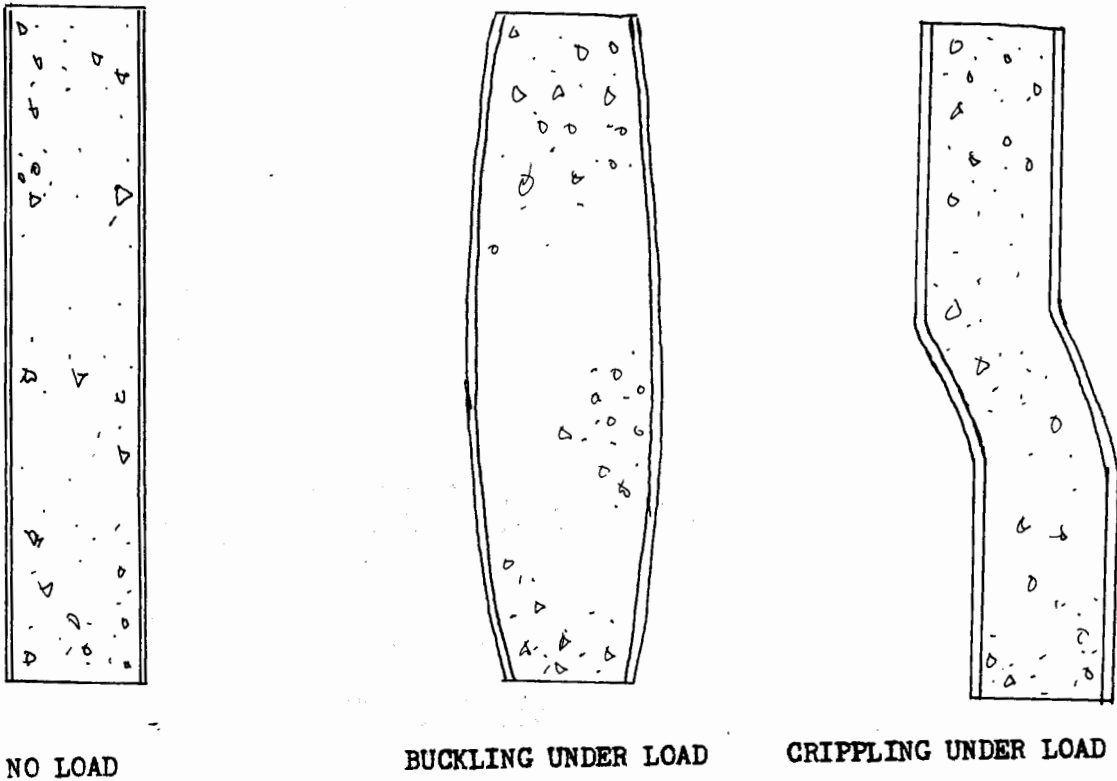


Figure 6

SANDWICH PANELS UNDER VERTICAL LOAD

Listed below are different adhesives which are used in bonding the skin and core together in sandwich construction, and a brief characteristic of each.

1. Epoxy resin. Epoxy resins are a two part adhesive, consisting of resin and a hardener. When mixed together, a chemical action takes place which provides an ideal adhesive material. These can be used to join wood to wood, or to almost any other material. Epoxy resin may be applied with a stick or brush at any temperature. No clamping is necessary, and it will dry faster if heat is applied. Epoxy resin is water proof, oil proof, and non-inflammable.
2. Resorcinol resin. This glue is good for any work that may be exposed to soaking, such as outdoor furniture, boats, etc. It is very strong as well as waterproof. It will work best at 70 degrees or warmer -- it will set faster at 90 degrees. It takes about sixteen hours to dry.
3. Contact cement. Contact cement is a neoprene-based resin, rubber-type adhesive. The adhesive is applied to both surfaces and allowed to dry. Then the surfaces are brought into contact. The bond is immediate so no clamping, nailing, or holding down is required. This makes contact cement particularly useful in applying

plastic laminates such as countertops. It should be applied at a temperature of 70 degrees or warmer.

4. Urea resin. Urea resin is available in either liquid form or as a powder. It is moisture resistant and hold wood surfaces together securely. At room temperature it takes from four to eight hours to set. This setting time may be reduces by increased temperature. Urea resin is often used for gluing plywood which is bonded in hot presses (240-260 degrees) in from three to five minutes. (Wagner, 1967, p. 7-1).
5. Vinyl acetate emulsions. This glue is sometimes used on panels for interior partitions. Generally, it should not be used where water resistance is required.

New adhesive products which will be on the market in the future are;

1. Polyaldehyde.
2. Polycarbonates.
3. Linear olefin polymers.
4. Flame-proof inorganic polymers. (Wagner, 1967, p. 7-1).

THERMAL CONDUCTIVITY

Types of Materials			Starting Temperature	Temperature 10 min. later	Thermal Conductivity
Bass Wood			70	103	33
1/8 " Aluminum Metal			70	111	41
Rigid Fiber Board			70	100	30
Skin	Core	Skin			
Formica	Rigid Fiber Board	Formica	70	94	24
Plywood	Rigid Fiber Board	Plywood	70	90	20
Metal	Rigid Fiber Board	Metal	70	99	29
Formica	Styro-foam	Plywood	70	98	28
Plywood	Styro-foam	Metal	70	99	29

Experiments were made of the thermal conductivity of different kinds of sandwich panels. These test results indicate that there was less thermal conductivity in the sandwich panel which was composed of plywood facings with a rigid fiber board core. Aluminum rated high in the test of thermal conductivity. Wood lumber possessed greater thermal conductivity than the sandwich constructed materials. The writer of this paper conducted these tests to verify the thermal conductivity of different materials which are used in sandwich construction.

Experiment of Thermal Conductivity of different sandwich panels.

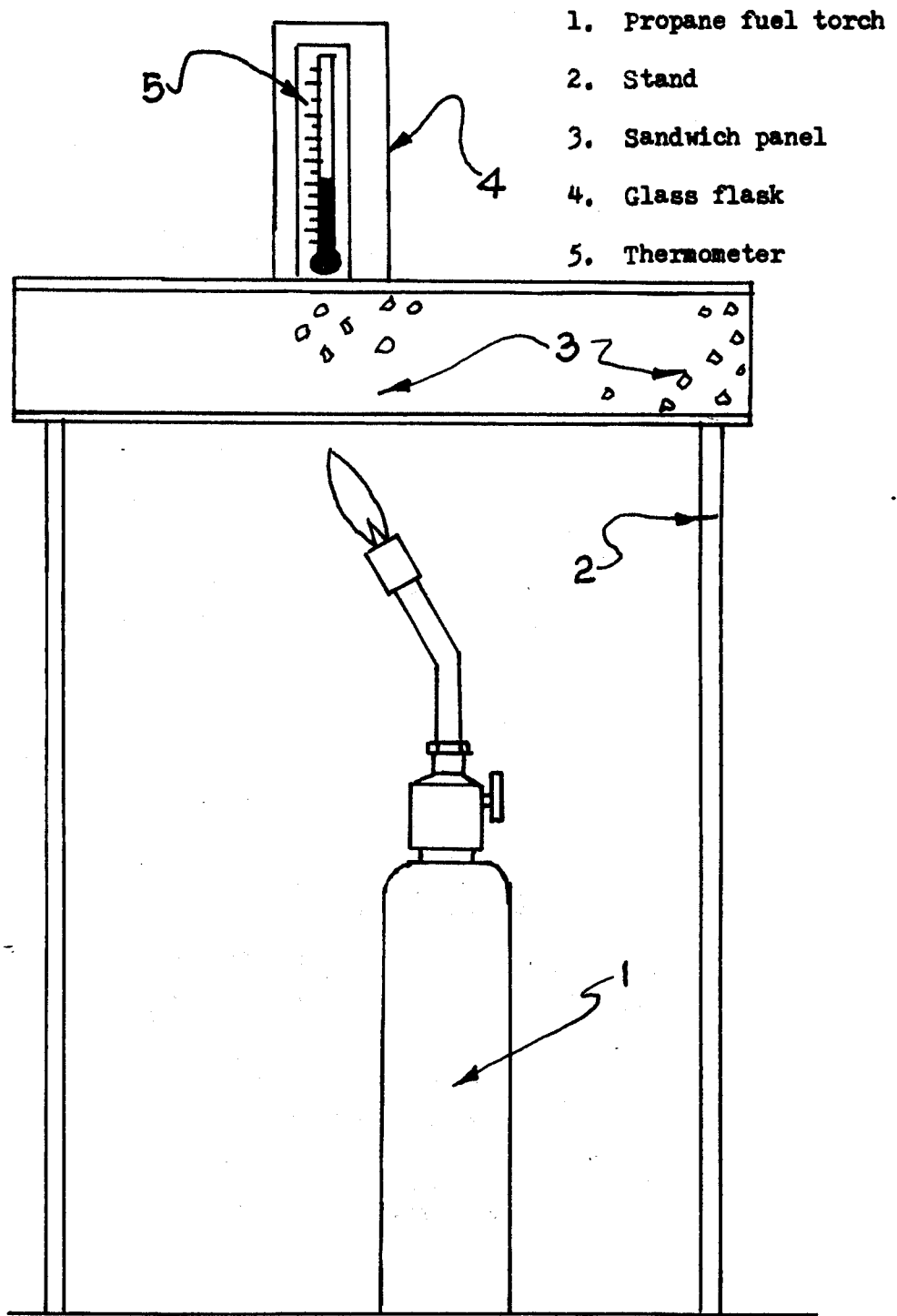


Figure 7

APPARATUS FOR THERMAL CONDUCTIVITY EXPERIMENT

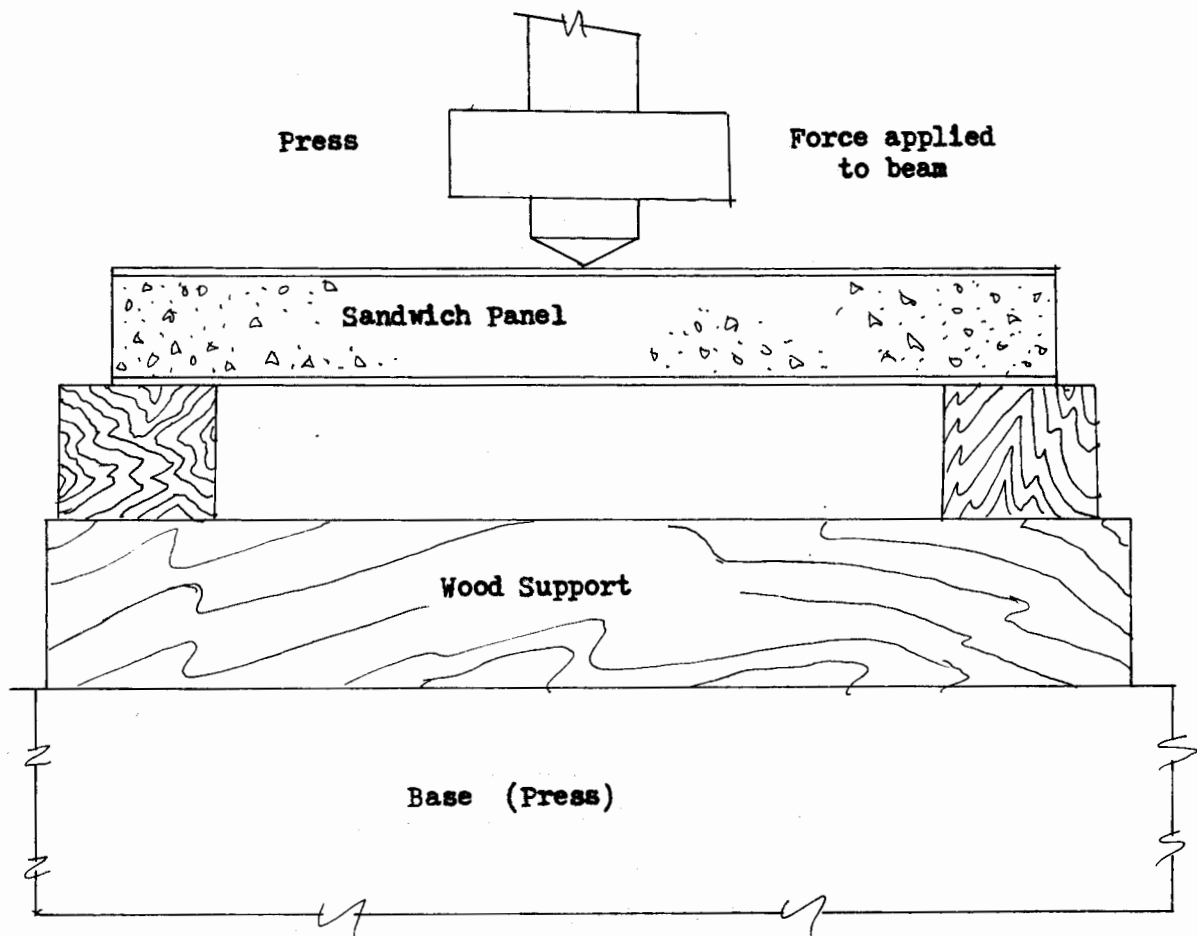


Figure 8

DEVICE FOR TESTING SANDWICH PANEL STRENGTH

The writer of this paper constructed this apparatus so that he could test the strength of sandwich panels. Results of these tests are not presented in this paper since this testing instrument did not prove to be reliable.

CHAPTER IV

RELATED INFORMATION

Sandwich construction is generally considered to be among the fastest growing industries today. The future of this type of construction appears to be good. This is due, in part, to the new and improved adhesives developed from plastics. From this entirely new method of construction and assembly could develop a vast number of new job opportunities which do not presently exist.

I. OCCUPATIONAL INFORMATION

Since there are no exact occupational statistics compiled for the field of sandwich construction, the writer has accumulated job requirements for the many jobs connected with this field. (See figure 8, p. 22).

It is interesting to note that very little advancement can be expected by persons with a limited education. Another thing to notice is that an industrial designer can increase his earnings far exceeding the average wage paid in his profession if he possesses exceptional talent, particularly in the area of creativity.

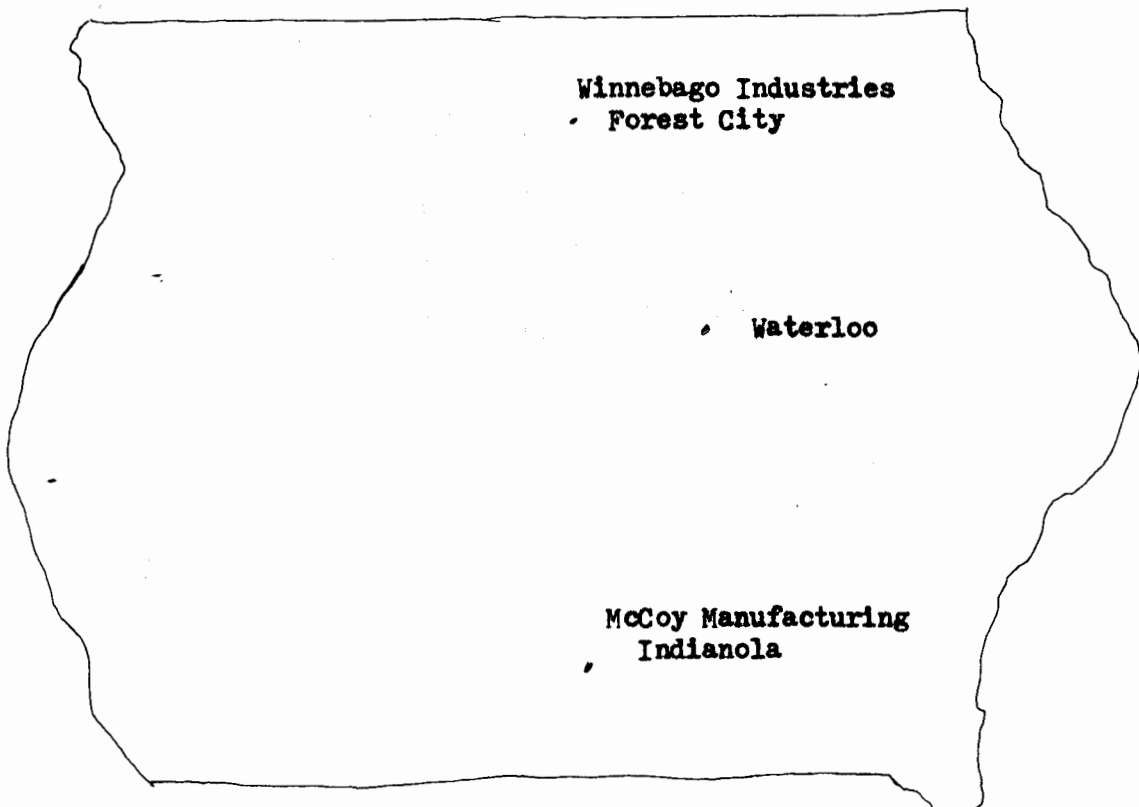
Table II.
OCCUPATIONAL INFORMATION

Occupation	EDUCATION							AGES					WORKING COND.		Employment Outlook	Promotion		
	No formal school.	Apprenticeship	High school	Vocational tech.	Jr. college	B.A. Degree	M.A. Degree	Ph.D. Degree	Semi-skilled HR.	Skilled HR.	B.A. Degree YR.	M.A. Degree YR.	Ph.D. Degree YR.	Exceptional Talent YR.			Working Inside	Working Outside
Carpenters		X	X	X				4.93	7.50					X	X	Good	Aver.	
Assemblers	X		X					2.76	4.69	11,560	13,450	19,090		X	X	Good	Aver.	
Chemists			X			X	X			11,890				X		Good	Good	
Engineers			X			X	X			17,525				X	X	Good	EXCL.	
Industrial Designer			X			X				12,300			23,800	50,000	X		EXCL.	EXCL.
Draftsman		X	X					5.95	13,900					X		Good	Good	
Construction Laborers	X							3.49	5.27					X	X	Good	Good	
Sheet Metal Workers		X	X					4.59	8.95					X	X	Aver.	Aver.	

(Occupational Outlook Handbook, 1972, pp. 320-332).

II. GEOGRAPHICAL INFORMATION

In Iowa there are two firms that are using this type of construction in their products. The Winnebago Industries, Inc. at Forest City, Iowa, uses sandwich construction in the manufacturing of motor homes, travel trailers, and campers. The McCoy Manufacturing and Sales Company in Indianola, Iowa, use this method of construction in manufacturing campers. The following map shows the location of these two Iowa industries.



III. FINANCIAL TRENDS

For the plastics industry, building is already a big business. Yet in terms of the over-all market, plastics still have a long way to go to achieve the full potential which building represents. Allied Chemical's Barrett Division, a large chemical firm, predicts that the current \$450 million value of plastics in building would multiply tenfold to a \$4.5 billion business by 1970. (Grove, 1962, p. 163).

The \$4.5 billion plastics business by 1970 is a prediction for the whole plastic industry. However, a large percentage of this huge sum of money will be spent for the manufacturing of sandwich construction materials.

IV. PATENT INFORMATION

Definition. In the United States a patent is a legal document issued by the federal government granting an inventor the sole right to make, use, or sell his invention for a specific period of time.

Years of protection. The federal law states that the inventor's ideas are protected for a period of seventeen years.

Application for a patent.

1. A petition, with power of attorney.
2. A specification, signed by the inventor, which sets forth a full description of and all the claims made for the invention.

It is in this connection that a patent attorney is most needed.

3. An oath signed by the inventor before an authorized official.
4. A drawing made according to the patent office rules of practice.
5. The filing fee of seventy-five dollars. (Fuglsby, 1963, p. 121).

Patent attorney fees. The fees paid to the patent attorney for his services in securing a patent for a client usually range from three hundred dollars (\$300) to four hundred fifty dollars (\$450), depending upon the idea that is being patented.

Iowa Development Commission. The Iowa Development Commission Foundation Incorporated is located in the center for Industrial Research and Service, 202 Building East, Iowa State University, Ames, Iowa, 50010. This commission will assist Iowans in procuring a patent for their ideas at a nominal fee or a percentage of the royalties received. They will also help in promoting sales for these ideas.

CHAPTER V

FIELD TRIP

On March 8, 1968 the writer of this report visited the Winnebago Industries, Incorporated, located at Forest City, Iowa. This motor home manufacturing factory is the largest of its kind in the United States.

The tour began in the area of the factory where the thermo sandwich panel was being constructed which is used for the floors, sides, and roofs.

At the first assembly visited, two material handlers were inspecting the plywood panels for defects before placing them on the production line. The panels are then sent through a heat oven to remove surface moisture to enable total contact for the bonding material. In the next operation the adhesive material was sprayed to the panels automatically.

As the panel passed to the next operation, rigid reinforcing members (wood) were placed on the panel in predetermined locations; then the styro-foam was placed on the remainder of the panel. The panel was then sent through a combination heat and pressure rolling machine which fused this panel and core into a single panel section.

Next the panel section was sent to another assembly line where the aluminum skin facing was bonded to this panel section.

The panel sections that were being assembled at this particular time were approximately eight feet wide and twenty-two feet long. This section would be, at a later time, a long side for the twenty-two foot motor home. It was interesting to note the ease at which two men could lift this panel section and transport it to another area for cutting. One can imagine the amount of energy it would require for two men to lift such a panel composed of metal or wood.

A template was lowered over this panel section and clamped into place. The windows and doors were then cut out of this panel with a router. The outer perimeter of the panel section was cut to match the outer edge of the template in the same manner.

The floor panel sections were constructed similarly to the side walls of the motor home. The floor section was fastened to the truck frame with special fasteners designed by their own engineering department. The cabinets, shower stall, and auxiliary light plant is then fastened to the floor section. The long side panel sections are then lifted into place and secured to the frame. Next the top, front, and end panels are installed and fastened into place. At this point of construction the motor coach is completely enclosed.

The assembly operations to follow in order to complete the motor home unit consist of installing the windows; hanging doors; installing the remainder of the plumbing fixtures; installing

interior equipment; thorough cleaning; inspecting and fine adjustment of improperly fitting equipment; and the replacement of damaged or imperfect parts.

The assembly line is geared to produce sixteen mobile units a day. In a year or two, however, production is expected to double its present capacity.

In September of 1964 the Winnebago factory burned completely to the ground from an unknown cause. In the new or existing building several safety measures were installed which they did not have before. The present building is fire proof. Dust collecting systems have been installed to further reduce the chance of fires, and also provide healthier working conditions. A large ventilation system was installed to remove toxic and combustible fumes from the lamination area for health reasons as well as for fire prevention. The paint and welding shops are independent structures removed from the assembly building to further reduce fire hazards. All the buildings are equipped with high pressure water spray systems to quench any fire which may get started. Smoking was confined to well protected and ventilated areas throughout the large assembly building.

The writer had made prior arrangements to visit with Mr. Wilson, public relations director, however at the last moment he was called out of town so this visit was not possible.

He did, however, leave some information telling about the Winnebago Industries factory as well as some material samples showing how these sandwich panels look.

This was a very valuable field trip for the writer because the system of sandwich construction was entirely new to him.

CHAPTER VI

INSTRUCTIONAL UNIT

An instructional unit on sandwich construction would be valuable as well as beneficial to all junior high and high school students. They should become familiar and aware of the many uses of sandwich construction, and its great potential in the manufacturing of buildings, ships, other vehicles, and home products.

In junior high school the instructional unit should be a general introductory unit. Shop projects should be small and relatively simple to construct.

In the high school a unit on sandwich construction should include technical information, testing methods, mass production projects, and conclude with occupational and other related information. The projects should not be considered as a means to an end, but rather as a device to assist in a better understanding of the method and use of sandwich construction.

Objectives of Course Content.

1. To inform students of the history and development of sandwich construction.
2. To develop with each student some understanding of the importance of sandwich construction and its effects on society.

3. To provide the students with an opportunity to practice some of the skills and to learn the problems involved in constructing sandwich panels.
4. To inform students of occupational and other related information concerning sandwich construction.

Course Outline.

1. Introduction to sandwich construction
 - A. History
 - B. Importance to society today
 - C. Industrial application
 1. Aircraft -- space vehicles
 2. Ship building industry
 3. Commercial and residential building
 4. Vehicles -- all types
 5. Furniture -- commercial and residential
 - D. Locations of industries producing sandwich construction panels
 - E. Employment opportunities -- existing jobs as well as new jobs in the future
- II. Technical information
 - A. Basic science
 1. Facing material properties for sandwich construction
 2. Core material properties for sandwich construction
 3. Adhesive material properties for sandwich construction

- B. Types of materials used
 - 1. Facing
 - 2. Core
 - 3. Adhesive
- C. Method of producing sandwich panels

III. Shop activity

- A. Prepare stock
- B. Laminating processes
- C. Finish

Safety Precautions.

- A. By law all students must wear safety glasses or goggles
- B. General shop safety
 - 1. Physical safety
 - 2. Clothing safety
 - 3. Tool safety
 - 4. Material safety
 - 5. Shop courtesy
- C. Specific safety rules while operating power tools
- D. Health safety
 - 1. Provide adequate ventilation
 - 2. Provide a dust collecting system to remove dust
in the air
 - 3. Provide adequate exhaust system to remove toxic
fumes from laboratory

Student Evaluation.

Students may be evaluated by the following techniques:

1. Testing
2. Interest, attitude, and cooperation
3. Class participation
4. Acquired skills in shop work

Sample test.

1. What is the difference between a sandwich panel and plywood?
2. Name several ways in which sandwich construction is used by industry.
3. Draw a simple sandwich panel and name its parts.
4. Name several advantages of using sandwich panels.
5. Explain what part of the sandwich resists shear, and what part resists the bending in a panel.
6. Name a bonding agent which could be used in the shop conveniently in the construction of a sandwich panel.

Instructional Aid.

I. Problem; Design and construct desk model pen and pencil holder.

II. Materials

- A. One piece of rigid fiber board approximately
1/2" x 4" x 6"
- B. One piece 1/4" x 4" x 6" plywood (fir or pine)
- C. One piece of formica 1/16" x 4" x 6"
- D. One strip formica 1/16" x 13/16" x 20"
- E. One piece 3/4" x 2" x 3 1/2" walnut
- F. Contact cement

III. Procedure

- A. Design -- student may innovate his own design
- B. Construction procedure
 - 1. Cut core material 1/8" less in length and width of top formica
 - 2. Cut plywood bottom same size as core
 - 3. Cut long formica sides 1/8" longer than length of core material
 - 4. Cut short sides of formica exact length and width of core.
- C. Pen holder
 - 1. Cut walnut piece to exact size
 - 2. Drill 5/16" holes in walnut which will receive pen. Number of holes and spacing determined by student
 - 3. Sand

D. Procedure for applying adhesive

1. Check to see if room is properly ventilated. Turn exhaust fan on to remove toxic fumes from the room.
2. Brush contact cement on plywood and core. Let set for five or ten minutes, or until cemented surfaces appear dry. Press plywood over core exactly, because a bond is formed instantly between the two contacted surfaces and they can not be forced apart.
3. Apply the formica sides to the core following procedure in number two.
4. Apply the formica to the top of core following procedure in number two.
5. Apply masking tape over formica that will be covered by pen holder.
6. Locate exact position of pen holder (walnut) and scribe a line around base.
7. Cut out masking tape covering this area.
8. Sand with #220 sandpaper until surface has a dull sheen to it.
9. Apply contact cement to this area and bottom of pen holder. When surfaces appear dry, press pen holder into the cemented surface. Hold for a few minutes.

10. Remove masking tape. Clean excess contact cement from all joints.
11. File (single cut mill file) all edges until they are flush and smooth.
12. Finish pen holder as desired.
13. Apply felt pads to each corner.
14. Clean up work area.

MASS PRODUCTION UNIT

Mass production of sandwich constructed units produced in industry is usually of component parts rather than a completed product. These parts are field erected, such as the assembling of a house or parts that are to be assembled on a production line basis.

It is imperative that students should become involved with industrial organization and production as related to industry, so that they will better understand methods of manufacturing products.

The following positions should be discussed so that each student will understand the function of industrial management.

1. Manager -- in charge of whole project.
2. Engineer -- design project; prepare working drawings; design jigs and fixtures.
3. Purchasing -- in charge of purchasing materials.
4. Accounting -- will figure cost analysis on project and handle finances.

5. Production -- draws up a flow chart; sets up production line; builds jigs and fixtures for production line.
6. Quality control -- keeps check on all departments; keeps management informed on progress and problems that arise; is in charge of inspection department.
7. Sales department -- salesmen; in charge of advertisement; sales promotional schemes.

During the manufacturing of the product, all students will participate.

The project used in this report will be a pen and pencil holder. A working drawing of this project is found on page 39. A flow chart for this project is on page 40 of this report.

TEXTS AND REFERENCES

The following are suggested texts and reference materials that would supply some information on sandwich construction. Since there is such a limited amount of information given in the textbooks it would be very difficult to write up an effective unit from the textbooks alone.

TEXTBOOKS

Frier, John L. Woodworking for Industry. Peoria, Ill.: Chas A. Bennett Co., Inc., 1963. \$5.70.

Wagner, Willis H. Modern Woodworking. Homewood, Ill.: Goodheart-Wilcox co., Inc., 1967. \$5.22.

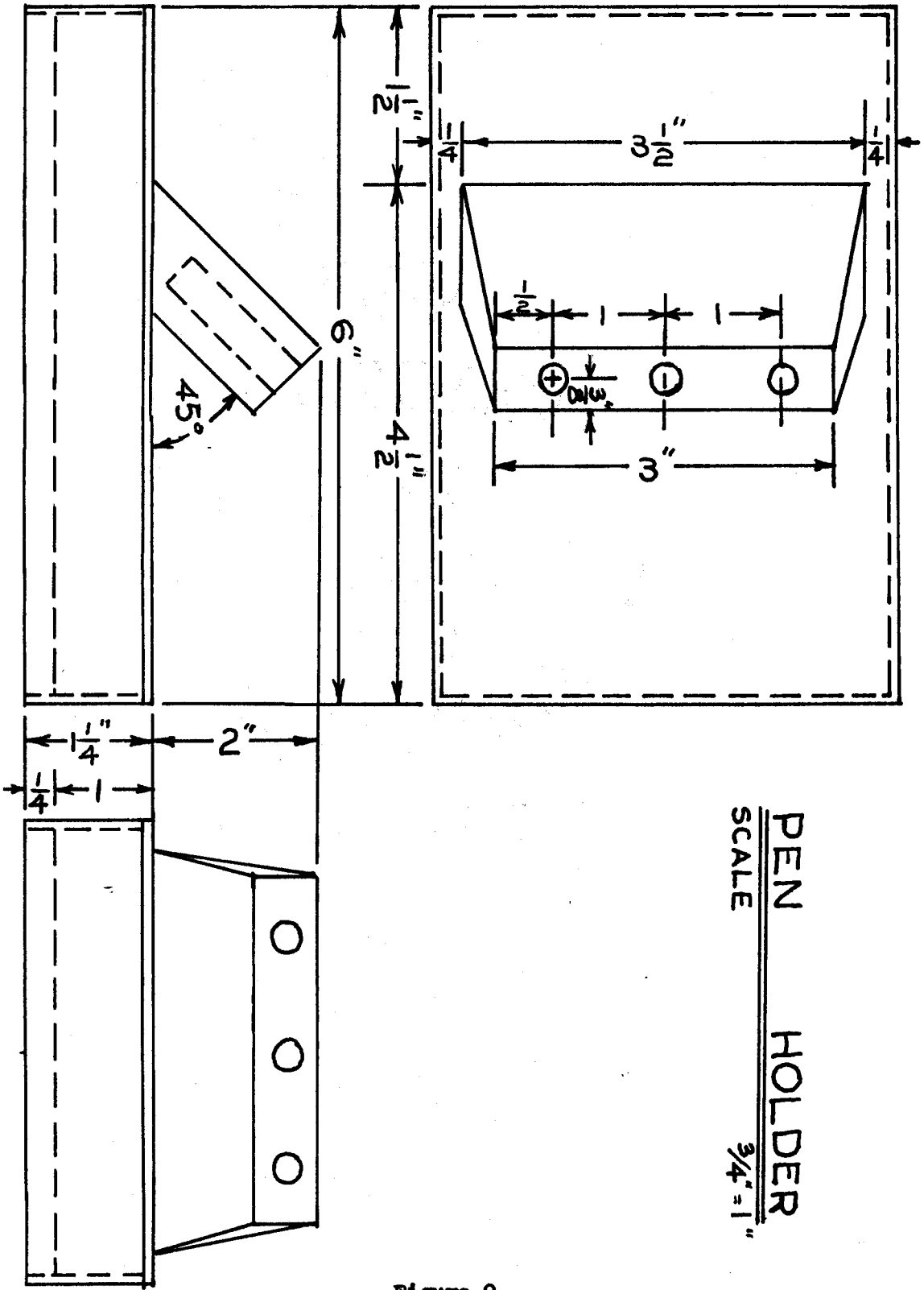
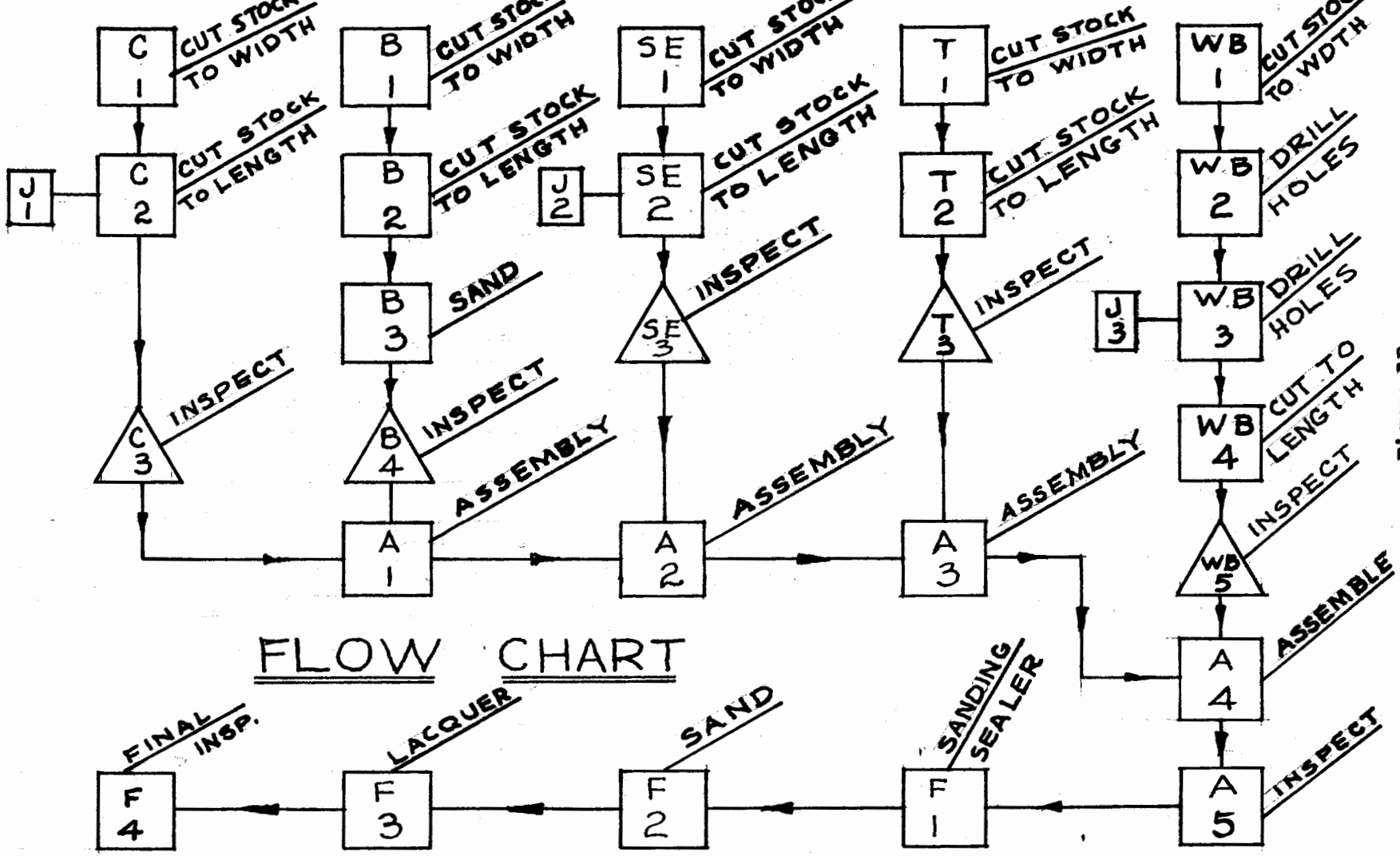


Figure 9

CORE BOTTON SIDES & ENDS TOP WALNUT BD.



FLOW CHART

Figure 10

REFERENCES

Building Research Institute. Adhesives and Sealants in Building.
Publication 577, Washington, D.C. 1958. \$5.00.

Building Research Institute. Performance of Plastics in Building.
Publication No. 1004, Washington, D. C. 1963. \$10.00.

PAMPHLETS

Pamphlets concerning sandwich construction are available from the following companies;

American Plywood Association, 1119A Street, Tacoma, Washington, 98401.

Harwood Plywood Manufacturers Association, 2310 South Walter Reed Dr.,
Arlington, Virginia, 22206.

Masonite Corporation, 29 North Wacker Drive, Chicago, Illinois, 60606.

United States Forest Products Laboratory, Madison Wisconsin.

Winnebago Industries, Inc., Forest City, Iowa.

FILMS

"Born of Foam". 16mm sound, color; 20 minutes. Sinclair-Coppers Co.,
Koppers Building, Pittsburgh, Pennsylvania, 15219. Produced by
Badische in Germany, this film describes the many applications
of foamed polystyrene.

"Fabrication Machinery for Flexible & Rigid Foams". 16mm. silent, color;
15 minutes. Falls Engineering & Machine Company, Sales
Department, 1734 Front Street, Cuyahoga Falls, Ohio. Various
horizontal and vertical saws as well as completely automated
fabrication lines.

"Focus on Foam". 16mm. sound, color; 20 minutes. The Dow Chemical Company, Visual Aids Department, Midland, Michigan, 48640. Describes the differences in plastic foams (Styrofoam, Ethafoam, Thurane, Corvon)., including manufacturing processes. Shows installation procedures for various applications and examples of completed buildings. Produced for architects and engineers, but of broad interest to all in the construction business.

"What Can the Matter Be?" 16mm. sound, color; 24 minutes. American Cyanamid Company, Public Relations Division, Wayne, New Jersey. This film tells how the molecules in matter have been put to work solving the big and little problems of man; plastic sandwiches to revolutionize home building; ...

TOOL INFORMATION AND SUPPLIES

In a well-equipped shop, no special type tools are necessary in building projects employing the method of sandwich construction.

Adhesives.

Casein	1 pound	\$1.41
Urea-Resin	1 pound	\$1.29
Liquid Resin (Polyvinyl)	1 pint	\$1.59
Resorcinol	1 pint	\$4.13
Contact Cement	1 pint	\$1.73

(Brodhead-Garrett Catalog, 1973).

Facing Materials.

$\frac{1}{4}$ " plywood	Pine	\$.18 sq. ft.
$\frac{1}{4}$ " plywood	Mahogany	\$.28 sq. ft.
$\frac{1}{4}$ " plywood	Birch	\$.44 sq. ft.
$\frac{1}{4}$ " plywood	Walnut	\$.86 sq. ft.

(Wickes Lumber Yard, Evansdale, Iowa).

Metal Facing Materials.

Aluminum Coiled Sheets	24 gauge	\$.68 sq. ft.
Soft Copper Coiled Sheet	24 gauge	\$1.98 sq. ft.
Brass Coiled Sheet	24 gauge	\$1.86 sq. ft.

(Brodhead-Garrett Catalog, 1973).

Formica Facing Material.

Formica	All patterns	\$.78 sq. ft.
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(Wickes Lumber Yard, Evansdale, Iowa).

Core Materials.

$\frac{1}{2}$ " rigid fiber board	\$.09 sq. ft.
Styrofoam	\$.31 sq. ft.

(Wickes Lumber Yard, Evansdale, Iowa).

A possible free source of face and core materials could be obtained from contractors, builders, lumber yards, and furniture stores -- materials which they would consider as scrap material.

SUMMARY

The writer of this report believes that he has gained a considerable amount of knowledge in sandwich panel construction. While searching for information relating to this subject, very little information concerning this type of construction was printed in Industrial Arts books. Although sandwich panels are a relatively new product on the United States market, it is being used extensively in many different manufacturing industries today. Experts in this field have indicated a greater use of this type of construction in the future. Therefore, it would appear that a unit on sandwich construction should be taught in the junior high and senior high school shop.

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