A BASIC STUDY
OF
DRAWERS IN WOOD HOUSEHOLD FURNITURE

By Harold E. Worth

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School of Forestry & Conservation
University of Michigan

Ann Arbor, Michigan

Report by

Harold E. Worth

June 2, 1949

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Dean
School of Forestry & Conservation
University of Michigan
Ann Arbor, Michigan

Dear Sir:

This report is submitted in partial fulfillment of the requirements for the degree of Master of Wood Technology.

The purpose of this report is to describe a basic study of drawers in wood household furniture, including a survey of the social, economic, and technical elements which pertain to the subject. It is intended that this will provide an ample framework of facts to serve as the foundation for development of a better type of drawer.

The assistance of L. A. Patronsky, Assistant Professor of Wood Technology, and A. K. Lahti, Assistant Professor of Design, is especially appreciated. The co-operation and advice tendered by the following individuals and organizations is also gratefully acknowledged.

Edward J. Wormley, Designer; George Nelson, Designer; Herbert TenHave and B. M. Baker, Grand Rapids Chair Co.; David B. Morgan, Jr., Morgan Furniture Co.; George W. Baughman, Cessna Aircraft Company; F. A. Seng and Art Pieritz, The Seng Company; C. D. Dosker, Gamble Brothers; Roger R. Smith, Pressed Wood Corporation; Mary Seaman, National Furniture Review; Elizabeth Gordon, House Beautiful Magazine; F. W. Dunn, National Association of Furniture Manufacturers; J. K. Detrick, Wood-Mosaic Co.; Department of the Army, Quartermaster Corps; Owen L. Miller, The National Hardwood Magazine; J. B. Ogden and A. L. Renton, J. L. Hudson Company; H. C. Barrett and Marlin Prindle, Barrett's House of Beautiful Furniture.

Sincerely yours,

Harold E. Worth

Harold E. Worth

SUMMARY

The problem of manufacturing satisfactory drawers is one of the most difficult confronting the wood furniture industry today. Specifically, this problem embraces the designing of the drawer, the means of making it, and the performance it gives in service. Each of these factors has been considered in this study, and an attempt has been made to determine the social, economic, and technical significance of each.

The conclusions reached are based on information obtained from personal correspondence with persons associated with drawer problems, from an investigation of actual drawer units, and by library research.

It is concluded that conventional drawer practice is no longer adequate in the light of modern industrial development. There is a need for new types of drawers which are more easily and cheaply manufactured and which give a greater degree of service to the consumer.

It is further concluded that no drawer type is now in production which is a total solution of the problem for the entire furniture industry.

It is recommended that immediate research action be taken to eliminate various problems in conventional drawer practice.

It is further recommended that drawers which are now in a developmental stage be investigated more completely and that other methods be projected and tested.

HISTORY

There is very little written information on the history of drawers. It is known, however, that the drawer has been used in much of the storage furniture produced since medieval times. The forerunner of the modern drawer is the chest or open box stored on a ledge or shelf. It was more convenient to have several small, light, easily moved boxes than one large one. The chest of drawers which developed out of this arrangement was a logical improvement on the coffer type chest of huge proportions since it permitted easy access to all of its contents in contrast to the rummaging required in the deep coffer.

By the end of the 17th Century the drawer had essentially reached its present state of development.[1] Old as the principle is, the drawer is still considered the most convenient arrangement for general storage that has yet been devised. It is one of the mechanisms used most frequently in the average household, with few families requiring less than twenty drawers for a multitude of diverse storage needs.

The need for better drawers is almost self-evident. Both consumers and retail sellers continually complain about drawer performance, and manufacturers have their perennial technical difficulties and cost problems in producing satisfactory drawers. Consequently, the problem is a very tangible one. In the number of dollars involved and consumers affected cutting the cost of a drawer ranks with the problem of cutting the cost of an automobile tire. It is certainly more urgent from the user's standpoint that a drawer be well engineered than an electric mixer. Is is often believed, however, that furniture, as opposed to other utility goods, does not lend itself to research and particularly that furniture mechanics can be left to the "practical" man. Consequently, there have been few attempts to design a drawer which functions as well as other household appliances despite its widespread use in modern living. Actually a drawer in the most expensive piece of furniture may fail to perform as well as a ten-cent can opener.

Only in the techniques of constructing drawers has any significant progress been made since the Eighteenth Century. A hundred drawers may now be produced by machine in the time formerly taken to make one by hand. But even this phase of the drawer situation seems to be due for considerable development. A "good drawer" still strongly resembles the first models made by the carpenter-craftsmen of the early Renaissance. It uses the same type of joints at the corners and is suspended in a similar way. The only noticeable differences would be the use of plywood for the fronts and bottoms in some cases and the addition of the center guide. Many minor alterations have been made to improve drawers, and some of them have gradually been accepted as standard by most of the furniture industry. These developments are largely of an evolutionary nature and are seldom attributable to any organized research effort.

A few designers and manufacturers have developed drawers through research which are real improvements over conventional types. Many of these have not been practicable from the economic or technical standpoints. Others have not been tried due to the conservatism of the furniture industry. This small amount of research does form a nucleus, however, for a more thorough study. It may show what cannot be done if not what can be done. Several of these ideas will be discussed later in this report.

In spite of the shortcomings of drawers generally the drawer principle does not appear to be losing its validity as a functional element in furniture as time passes. In the light of present thinking on furniture it seems doubtful that the general principle of the drawer will be supplanted by any other form of storage mechanism. Although other storage space arrangements are suitable for some purposes, their uses are rather limited and specialized. No other mechanism which is conceivably practicable offers all the advantages of the drawer principle. The present drawer designs with their many parts are rapidly becoming an anachronism, however, in today's industrial picture.(2) A drawer with fewer parts which can be assembled in fewer operations is essential. If progress is not made toward a drawer of this type, it seems probable that the special utility of the drawer principle must be sacrificed to keep the price of furniture within the limits of the consumer's pocketbook.

NATURE OF THE STUDY

This study is an analytical survey of drawers in wood household furniture. It deals in particular with the problems of design, construction, and performance of drawers and attempts to analyze these problems in the light of their social, economic, and technical implications. It is intended that this survey, coming before any attempted development of an improved type of drawer, will give laboratory research a sound basis in fact and enable an investigator to take advantage of the experience of others in planning an efficient method of approach.

This investigation has proceeded on the thesis that any solution of the problem of drawers will be of no real significance to the furniture industry or to society as a whole unless it is based on a sound knowledge of the economics, technology, and sociology involved. Consequently, this study has attempted to establish just what the relationship is between the drawer and the man who makes it and the drawer and the man who uses it. Since there is little or no documentation of these relationships, the investigator must solicit this information from those who are most intimately associated with the problem in its various aspects.

Information for this study has been collected from many sources -- furniture designers, manufacturers, merchants, associations, publishers, and from literature on the subject -- by means of personal correspondence and interviews and by library research. For convenience in analyzing this body of information a framework of three arbitrary parts has been established. The first deals with the problem of drawer design; the second is concerned with construction; and the third evaluates drawer performance.

It should be realized that the conclusions and recommendations drawn here are based on a relatively small sampling of facts and opinions. Care has been exercised, however, in soliciting samples which are representative of better practice in designing, manufacturing, and selling furniture, and because of this it is felt that the opinions expressed are typical of the trade in general.

The methods used for obtaining information for this report were (1) correspondence, (2) field investigation, and (3) library research. Considerable information resulted from each type of inquiry, but the most important contributions came through correspondence.

(1) A prospective list of correspondents was drawn up at the outset of the study which included designers and manufacturers believed to be interested in the subject of drawers. Each of these was approached with a letter explaining the nature of this study and requesting a brief description of his experience with drawers or drawer research. The response was exceedingly generous. When the reply seemed to invite or warrant it, more specific information was requested. Other sources of information were often suggested by the correspondents, and in many cases blueprints or sample mechanisms were sent with letters of explanation. As the study proceeded, further information was solicited from associations, retail organizations, and from government agencies. The more important excerpts from this correspondence have been embodied in Appendix A.

(2) The amount of field investigation which could be carried on was necessarily limited by time and expense to the immediate vicinity of Ann Arbor. This method appeared to be the best way to obtain accurate information on drawer design practice and performance. Analyses were made of approximately one hundred drawers selected to give a random sample of

low-medium to high grade furniture. Where possible these samples were taken from chests of drawers or desks. The tests were conducted in the furniture section of The J. L. Hudson Company, Detroit, and at Barrett's House of Beautiful Furniture, Ann Arbor. Analyses were also made of drawers which had been in use for a period of years in homes and offices. Plate I is a sample of the analysis sheet used with hypothetical information given for purposes of illustration. The opinions of furniture buyers, furniture salesmen, and housewives were obtained by interview, and these were often valuable in establishing some of the social and economic relationships involved in an evaluation of drawers.

(3) The library research produced only a few articles directly related to drawers. A systematic search through all woodworking publications available in the collection of the Forestry Library, University of Michigan, emphasized the fact that very little formal thought has been given to the subject. Some of the few articles found were rather comprehensive, however, and proved to be of considerable value.

The information obtained by the methods described above forms the basis for the analyses, conclusions, and recommendations which follow. Because of the expanse of this subject in its broader aspects the search for information has been confined to that which applies directly to drawers. Many of the collateral issues seem to be worthy of separate investigations.

DRAWER ANALYSIS SHEET (RETAIL STORE)

Company *Jacobs, Inc.* Date *April 6, 1949*

Manufacturer *Doe & Scott* Type *Chest* Retail Price *$74.95*

Drawers: Number *5* Number with guides *5*

Approximate inside dimensions

No.	Front	Side	Depth
2	13"	14"	4"
2	29"	17"	7½"
1	29"	17"	8"

Front fit: Average lateral tolerance for each size drawer

1. *1/16* " 2. *3/32* " 3. *1/8* " 4. ____ "

Average vertical tolerance for each size drawer

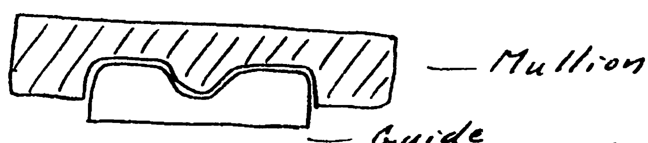
1. *1/8* " 2. *1/8* " 3. *1/8* " 4. ____ "

Average sag at full extension minus 2", each size drawer

1. *3/4* " 2. *1/2* " 3. *1* " 4. ____ "

Tendency to slew: None ____ Slight ✓ Noticeable ____ Bad ____

Design: *Conventional except guide & mullion.*



Sides: Species *Oak* Thickness *3/8"*

Backs: Species *Oak* Thickness *3/8"*

Fronts: Solid ✓ Plies ____ Sawed core ____ Bent core ____

Bottoms: Solid ____ Plies *?* Face species *Maple*

Mullion: Species *Maple* Guide: Species *Tulip Poplar*

Joints: Front corners *Dovetail* Back corners *Dovetail*

Bottoms *Groove*

Quality: Excellent ____ Good ____ Fair ✓ Poor ____

Finish: Inside: Excellent ____ Good ✓ Fair ____ Poor ____ None ____

Outside: Excellent ____ Good ✓ Fair ____ Poor ____ None ____

PLATE I

DRAWER DESIGN

The design is the most important consideration in the problem of drawers. All of the subsequent elements of construction and performance depend upon it. It largely determines the economics of the drawer as well as its usefulness and is the link between the drawer as a separate structure and the case as a whole. Due to the significance of the design a preponderant part of this study has been devoted to it.

The drawer design in usual practice is not the product of the furniture designer, but instead is a part of the interior construction laid out by the manufacturer's engineering staff. This does not imply that the designer is not aware of its features, which are usually standard with the manufacturer, but that his function is generally to formulate only the superficial appearance of the piece. The engineering of such mechanical and structural elements as drawers is usually delegated to those who have learned their trade through apprenticeship. It seldom departs from accepted practice, and initiative is required only to modify the conventional type of drawer to fit a particular application. While this arrangement is workable, it is hardly efficient or progressive.

To overcome the lack of unity which such parceled-out designing produces, many furniture designers have also equipped themselves to solve technical problems and are able to execute a better integrated design because of their dual skills. As the design function becomes more complex, however, any individual working alone necessarily lacks some of the various abilities required to develop an adequate solution. At this level the design must become a specialized, collaborative effort of the designer and technologist. This highly developed process, which is common in the designing of most consumer goods, is still relatively rare in furniture. The evidence of its great productiveness, however, seems to forecast a rapid growth.

Instances of each of these methods of approach to the design solution will be included in this report. Regardless of the method of approach the design of any drawer must be based on certain fundamental considerations.

Considerations Affecting Drawer Design

The considerations which affect drawer design are function, structure, and means of construction. Each of these related factors must be fully considered in any good drawer design.

Function is obviously the most important of these factors, since the drawer loses its reason for being if it does not serve its intended purpose. The purpose of a drawer is to store articles in such a way as to make them easily available and to keep them clean. It is further expected that the drawer will present a reasonably good appearance and reasonably smooth performance. Good appearance and smooth performance, consequently, are also legitimate parts of the function. These purposes or functions roughly define the size and shape of the drawer and strongly influence the structure which is used.

The primary function of a drawer -- to make its contents easily available -- is closely related to performance. If the drawer is difficult to open or if the drawer sags precariously when opened, the contents are not easily available. A good view is also implied in easy availability since the selection of a particular article from a drawer is easy only when all can be readily seen.

Specialized storage for particular items versus general storage for miscellaneous items is a currently important consideration in planning convenient drawer space. Through surveys which have been conducted by various agencies since the War, consumers have shown an increasing preference for specialized storage space.[3] Several studies have been made to determine the usual contents of drawers and to analyze them from the standpoint of average size and number. These studies have generally resulted in the designing of new types of drawers for specialized use.[4] Too great a degree of specialization in the function of drawers has disadvantages, however, since production of many shapes and sizes is not economical and since flexibility is desirable in many cases.

The functional problem of keeping dust out of drawers has usually been recognized by the incorporation of dust panels between adjacent drawers. A relatively tight fit around the drawer front is also considered essential to effect a good dust seal. Several manufacturers have recently eliminated dust panels, however, on the theory that they actually trap dust, which is siphoned through the case by the opening and closing of drawers. In such designs all the framework between the drawers is usually eliminated also, and the drawers are suspended from the sides of the case. This further prevents the jamming of articles projecting from the top of the drawer.

The appearance of the drawer is an important consideration in the design. The front is a part of the design of the entire case, and consequently, the overall design of the piece greatly influences the drawer design. If the piece is made of solid wood, the drawer fronts are normally solid also. This usually indicates further that the front will be flat rather than of the bow or serpentine types. If plywood construction is used, the drawer front will be faced with the same veneer as the top and sides of the piece or perhaps a fancy veneer of contrasting figure and color. Whether the front is curved or flat, plied or solid also affects the drawer design.

The good appearance of the interior of the drawer is not achieved without considerable trouble and expense, and since this part of the drawer is always hidden from the casual observer, it is tempting for the manufacturer to omit a good interior finish from his drawer design. The appeal of a well-finished drawer interior is a valuable asset in selling the piece, however, Consequently, the degree of expense which is to be allowed must be considered in the design.

The last of the elements of function which were enumerated above is good performance. Since performance is actually the fruition of the design and construction effort, the final section of this report deals with it entirely. Therefore, performance will not be discussed at this point.

Structure, the second of the principal considerations affecting drawer design, is influenced by or influences each of the other factors of the design. Functions determine the size of the structure and its shape. They also determine its superficial characteristics, such as finish, grain patterns, and hardware. Functions further dictate the degree of strength that must be attained by the structure, and the structural materials used. Drawers that must carry heavy or bulky loads will obviously be of a different structural nature than those meant for small, light articles. Methods of construction are adapted to the structure but also limit the form it takes. Although the tools and techniques for constructing drawers are originally developed or adapted to produce a certain structure, the scheme of the structure is effectively limited by these tools and techniques.

The conventional wood drawer is composed of from five to twenty-five or more separate parts. This indicates that the joints and adhesives used to hold these various members together in the proper position are the most critical components of the drawer structure. The strength and other physical properties of solid wood parts, plied parts, and of any other materials used should certainly be considered in arriving at a good design.

At least fundamentally the structural design of drawers has become highly conventionalized in a large proportion of the furniture now produced. This conventional practice has evolved over a very long period and resists change even in the face of continual difficulties. Other than some variety in wood species and types of joints, drawer structures produced by hundreds of different manufacturers are nearly identical.

The means of construction of conventional drawers are basically mechanized versions of old hand methods. These operations include machining, plywood manufacture, and finishing. Since the means of construction are suggested by a highly standardized structural design, they are rather uniform from plant to plant. The precision used in these operations varies considerably, however, and it is this degree of exactness which determines the "quality" of the drawer.

Since changing the drawer design would normally involve a retooling program, most manufacturers hesitate to diverge from their standard methods even though another means might be better. Consequently, where this condition exists the design is held within rather narrow limits to comply with available production facilities. As better and cheaper means of construction are devised, they will undoubtedly influence drawer design, and the invention of new means will probably be the greatest stimulus for improving drawers.

The significance of design in a good drawer has been discussed together with the various considerations which affect the design. The success of the drawer rests largely on the excellence of the design. It determines the major economic factors, its sociological validity, and the technical implications. Activity in this phase of the drawer problem has been extremely stagnant for many years. Not until after World War II were there any promising developments in drawer design which gained any degree of acceptance in the industry. Thus far the use of improved types of drawers has been confined to a restricted group of high-priced furniture due to their cost. Even though none of these types may be capable of development for use by the entire industry, they have had the effect of stimulating design thought, and it is to be expected that many ingenious solutions will now come forth to meet the need.

DRAWER CONSTRUCTION

The term "construction" as used here means the series of operations the drawer must undergo from the raw material after primary processing to the final installation of the drawer in the case. This includes machining, assembly, sanding, fitting, finishing, and trimming in conventional drawer practice. To improve drawers from the standpoint of the manufacturer it would be highly desirable to eliminate as many of these operations as possible and to reduce the cost of the remaining ones. This would have to be accomplished, of course, without reducing the manufacturer's standard of quality.

One of the most obvious faults of conventional drawer design is the large number of individual parts which make up the drawer. In a conventional drawer of the best quality this number may be twenty-five or more. Each of these must be handled and processed several times. The resulting in-economies of this system are evident. The ideal solution of the problem of construction would seem to be a one-piece drawer, fabricated in a single operation, being held to such close tolerances that all fitting is eliminated.[5] Technically, a drawer can be produced from several materials in this way, but none of the methods and materials yet tried have proved to be economically feasible. Furthermore there is a certain stigma attached to materials other than the traditional ones, both to the manufacturer and the consumer.

Certain of the methods which approach this ideal are discussed later in this report. Many of them look really promising when considered from a long-term viewpoint. Whether or not any such radical development can be successful throughout the entire furniture industry undoubtedly depends on many economic and social factors which are not yet determinable. It is probable that there will be intermediate stages between present drawer practice and the ideal. The present means of making drawers are definitely limited in the degree to which they may be made automatic, however, and it seems that the trend toward economy through simplification will undoubtedly make progress under highly competitive conditions.

DRAWER PERFORMANCE

Drawer performance being a purely objective quality cannot be acted upon in itself, but must be acted upon through the other factors of the drawer problem -- design and construction. The purpose of the discussions on performance found in this report then is to evaluate performance in the light of design and construction and to point out where possible the weaknesses in these other factors which are reflected in poor performance.

As has been previously mentioned, performance is a major consideration in the drawer design. The designer (engineer) consciously affects the performance by his selection of materials and scheduling of operations. A greater effect is often due to a lack of understanding of the materials and the techniques of construction.

A lesser level of performance is tolerable in inexpensive furniture than in costly furniture, and the designer is free, within limits, to adjust the cost and performance of the drawer to the price level of the piece. The field investigation made in connection with this study showed rather conclusively, however, that performance does not always reflect the cost of the drawer or the general standard of the piece. This seemed to be attributable to both inadequate designing and poor quality of construction.

When poor quality of construction enters into the picture, the designer loses his control. The best design if poorly executed cannot add up to good performance. Inferior construction may or may not be consciously condoned. Inexpensive furniture obviously cannot command a work force of the skill level required for high-cost furniture. As in the design, however, workmanship on drawers is not always commensurate with their cost. This leads one to believe that inadequate supervision and inspection are often responsible for poor drawer performance.

Whether drawer performance -- good or bad -- is traceable to the design or to the construction standards or to both, it is the only factor which the consumer recognizes as being important. To him a drawer is a failure unless it renders all the services he feels he can expect. His satisfaction is the only reliable standard for evaluating drawer performance, and unless it is keyed to his wants, it becomes an obstacle to social and economic harmony between maker and user.

CONVENTIONAL TYPE DRAWER

Design

As has been previously stated drawer practice has evolved into a series of techniques which are surprisingly uniform throughout the furniture industry. The composite design which expresses this practice is illustrated in Figure 1. This design, for the purposes of this report, has been termed a conventional design. It represents the general form of approximately ninety per cent of the drawers analyzed in this study. But it is probable that this composite design would represent an even higher percentage of all drawers, since special types were particularly sought out for analysis in this study and make up a disproportionate share of the total.

Although most drawers can be grouped into one general design class, they are not entirely identical in design. Many variations occur within the limits of conventional practice and these variations coupled with precision of manufacture determine the "quality" of the drawer.

This conventional drawer consists of five essential structural members -- the front, the two sides, the back, and the bottom. For economy and technical reasons these five members are ordinarily manufactured from at least three different types and sizes of material. These must be assembled into a thoroughly rigid structure which will stand the loads placed in it, the stresses imposed in opening and closing it, and the destructive tendencies of changes in dimension due to climate. The method of joining these components together is obviously the most critical problem in the design.

Joints

Figure 2 shows several variations of joints which have been widely used to connect fronts and sides. The rabbet joint (Fig. 2a) is commonly

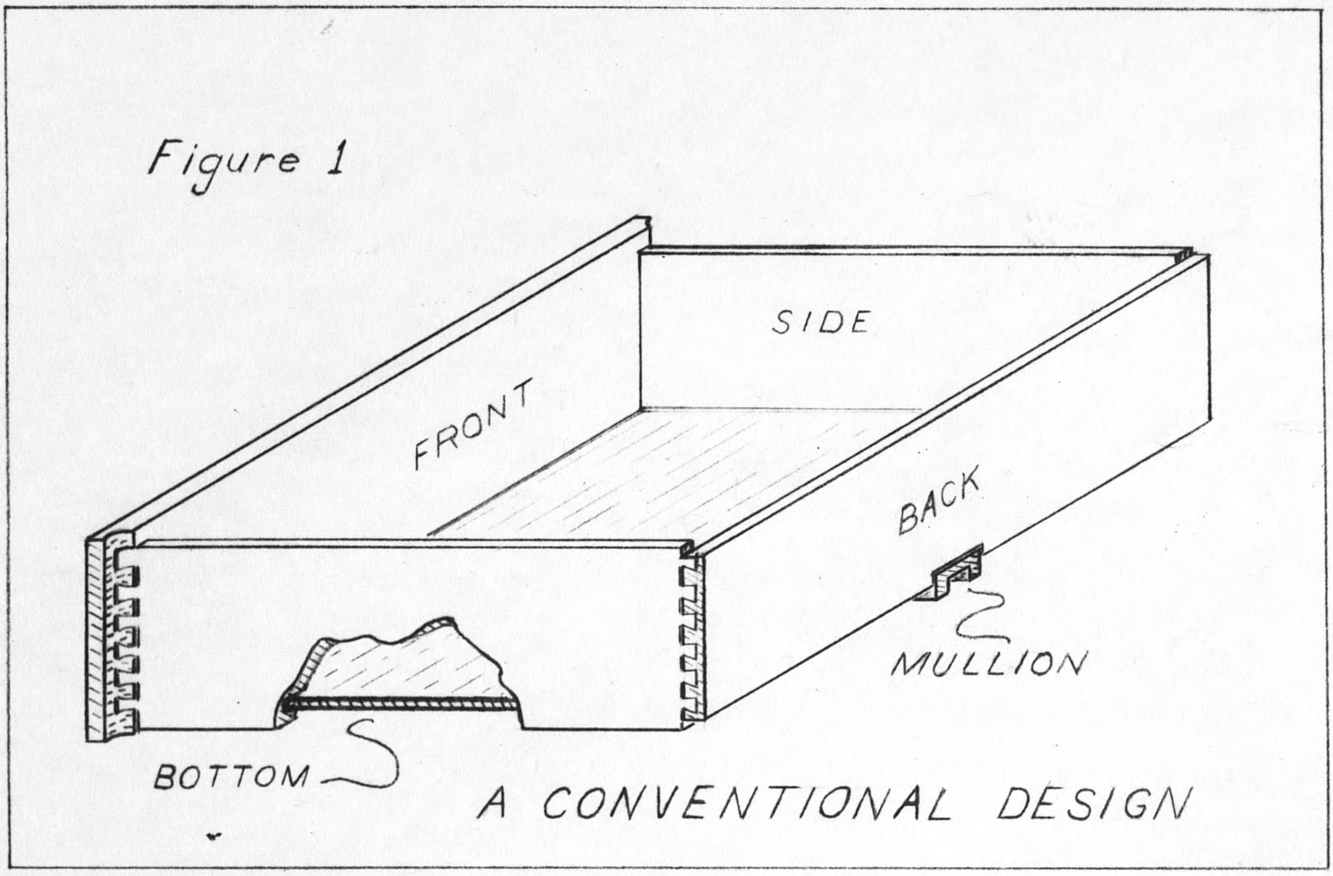


Figure 1
SIDE
FRONT
BACK
MULLION
BOTTOM
A CONVENTIONAL DESIGN

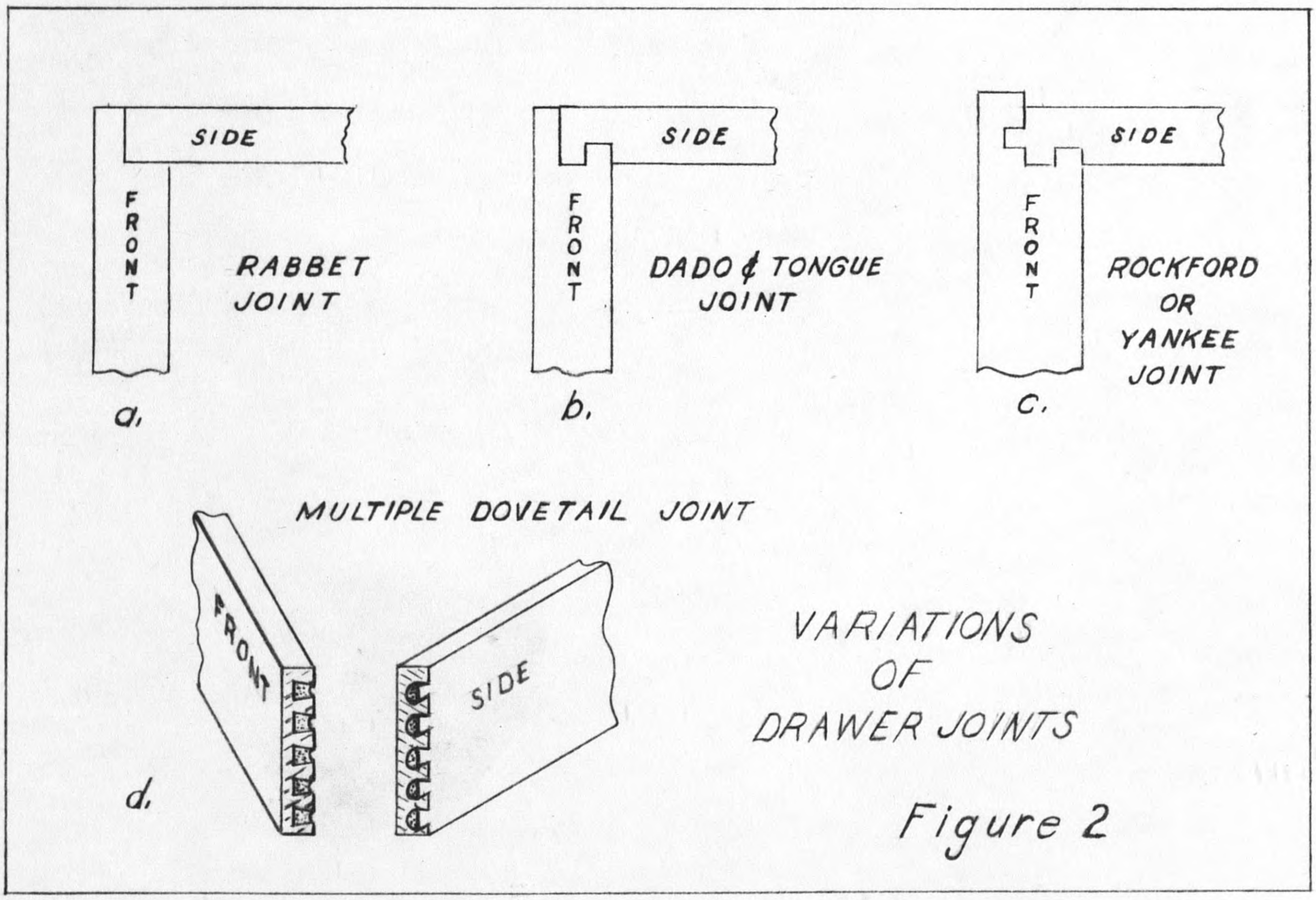

SIDE
FRONT
RABBET JOINT
a.
SIDE
FRONT
DADO & TONGUE JOINT
b.
SIDE
FRONT
ROCKFORD OR YANKEE JOINT
c.
MULTIPLE DOVETAIL JOINT
FRONT
SIDE
d.
VARIATIONS OF DRAWER JOINTS
Figure 2

PLATE II

used in the cheapest grades of furniture. In this type of joint the side is glued and nailed to the front. This entails gluing and nailing to end grain, and even in joints showing the best quality of machining and gluing there is little resistance to lateral or diagonal racking forces. Its advantage is obviously its low cost.

The dado and tongue (Fig. 2b) is a less frequently used joint. Although slightly stronger and more expensive than the simple rabbet type, it is not ample in strength for best quality drawers but is simple to produce and assemble.

Figure 2c shows another type of joint which is especially popular for heavy duty, as in desks. This joint is locked in two directions and can be assembled only by driving one member down over the other.

The most important of the drawer joints and that which is used most frequently is the dovetail joint. This joint (Fig. 2d) has long been considered the ideal drawer joint.[6] The manufacturers of almost all medium- and high-grade furniture employ the dovetail for both the front and back corners of drawers. Although the original dovetail joint, as made by hand, was rectangular in cross-section, the most widely used version now is half-round in section. This type of dovetail is normally produced by special dovetailing machines. Although the half-round is not as strong as the rectangular type, it is the only method that can be used conveniently in machine production of "blind" dovetails.

In spite of the wide acceptance of the dovetail joint it has several significant disadvantages. Among these is the relative difficulty of machining male and female parts to give a good tight fit. Unless very close tolerances are held, the joint strength becomes almost entirely dependent on the strength of the glue. If the customary assembly glues are used, these joints frequently break down completely. Another difficulty is the bad appearance the dovetails give if they do not fit exactly. To remedy this a great deal of filling and sanding must be done at considerable expense.

The same joints used for the front corners are usually specified for the back corners also. Occassionally, however, a simple groove is cut into the sides to hold the back, or a dovetail joint may be used in the easily seen front corners while an inferior joint is specified for the hidden back corners. Approximately ninety per cent of the drawers which were analyzed employed dovetail joints at both the front and back corners.

The only remaining joint to be considered is the groove for the bottom. This is normally cut to a depth of about 13/16 inch and about 1/32 inch wider than the thickness of the bottom.

Fronts

The drawer front is the next element to be considered. The surface of a drawer front should be treated as a part of the piece as a whole, not the drawer alone. In conventional practice the superficial appearance is decided first and then the other factors are considered. Fronts are usually made of the same wood as that of the exposed portions of the piece or are faced with the same veneers. This means that they will be of either solid or plied construction. The surfaces of drawer fronts lie in either flat or curved lines and are either of flush-front or lipped-front design. A few solid fronts are machined to compound curvatures.

Solid wood drawer fronts may be produced from a single board in one piece. The more usual practice, however, is to glue carefully selected narrow boards. In most plants these boards are tongue-and-grooved at the joints. Solid wood fronts are normally of the flat rather than the curved type.

Curved and flat plied fronts may be of the more usual lumber core type or of all veneer construction. In good furniture plied construction is balanced with both faces being of the same species and thickness. Cores for curved fronts are normally band-sawed in multiples from large glued-up blocks. Almost all of the species commonly used for core stock are used for drawer front cores.

Sides

Drawer sides in all pieces investigated in this study were made of solid stock. Plywood has not been very satisfactory for this purpose because of the difficulty of dovetailing the finished drawer side. It is used in some of the cheapest grades of furniture, but when this is done, a tongue-and-groove joint is used rather than a dovetail.[7] Laminated construction has been tried for drawer sides also, but it is difficult to maintain flat stock.[8]

Certain species are traditionally used for drawer sides. Oak was most frequently encountered in the field study. Also found were maple, birch, beech, sycamore, gum, and in one case, hard pine. This stock ranged from 5/16 inch to 3/4 inch in thickness with most indicating that 3/8 inch had been the nominal dimension, leaving about 11/32 inch after sanding. For shallow drawers the sides may be cut from one piece. In most cases, however, and particularly for deep drawers the stock is resawed from glued-up plates. Apparently no attempt is made to select quartered stock or to balance adjoining pieces, and drawer sides often show considerable warpage and transverse expansion at elevated humidities. This transverse expansion is usually the cause for sticking drawers in spring and summer. To eliminate this the drawer sides are often dropped slightly below the height of the drawer front and the dust panel frame above. If the drawer side is lower, however, it permits the drawer to sag when opened. A method formerly used extensively but rarely seen now was to shape out the top edge of the side except for about 3/4 inch at each end. This minimized the area of friction in case of swelling and prevented sag to a greater degree. Rounding or bead moulding of the entire edge also reduces the friction area.

One type of drawer observed had rubber shock-mounted glides on the top and bottom of the drawer back and at each end of the parting rail. The elasticity of the rubber permitted the glides to move with the swelling and shrinking of the various members. It also acted to produce quieter operation. This arrangement did not entirely eliminate sag, however.

In a few cases metal fingers have been installed at the back of the drawer to prevent tipping up. These either have a strong spring to compensate for shrinking and swelling or may be adjusted by hand for various climates.

Because the sides of the drawer have the most important affect on performance, they should be carefully considered in any good design.

Back

The drawer back is usually made from the same stock as the sides and is nearly always the same thickness. The width may not be the same, however. The width of the back is not so critical in shrinking and swelling since it need not bear upon other members above or below. It is often made slightly wider or narrower than the side or the same width as the front.

Prior to the advent of plywood bottoms, the bottom was allowed to run under the back to allow for expansion. When plywood bottoms are used, the back is grooved to receive the bottom in the same way as the front and sides.

Bottoms

When drawer bottoms were made of solid stock or thick veneer, the grain ran parallel to the front, leaving the bottom free to expand under the back. Drawer bottom stock now is almost universally 1/4 inch three-ply plywood with one good face. Its advantages are numerous; dimensional stability, ease of preparation and finishing, and strength, among others.

Although some still recommend that the bottom be cut slightly smaller than the grooves and that it not be glued in tight, most drawer bottoms are now glued securely to the other members by means of glue blocks. The bottom is normally set about 3/4 inch above the bottom edges of the front to allow space for the mullion.

Mullion and Guide

The drawer mullion and guide are intended to keep the drawer from slewing and binding as it is moved in and out. The center guide has become practically standard on all low-medium- to high-grade furniture and has become a hallmark of a "quality" drawer along with the dovetail joint. On observation, however, it was found that in many instances these parts were so poorly manufactured that they had practically no effect in stabilizing the drawer action. This is caused by leaving too much clearance between the sides of the guide and the mullion. Some clearance is essential to allow for dimensional change obviously, but the guide loses its effectiveness entirely if this clearance is not carefully computed.

The usual practice is to make guides and mullions from scrap such as core stock trimmings. This material generally being of the softer hardwood species is fairly stable in dimension but does have rather high coefficients of friction and rather poor resistance to wear. Since most of the weight of the drawer rests on the guide and mullion, smooth, easy operation depends largely on the frictional relationship between the guide and mullion. This can be improved by waxing or soaping one or both of these members.

The mullion also performs a secondary function in acting as a support for the drawer bottom. The two arrangements commonly found are illustrated in Figure 3. The type of mullion which divides the bottom into two separate panels gives some advantage in strength but is more expensive and is used very little at present.

Finish

The finish of the drawer is an important consideration in the design from both the standpoint of appearance and structure. Some drawers show that considerable care and expense have gone into their finish. Others show almost no evidence of any type of finish. Finishes vary from nothing more than a rough-sanding to a rubbed lacquer coat. The interior appearance of a drawer is a significant selling feature.

A good drawer finish seals the wood so that it may be cleaned and dusted readily without becoming spotted or dull. From a production viewpoint it must be economical and easy to apply. The color should, if possible, harmonize with the exterior color of the piece.[9]

About 50 per cent of the drawers which were analyzed in this study had finishes which were graded as less than "good." This arbitrary designation of "good" described a drawer whose surface was relatively smooth, had a uniform color, and was well filled and sealed. Manufacturers of finishing materials market several one-stage drawer coaters. Also many furniture manufacturers have their own "secret" process. Several typical finishes for drawers have been described in a recent book on furniture finishing. These are given in Appendix B of this report.

Finishes also have an important bearing upon the drawer structure. Any sort of sealing coat has some effect on the rapidity with which the various parts pick up moisture. The effect is particularly noticeable when only one side of a solid part is coated. This permits more rapid penetration of moisture on the uncoated side than on the coated side. The result is a gradient moisture condition and unequal swelling -- the elements of warpage. According to the results of some recent tests warpage and dimensional change can be limited somewhat by application of one of several proprietary "dimensional stabilizers."(10) One desk manufacturer has found that all drawer fitting can be eliminated if one of these solutions is applied to the drawers. It is also claimed that this prevents sticking, warpage, and joint failure due to high humidities for short periods of exposure.(11)

Construction

The construction methods used for making the conventional type drawer vary considerably from plant to plant in respect to their details, depending on the kind of machinery available and the scale of the enterprise. Due to the flexibility of woodworking machinery each operation usually can be performed by several different methods. Small shops may perform almost the entire operation on the variety saw. Large production plants will have many specialized machines which can be set up to run hundreds of parts with a minimum of hand labor. Regardless of the physical equipment employed, however, there is a chain of operations which is practically constant for any drawer-making venture.

The degree to which this chain of processes can be made automatic is a large factor in the economics of the drawer. As has been mentioned previously a single drawer may be composed of twenty-five or more parts. Each of these must have several operations performed on it before the drawer is finally finished, and since the labor cost and machine charges on each operation are increasingly significant, it is essential to reduce these elements to a minimum. Other economies can be effected through more efficient handling of materials as they move from one operation to another and through improved motion patterns in each operation. When all possible economies have been realized from these improvements, however, the cost of constructing a conventional type drawer cannot be reduced further.

Just to illustrate the magnitude of the problem, rough process route sheets have been drawn up for a typical drawer, showing the approximate operations required.

This drawer is of the type illustrated in Figure 1. All parts are made of 3/8 inch solid stock except the front and the bottom. The front is 13/16 inch five-ply, lumber core. The bottom is 1/4 inch, three-ply, veneer core. The depth of the drawer is 6 inches at the outside of the front. The finish is a sprayed stain and dipped wax coating.

Oper. No.	Front
1.	Cut rough-planed material to length
2.	Rip core strips
3.	Glue core plates
4.	Condition core plates
5.	Plane core plates to thickness
6.	Rip front cores to rough width
7.	Cut cores to rough length
8.	Clip face veneers to rough size
9.	Clip cross bands to rough size
10.	Ply up fronts
11.	Condition fronts
12.	Size fronts to width
13.	Size fronts to length
14.	Joint edges
15.	Dovetail ends
16.	Bore for pulls
17.	Cut groove for bottom
18.	Sand faces
19.	Sand edges
20.	Sand ends

I	II	2 Sides
1.	10.	Plane resawed side stock to thickness
2.	11.	Rip sides to width
3.	12.	Cut sides to length
4.	13.	Dovetail one end
5.	14.	Dovetail other end
6.	15.	Joint edges
7.	16.	Cut groove for bottom
8.	17.	Sand faces
9.	18.	Sand edges

Back

1-9.	Same operations as on sides

Bottom

1.	Clip veneers to size
2.	Ply up bottom panels
3.	Condition panels
4.	Trim panels to width
5.	Trim panels to length
6.	Sand faces

Mullions

1. Plane stock to thickness
2. Rip to width
3. Shape out channel

Assembly

1. Apply glue to all joints
2. Assemble the front and one side
3. Add bottom
4. Add back
5. Add remaining side
6. Clamp
7. Glue and tack mullion to bottom
8. Rub in glue blocks

Finishing

1. Fill
2. Sand
3. Clean with air
4. Spray stain
5. Dry
6. Dip into wax coating material
7. Dry
8. Wax the mullion channel

Seventy-two major operations are represented in this hypothetical process sheet. Not included in this illustration are the various moves which occur between operations and the operations of finishing the drawer front, trimming, and fitting.

A summary cost analysis of these operations indicates that the labor and burden charges are surprisingly low. A plant of better-than-average efficiency in the Grand Rapids area has reported for a drawer 12 inches x 7 inches x 13 inches a labor cost of $0.96 and a burden of $0.85. At an average rate of about $1.25 per hour for labor, this would indicate that the above operations plus those excluded in the hypothetical process sheet could be performed in a total time of 46.08 minutes. The burden charge including machine rate and all other overhead would average about $0.01 per operation. Material cost was $1.00.

Cost analysis is sufficiently complex and important to become a separate study in the problem of drawers. Consequently, only a brief, comparative study has been included in this report.

The means of construction of drawers are intimately connected with costs. Already manufacturers are beginning to search out new ways of making drawers which are more in tune with modern industrial practice. Just how long the now conventional method of making drawers can survive seems to depend largely upon the ability of the manufacturers to keep costs lower than in newer methods. Some of the new methods now being tried are running a close race with the conventional on costs and with further development may easily fall below.

Performance

Performance is the phase of the drawer problem which is most tangible to the consumer and to the salesman. In the field investigation connected with this study consumers and retail salesmen were sounded out on various aspects of the problem. Performance was always the thing that concerned them most. Nearly every consumer questioned had several complaints which discredited the conventional wood drawer. These ranged from instances of sticking in summer to complaints of bottoms falling out.

One interesting opinion held by all of the retail salesmen questioned was -- "You get what you pay for in a drawer." It was observed in the tests made, however, that there is a very imperfect relationship between price and performance. Often the performance of drawers in a low-medium priced piece was as good or better than that in a high-priced piece.

New pieces were tested which ranged from a buffet at $425 to a three-drawer chest at $44. The fault which occurred most often was the tendency of the drawer to sag in an extended position. In some cases this sag was as much as two inches, but the average was about three-quarters inch. The tendency for the drawer to slew noticeably as it was moved in and out was also a common fault. This defect, if great enough, causes the drawer to bind. If it is present in a lesser degree, the only trouble may be a noisy action.

In only a very few of the tests could it be said that the operation of the drawer was really pleasing. The feeling of operating a well-oiled machine was seldom experienced. It seems then that a drawer can be free of major faults and still not be ideal from the standpoint of performance. This added feature of performance, which is extremely important in influencing the consumer, could often be achieved at very little cost. Frictional qualities can easily be improved by the addition of rollers or even thumb tacks at points of contact. A heavy coating of wax may be sufficient for temporary improvement.

Most of the tests were made in April. Inside humidity was moderate and very little sticking was experienced in the new pieces. In many of these pieces, however, considerable clearance had been left to compensate for swelling. This is not altogether satisfactory since the drawer tends to rattle in dry weather and does not effect a good dust seal.

Several pieces were tested which had been in service for periods ranging from four years to approximately eighty years. These pieces seemed to represent a fairly wide spread in price range. It was difficult to determine whether or not any of these pieces had been restored during its period of service, but it appeared that none had been.

The defects found in these pieces were naturally more pronounced than in new pieces. In the oldest pieces mechanical wear on wood parts was quite noticeable, particularly on the drawer sides. The face of the drawer seldom lined up in its intended position because of the wear on the drawer stops. In a desk which was estimated to have been in service about forty-five years several of the drawer sides which were made of glued up stock had partially failed at the glue lines. Most of the dovetail corner joints had complete glue failure. Drawer bottoms were all loose and tended to slide out the back. The newer pieces, however, showed no more defects than those on sales floors.

A comprehensive picture of drawer performance and the attitude of the consumer would require a much larger sampling than has been made for this report. It is believed, however, that the conditions in general have been fairly well established.

Conclusions

1. On the basis of the field study and general knowledge, it can be concluded that this general design type represents about 90 - 95% of all wood drawer construction for medium- and high-grade furniture.
2. Conventional drawer practice is deeply entrenched in the furniture industry and stringently limits freedom in designing drawers. Even within these narrow limits, however, variations in design considerably affect costs and establish, in conjunction with precision of manufacture, the performance level of the drawer.
3. The dovetail joint is now used more for its prestige value than for the inherent strength properties of the joint in its machine-produced half-round form. It is relatively costly to manufacture well. The superiority of this joint over other simpler types that might replace it is questionable.
4. No entirely successful way has been found to design drawers that will not stick in humid weather and yet not be too loose in dry weather.
5. Another effect of too large a clearance is a noticeable sag of the drawer when extended. This is one of the major problems of performance.
6. The recommended center guide assembly often performs no other function than to provide the salesman with a talking point. High coefficients of friction between the guide and mullion often cause the drawer to have an uneven, noisy action.
7. Plywood bottoms are very much superior to lumber or veneer bottoms. Drawer designs seldom take full advantage of the strength qualities of the plywood.
8. Dimensional change and warpage may be retarded by the use of "dimensional

stabilizers." This tends to eliminate drawer fitting and makes interchangeability possible.

9. A drawer of conventional design may contain as many as twenty-five separate parts. Large numbers of parts militate against economical production. The cost of the conventional method, however, is still as low or lower than other available methods.

10. Drawer performance plays an important part in consumer acceptance of furniture.

Recommendations

It is recommended that individual research projects be conducted on the following:

1. Efficiency of the dovetail joint in comparison with simpler types.
2. Structural changes to avoid effect of dimensional change.
3. Effect of "dimensional stabilizers" on the shrinking and swelling of drawers.
4. Methods of eliminating drawer sag.
5. The correct tolerances for drawer guides and mullions of several species.
6. The effect of species and finish on the coefficient of friction of drawer guides and mullions.
7. Better utilization of the panel strength of the plywood drawer bottom.
8. Reducing the total number of parts in the drawer.
9. Determine the average costs of manufacturing drawers in the furniture industry.
10. Make a survey of consumers to get their reaction on the drawer problem.

OTHER TYPES OF DRAWERS

About five per cent of the drawers used in wood household furniture differ basically from the conventional type. Most of these have been developed recently for use in furniture of the style popularly known as "functional." Because of the fundamental structural innovations in this type of furniture it has often been desirable or necessary to change the type of drawer and the way in which it is suspended. In almost all instances these changes have been in the direction of simplification with an attempt to modify the design to harmonize with modern production techniques.

Some of the most interesting of these developments have not yet been tried on a production basis. Two methods included here seem very logical in their approach to the solution of the drawer problem and most certainly would bear more extensive investigation.

Consumer reaction apparently has not been unfavorable to unconventional drawers where performance standards have been maintained or improved. Since these drawers are normally associated with furniture which appeals to consumers willing to forget tradition, it is not determinable, however, just what response can be expected from consumers in general.

Side Suspensions

Drawer by Cessna Aircraft Company

In a line of furniture recently brought out by the Cessna Aircraft Company of Wichita, Kansas, the drawers have been made of a combination of wood and aluminum. (See Fig. 4) The sides and bottom are stamped from .032 3S$\frac{1}{2}$H aluminum as a single piece and a back of the same material is spot-welded to this unit. A five-ply veneered front which matches the exterior panels is screwed to the aluminum drawer body.

The entire design of this line of furniture is unconventional; it makes use of a steel frame covered with a plywood skin. The drawers are suspended at the sides from .050 body steel "U" channels which are structural parts of the framework. There are no dust panel frames in this construction, and no cross-bracing is used except on the back of the frames of large cases. The drawer guide is a specially shaped channel of .064 61SW aluminum which is spot-welded to the drawer side (See Fig. 4). In order to deaden the metallic sound of the drawer action the bottoms are sprayed with a coat of sound-deadening agent approximately 1/16 inch thick.

This line of furniture has been placed on the market so recently that it has not been possible to make a performance test. Consequently, no comments will be made other than that metal drawers have not generally been accepted for use in household furniture.

It was found, on the basis of a rough comparison, that the cost of producing a drawer of this type is about 30% less than for a conventional wood drawer of the same size. Materials are about the same; labor cost is approximately 30% of that for the wood drawer; and the burden is about 40%.

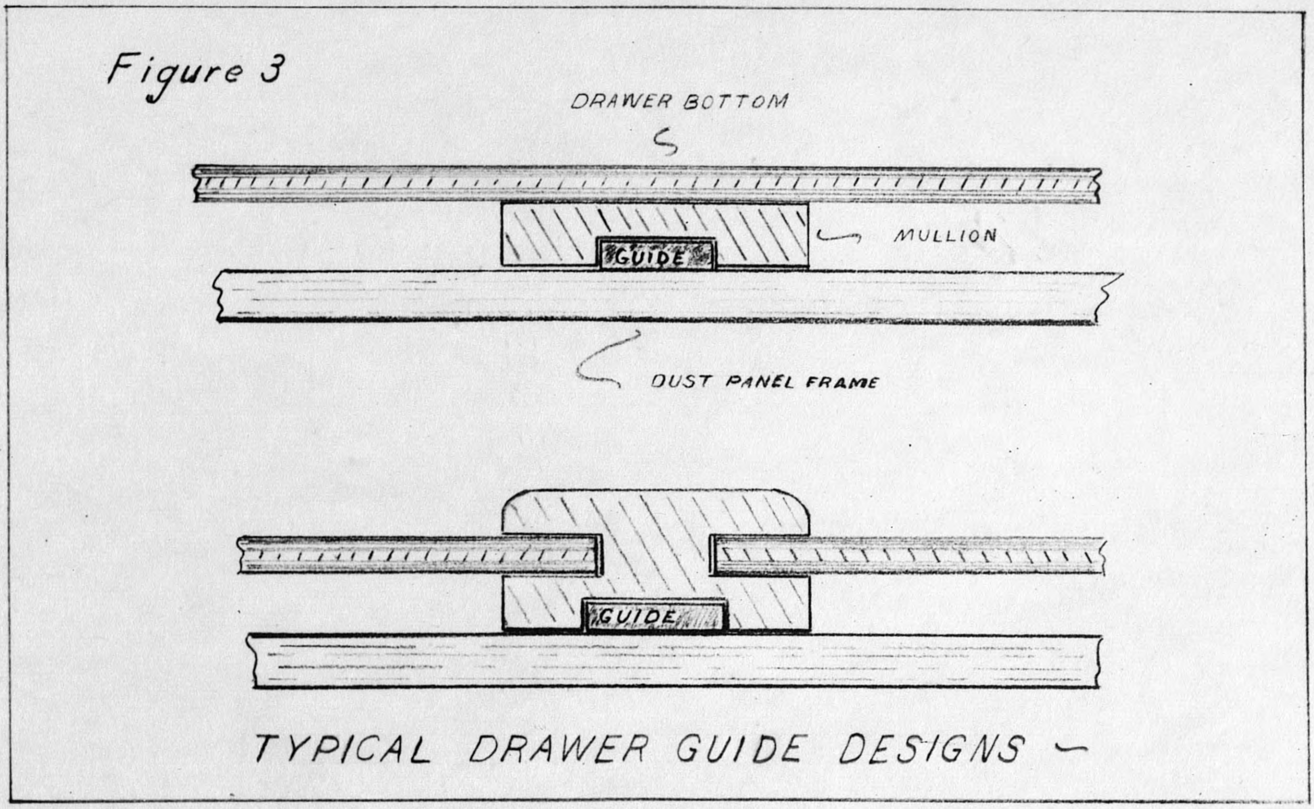


Figure 3
DRAWER BOTTOM
MULLION
GUIDE
DUST PANEL FRAME
GUIDE
TYPICAL DRAWER GUIDE DESIGNS

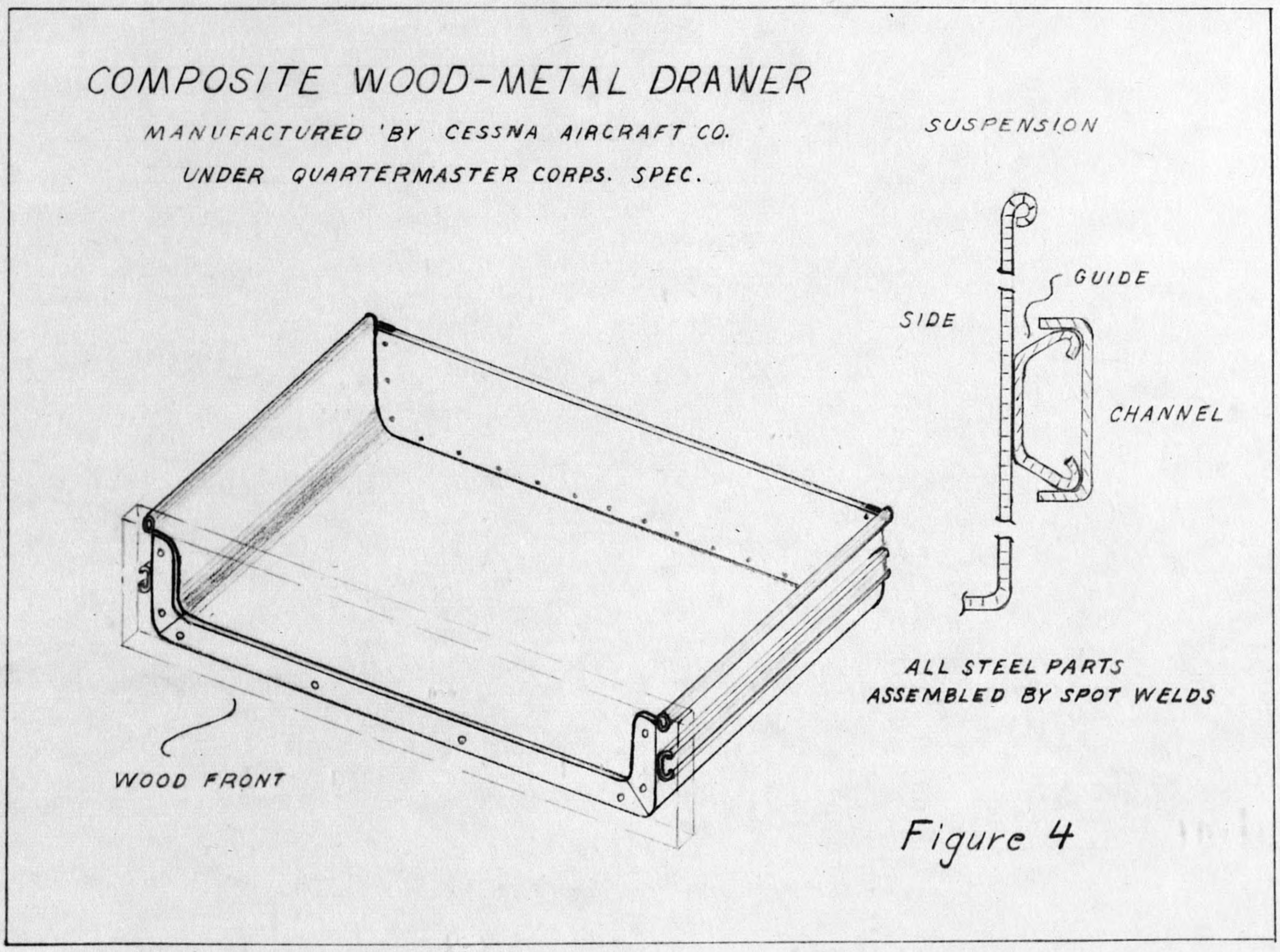

COMPOSITE WOOD-METAL DRAWER
MANUFACTURED BY CESSNA AIRCRAFT CO.
UNDER QUARTERMASTER CORPS. SPEC.
SUSPENSION
GUIDE
SIDE
CHANNEL
ALL STEEL PARTS
ASSEMBLED BY SPOT WELDS
WOOD FRONT
Figure 4

PLATE III

Conclusions:

1. Considerable economy is effected by reducing the number of separate parts and operations.
2. Certain materials may be more adaptable to large-scale drawer production than wood.

Drawer by Herman Miller Furniture Company

The standard drawer designed by George Nelson for the Herman Miller Furniture Company of Zeeland, Michigan, is suspended from the side panels of the case (See Fig. 5). The structural parts of this case consist only of the top, bottom, and side panels and the back. The case is of the flush mitered corner type. There is no interior framework or parting rails, and dust panels have been eliminated. When the drawers are removed, there are no internal projections except the 3/4 inch dowels which support the drawers (See Fig. 5).

Obviously the use of a center guide and conventional suspension was impossible in a case of this structure. A simple side suspension and guide have been used instead. Three-quarter inch dowels extend from the side panels about 5/8 inch into a channel cut into the drawer side. The channel in the drawer side extends from the back of the drawer to a point about 2 inches from the front. The position of the front dowel and the end of the channel are so located that the dowel acts as a stop for the drawer in its closed position.

In general, the structure of the drawer is quite similar to the conventional design with the exception of the sides, which have been increased in width to 5/8 inch in order that they may be routed out for the guide channel.

Figure 5

DRAWER WITH SIDE SUSPENSION

MANUFACTURED BY HERMAN MILLER FURN. CO.

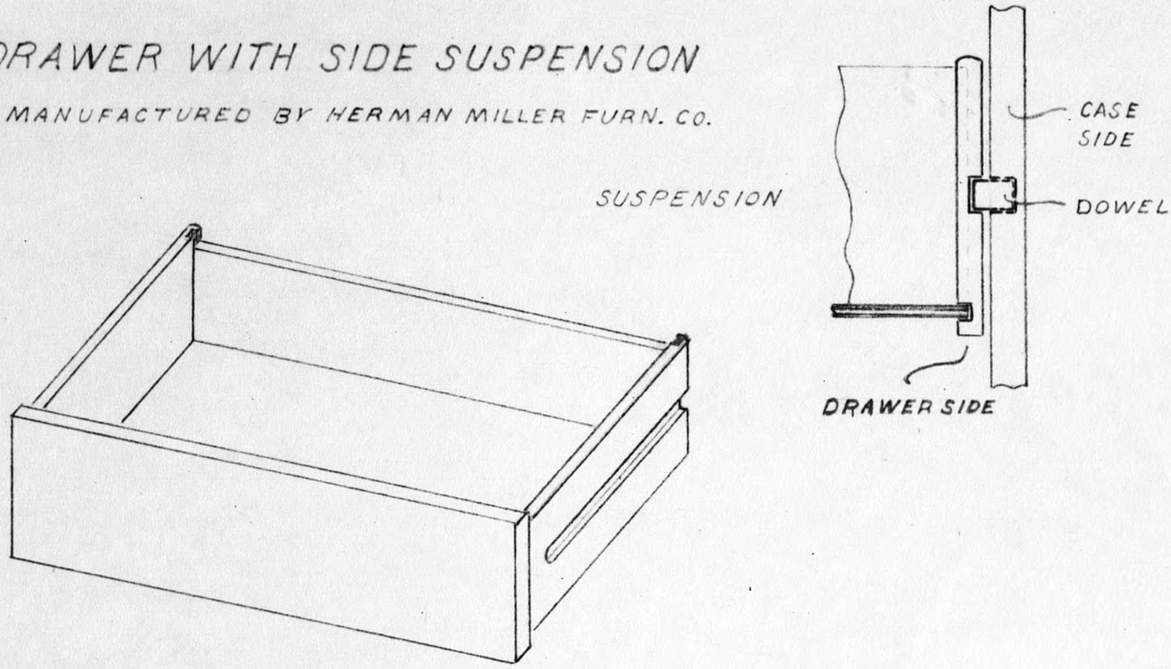


Figure 6

DRAWER WITH SIDE SUSPENSION

MANUFACTURED AND PATENTED BY
MORGAN FURNITURE CO.

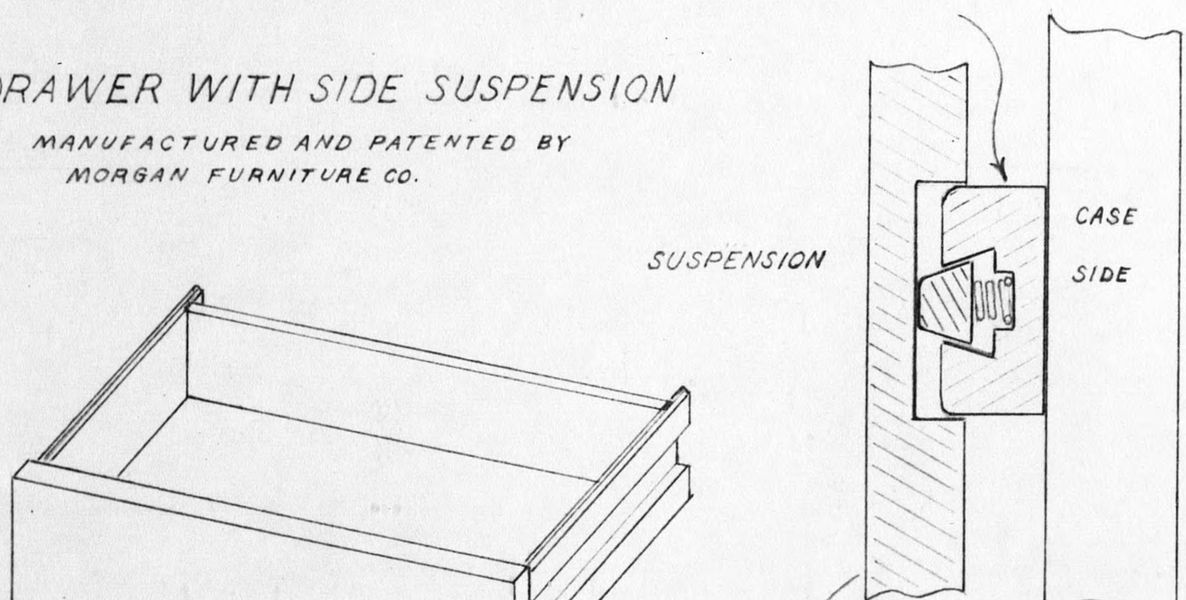


PLATE IV

It was observed that this drawer was somewhat looser in action than the average conventional drawer. There was a noticeable tendency for the drawer to slew in opening and closing, but there was very little binding. The tendency to sag was somewhat less than the average conventional drawer.

Conclusions:

1. Side suspension is essential for this type of case.
2. The performance of this type of drawer is about equivalent to the average conventional drawers.
3. The trend toward simplification is encouraging in respect to economy.

Drawer by Morgan Furniture Company

The Morgan Furniture Company of Asheville, North Carolina has recently developed a side suspension type of drawer which incorporates several new features (See Fig. 6). The case used by this company is basically similar to the Herman Miller case described on page 43. Therefore side suspension was essential.

A patented spring-controlled guide (See Fig. 6) forms a dustproof seal at the side of the drawer and prevents sticking by controlled alignment throughout its travel.

The drawer itself departs from the usual practice to some extent in that simple rabbet joints are used at both front and back corners. This is an unusual variation for a piece of this grade (high-medium). The drawer sides are 3/4 inch to allow for the channel.

It was observed that this drawer moved with some difficulty due to the friction of the spring controlled guide against the side of the channel. Although there was a noticeable tendency for the drawer to slew, it did not produce binding.

Conclusions:

1. Side suspension was required by the case design.
2. This system is probably too expensive to be used in most furniture.
3. The action of the drawer should be smoother and freer.
4. Dovetail joints can be successfully replaced by simpler joints in quality furniture.

Curved Plywood Drawer

The Mengel Company of Louisville, Kentucky, was one of the first manufacturers to introduce an unconventional type of drawer. Their "Permaslide" drawer was developed after considerable technical and consumer research.

The drawer which was developed has bottoms and sides formed as one continuous sheet of mould-curved plywood. The upper edges of the plywood sheet are let into solid wood members which are channeled on the outer side to mate with the drawer guide (See Fig. 7). The drawer guides are doweled to the side panels and run the full length of the drawer. Both the front and back are grooved to the right curvature to take the curved plywood.

No technical information was available for this drawer, but it was observed that oak had been used for the face and that the grain ran across the drawer. The back veneer was one of the softer hardwoods.

The performance of the drawer was observed to be only moderately good. It showed a very marked tendency to slew with some binding. There was also a greater-than-average sag at full extension.

Since the Mengel Company uses this drawer construction only in their most expensive lines, it is assumed that the cost is comparatively high.

Conclusions:

1. This type of drawer is not practicable for general use unless its cost can be reduced.

Figure 7

CURVED PLYWOOD DRAWER

MANUFACTURED & PATENTED BY THE MENGEL CO.

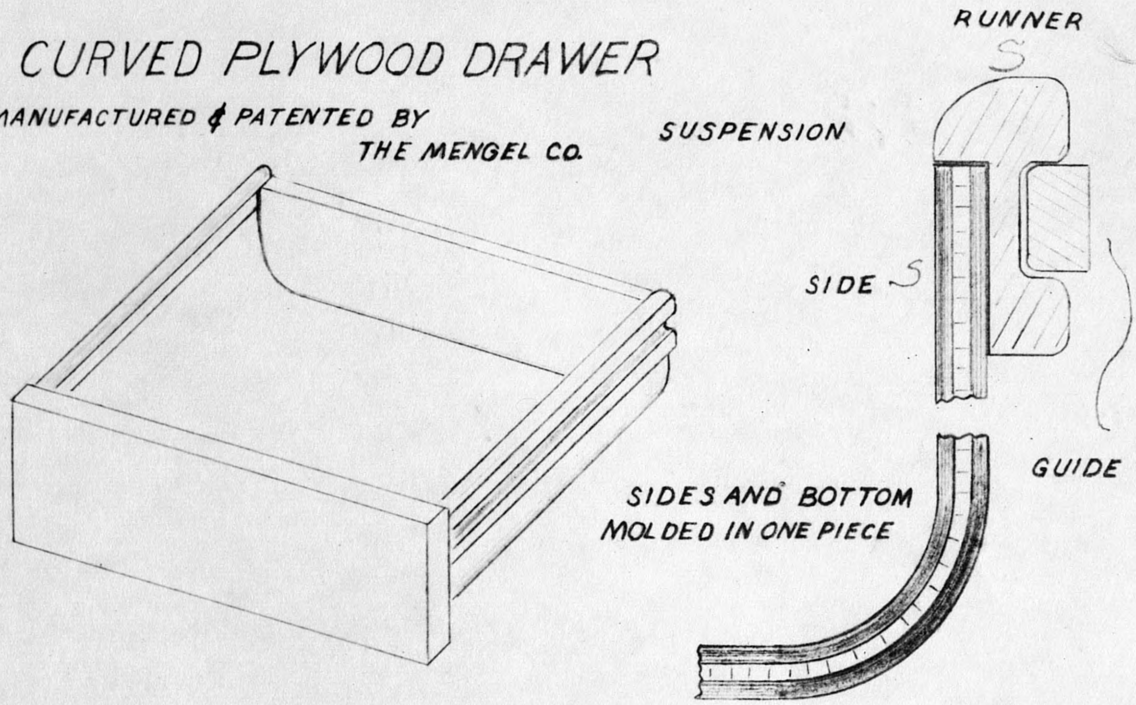
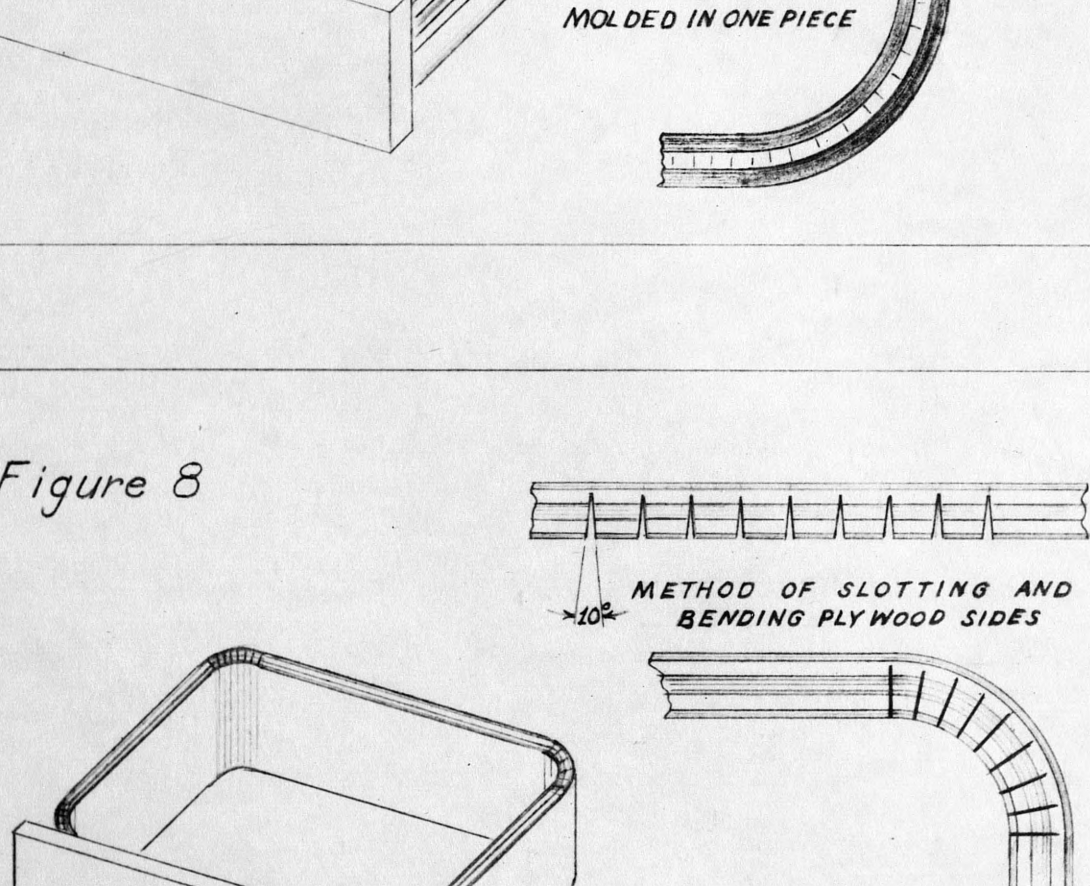


Figure 8



BENT PLYWOOD DRAWER

DEVELOPED FOR THE VENEER ASSOCIATION, INC. BY L.A. PATRONSKY - A.K. LAHTI UNIVERSITY OF MICHIGAN

PLATE V

2. Performance should be improved.

Bent Plywood Drawer

A bent plywood drawer was developed in 1945 at the Wood Utilization Laboratory, University of Michigan, as a part of a project on veneer products for The Veneer Association, Inc. Wm. Kynoch and L. A. Patronsky of the School of Forestry and Conservation and A. K. Lahti of the College of Architecture and Design were responsible for its development.

After considerable experimentation with methods of producing curved plywood, it was determined that the method of slotting with 10° V cutters could best be applied to drawers (See Fig. 8). It was found that this method "produced both clean, smooth corners ...... and sides free of stresses that might result in subsequent bowing and drawer sticking."[12]

The drawer as finally developed consists of two sheets of plywood -- one which forms the front, the back, and the sides of the drawer and one which forms the bottom. The first is grooved about 1/4 inch from one edge to receive the bottom. A front is usually added which is made of solid wood or thicker plywood. It was found that 3/8 inch birch-face plywood was suitable for the back-and-sides unit and that bottoms of 1/4 inch plywood were satisfactory. The adhesive used to stabilize the V-slot corners was a resorcinal resin.

On a mass production basis this drawer shows considerable promise. Using a series of V-cutter gangs spaced on a single shaft entire sheets of plywood could be cut with one pass. Another pass through a series of dado heads would cut the grooves for the bottoms. A third pass through a series of saws would cut the individual drawer panels. The assembly procedure is relatively simple and could be readily mechanized with a minimum of jigs and fixtures.

At the time this drawer was developed a preliminary cost study showed that the cost of making the drawer on a semi-mass production basis was only slightly higher than for the conventional drawer.

A number of these drawers have been in service since 1945 and even under extremely heavy loading have stood up very well. No special suspension has ever been devised for this drawer. Conventional suspension proves to be subject to the same faults with this drawer as with the conventional type.

Conclusions:

1. This is one of the strongest drawers yet devised.
2. This design closely approaches the ideal of one-piece construction.
3. This type of drawer is suitable for a high rate of production.

Felted Pulp Drawer

The felted pulp drawer is not an actual achievement but rather is a suggested use of a pulp-felting method developed by the Armour Research Foundation, of the Illinois Institute of Technology. The general purpose of this project was to develop a low-cost method of producing furniture.

Since the technical description of this process is rather complex, the Foundation's report as published in their organ, "The Frontier," is included in this report as Appendix C. Flow charts of the process are shown in Figure 9.

The resin-impregnated felted preforms may be handled in either of two ways. If a dense, hard product is desired, the preform may be cured under pressure. If a lighter, slightly dimpled product is satisfactory, however, an oven cure is sufficient. This will explain the separate flow sheets.

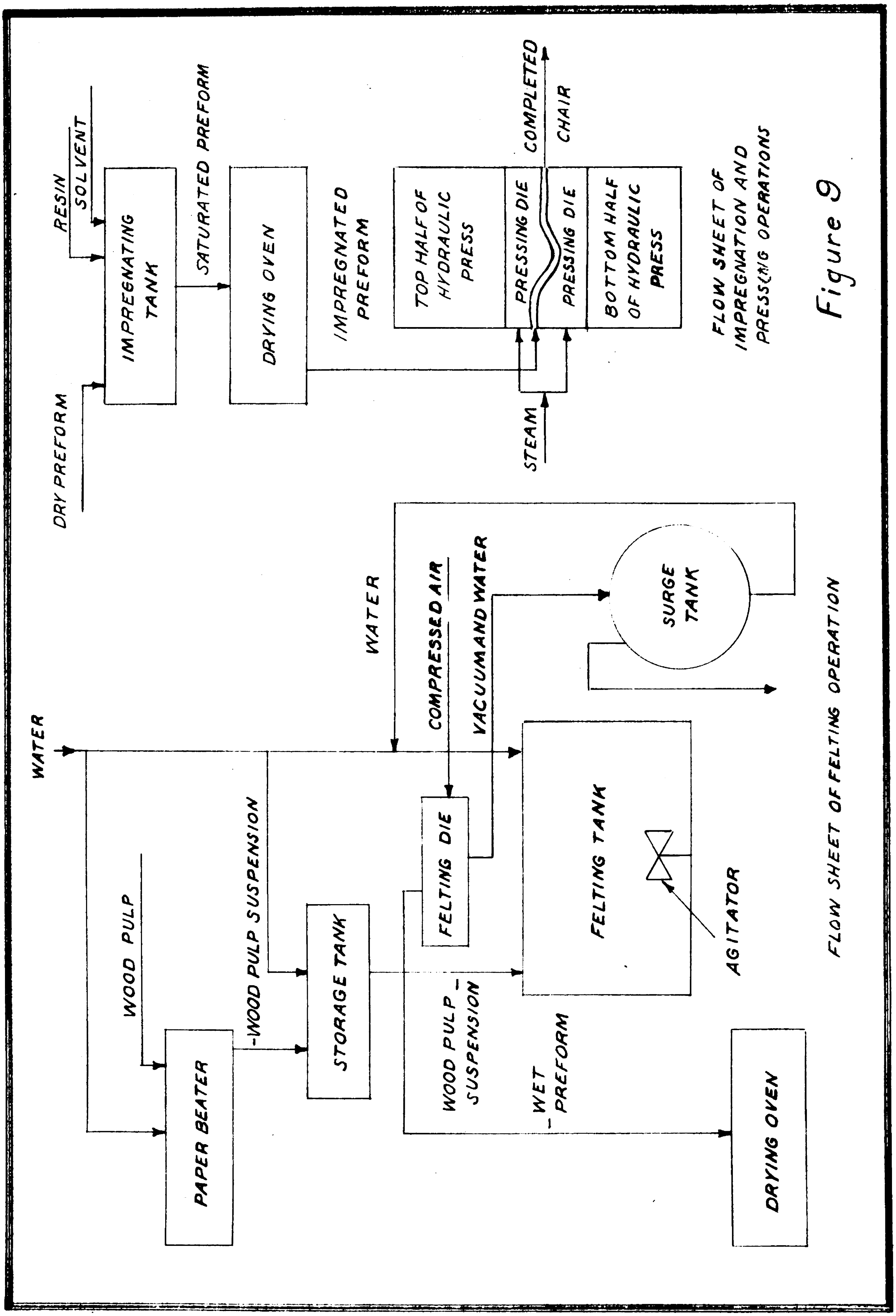


Figure 9

PLATE VI

According to the technical and cost information released by the Armour Research Foundation, this process shows considerable promise. The major drawback seems to be the relatively large cost of setting up a set of dies for an operation involving several sizes of drawers.[13] Perhaps the only way this could be made to work for the average furniture manufacturer is through contracting for his drawers from a large-scale supplier.

Conclusions:

1. This method reaches the ideal of one-piece construction.
2. A very acceptable drawer could be made by this process.
3. This method appears to be an economic possibility -- in fact may be considerably lower in cost than present methods.

APPENDIX A

EXCERPTS FROM PERSONAL COMMUNICATIONS

1. Mr. George Nelson, Designer, on January 27, 1949, stated:

"Technically, the wood drawer is an anachronism; obviously it should be formed somehow as a single unit. Since most people are aware of this fact and no one to date has come up with an answer, I don't quite know what to say. We did some research on the possibility of forming drawers using various materials and in each case were defeated by the enormous quantities required.

"I would imagine that with laboratory facilities at your disposal, the problem would become one of investigating every technique that looked reasonably promising and then going through a rigorous costing procedure. I suspect that the latter is more difficult than the former because the tendency to gloss over the facts of life when one likes a design is practically irresistible.

"My best guess on materials -- and this guess is not worth a great deal -- is that sheet metal offers the best possibilities for a solution. Glass fibre, plastics and plywood all seem to turn out to be much too expensive."

2. Mr. Edward J. Wormley, Designer, on February 3, 1949, stated:

"A couple of years ago, ... I carried on a considerable correspondence with the Columbian Rope Company (Allied Products Division), Auburn, New York, about the molding of one-piece drawer interiors by a process they had used for making a one-piece baby-carriage body.

"In general, the technique and problems were somewhat similar to those employed by James Prestini for his molded one-piece chair which you have probably read about in reports on the low cost furniture competition sponsored by the Museum of Modern Art in New York..........

"The great difficulty, of course, either for the production of the Prestini chair or for drawer construction is the cost of dies. I have understood from Mr. Prestini or one of his helpers that the dies to produce his chair would cost in the neighborhood of fifty thousand dollars. A series of dies necessary to create a system of graduated standardized drawer interiors would cost several hundred thousand dollars, no doubt, whether the Prestini mesh-and-pulp method method were used or a molded product such as the plasticized wood fiber baby-carriage developed by the Columbian Rope Company. The furniture industry must grow up, however, and realize that such big-time expenditures are necessary before it can escape the yoke of mechanized handicraft processes from which it now suffers."

3. Mr. Herbert Ten Have, Designer, Grand Rapids Chair Company, on January 13, 1949, stated:

"The development of a better construction certainly would be welcome."

4. Mr. William A. Spencer, Asst.-Public Relations, Armour Research Foundation, on February 23, 1949, stated:

"The pulp felting method of making furniture was one phase of the furniture study and forms a part of the report which went to the Museum of Modern Art. A pilot plant was set up to investigate the feasibility of this method. I am enclosing a copy of the Foundation's house organ, The Frontier, which contains an article describing the method.

"The aspect of cost is discussed briefly in the article. Informed technical opinion would seem to be the only way to examine the cost element, and I have been told that resin-impregnated fiber offers definite possibilities. Extensive economics data would require further research, of course; and we do hope to do this. The virtual elimination of hand labor and joints has been mentioned as a cost factor, while the acquisition of dies and presses in the beginning would require a rather substantial investment. Rapid production would be possible, however.

"It is interesting that drawers have been mentioned as a possible item to be fabricated by pulp felting. The lack of joints in felted pieces has been mentioned specifically in regard to drawers which, as you know, present problems of manufacture along that line."

5. Mr. Art Pieritz, of the Seng Company, on March 8, 1949, stated:

"Our experience has been that in stamped metal drawers the cost runs approximate 5 times higher than the conventional wood drawers. I speak of this in conjunction with office furniture, and the variable sizes required in this type generally means the necessity of making considerable additional tooling, thereby increasing the price to the point where they could not be sold competitively in the general run of office desks."

On February 8, 1949, Mr. Pieritz had stated:

"You are no doubt acquainted with the present construction of drawers as are used in wood desks. There has been much discussion regarding the possibility of having these drawers work more smoothly and easily when they are loaded with the articles that are ordinarily put in office desk drawers. We have constructed and now have in production several types of mechanical devices for use on these drawers to simplify their operation.....

"Then our "Rolls Runner drawer suspension which is an exceptional "piece of equipment and takes approximately 3" on each side of the drawer panel. This mechanism is entirely encased around two sets of rollers, there being no contact between the rollers and the wood. However, this is not in production although very well accepted by the desk manufacturers. The reason for it not being used is due to its excessive cost. Print of this mechanism is also attached.

"We have recently gone into production of our #290 drawer suspension, which is made up of a pair of channels, one on each side of the desk panel. Rollers on a bracket are fastened to the back of the drawer and the rollers are inserted into the side channels. A pair of rollers is also fastened to the side of the desk pedestal at the front at the bottom of the drawer. In this way the drawer is hanging on the back top when the drawer is all the way in, and the bottom of the drawer sides are rolling entirely on the front lower rollers.....

"The purpose of these drawer suspensions is to give full extension of the drawers at a minimum cost, and to prevent drawer sag when in the extended position. The ideal situation for full drawer suspension is a progressive extension slide as is used generally in filing cases, but this type is not used because of its excessive cost.

"In the past we have advocated that drawers could be stamped out of metal as one piece and have a wood front fastened thereon. However, the cost on these is so much higher than the present wood construction that this idea has not been incorporated in most wood constructed furniture.

"In many metal desks of higher quality all of the drawers are equipped with the regular extension slides and are not as costly when installed in metal desks. This is because arrangements can be made in production to offset some of the necessary channels as a part of the drawer and pedestal construction.

"We have done considerable test work on all of our drawer suspensions mentioned above, and they have all performed exceptionally well at a reasonable cost of installation."

6. Mr. David B. Morgan, Jr., of the Morgan Furniture Company, wrote on March 28, 1949:

"We do have a new spring action controlled drawer construction and our experiences have been very good so far and has eliminated to a great extent pasttroubles with drawers sticking in damp weather and in more humid climates. Various tests have proven successful."

On April 13, 1949, Mr. Morgan wrote:

"We have had several engineering tests made as regards strength all being satisfactory. Further analysis should be made before final recommendations or conclusions are drawn. As you can see from observation, the assembly of the case is relatively simple once the proper tooling and machinery is made in order to perform the operation accurately."

7. Mr. C. D. Dosker, President, Gamble Brothers, wrote on May 9, 1949:

"Plywood drawer sides have not been very satisfactory nor have they been very acceptable in the furniture trade. The principal problem has been one of difficulty in dovetailing the finished drawer side.

"Some furniture manufacturers do use a plywood drawer side, but when they do so it is usually with a tongue and grove construction rather than with a dovetail construction on the corners. For the most part, plywood drawer sides are only used in the cheapest grades of furniture.

"Some drawer sides have been made in plywood in parallel laminates, but here again is a difficulty produced in maintaining flat stock. Where "these drawers are made, it is done with special precaution in maintaining flat stock by thoroughly re-drying veneers and balancing the two plies or three plies that make the drawer side. Drawer sides made in this fashion are more costly than drawer sides produced from re-sawing lumber."

8. Mr. Roger R. Smith of the Pressed Wood Corporation wrote on March 31, 1949:

"We have your letter of March 28th and we are not far enough along with our moulding process to know whether it is possible to make a drawer in one piece or not.

"We know that it can be made of flat moulded sheets and then fabricated, but to mould the same completely at one time we regret to advise we are unable to answer your question."

9. A technical adviser for the National Furniture Review wrote the following material to Miss Mary Seaman, Editorial Director, who forwarded it on February 28, 1949:

"The drawer is an ear mark of well made furniture. No one wants to buy furniture equipped with drawers that are hard to open and not properly fitted. That is, they have to be loose enough to move smoothly and yet not so loose as to permit a wide opening through which dust can enter.

"The important thing of good drawer construction is to have a center drawer guide. It prevents the drawer from jamming when open. In well made furniture there usually are thumb tacks at both ends of the rail to provide a smooth surface on which the drawer will slide.

"Well made drawer construction calls for dove-tailed joints at the corners. The drawer bottom, which should be of three ply construction, "should be rabbitted into the sides. There should be a stop at the back to prevent the drawer from being pushed in too far. Another feature of good drawer construction is to have the bottom faced with mahogany or oak. In high quality furniture the drawer side is made with the same kind of wood that is used on the exterior, such as walnut or mahogany.

"A good test of drawer construction is to remove the drawer, turn it upside down and then 'touch it,' if it rattles then the bottom is not securely glued."

APPENDIX B

SUGGESTED DRAWER FINISHES[14]

Close-Pored Woods

1. Shellac.--One coat of the pure orange article, three to four and one-half pound cut, drys quickly, fills well and gives a fairly agreeable natural lustre without rubbing. However it mars readily on contact with moisture.

2. Shellac Substitute.--Usually cheaper than the above and popular chiefly for this reason. A few are waterproof, but most are not; when tinted with alcohol soluble anilines the color will fade and possibly come off on contact with moisture, as spirit colors are partially soluble in water.

3. Wax.--Over one coat of shellac or substitute, wax offers a surface easy to keep clean and more agreeable in lustre than either of the above. The wax may be tinted.

4. Wax.--Used alone it is a purely temporary proposition. When tinted with color in oil, heat or contact with anything greasy or oily may soften it and cause the color to come off. If wax alone is applied, the wood must be sanded extra smooth.

5. Varnish Leavings.--A slush coat may be made by working over the drippings and skins of varnish with benzine that will answer as a finish on very cheap work. Unless the mixture is well strained it gives a coarse finish with an uneven gloss. An economy job pure and simple best suited to backs.

6. Flat Varnish.--Very popular for the better class of furniture, usually applied over a first coat of shellac, substitute, or varnish first-coater. Possesses much of the merit of wax with none of the drawbacks, though naturally more expensive in cost and slower in drying than any of the above.

7. Oil.--This method operates as follows: Apply two thin coats of shellac or substitute; sand and oil off with a rag saturated in paraffin oil. This is quick and inexpensive and gives an agreeable lustre, but is not durable and may be affected by heat.

8. Drawer Coater.--There are a number of leading brands most of which are based on one or another of the above. They are waterproof, may be obtained tinted, and vary in cost and speed of drying according to whether on a shellac, substitute or varnish base.

9. Coach Varnish.--May be obtained at low cost and makes an excellent undercoat for wax or flat varnish, but alone is not recommended on porous softwoods and does not give an agreeable lustre. It is sometimes tinted a light oak or walnut shade by adding a little asphaltum varnish. One objection, which also applies to varnish leavings is that hot weather may tend to make it sticky.

10. Rubbing Varnish.--When employed as a drawer finish only a light rub is given--just enough to knock off the gloss. An undercoat is required as for flat varnish; for a tinted effect the wood must first be stained or wiped over with filler. This is distinctly a quality method for quality furniture.

11. Lacquer.--Excellent over filler on open-pored woods and is waterproof, quick drying and tight sealing, but used alone lacks body and filling qualities and possesses an odor that lingers in closed interiors. Lacquer may be tinted in all wood shades with spirit soluble anilines and at least two coats should be applied, the first lacquer or lacquer sealer, the second flat lacquer for its agreeable lustre.

Open-Pored Woods and Cedar

These may be finished the same as above except that paste wood filler of desired shade is required first. Where filler is used no stain need be applied even on high class work as it imparts sufficient coloring in being wiped off. Liquid filler will often serve for this "wash" veneers on bottoms. Aromatic cedar should be left unfinished.

Coloring

On cheaper work an orange tone as found in shellac or the amber tone of substitute or varnish is sufficient, except possibly in the case of very white woods like birch. Where stain is used it should be reduced many shades lighter than the exterior, but should harmonize in tone; thinned paste wood filler may be wiped on the wood and then quickly wiped off to give a semi-stained effect at low cost.

Application

A well sanded drawer or interior is already half finished. If stained or filled the drawer bottoms may be dipped, dried and then assembled to be finished by spraying. All but lacquer and some substitute shellacs may be successfully applied by brushing as well as spraying and very cheap work can be dipped in varnish, reduced very thin. Varnish on work of any quality, however, should never be applied to the outside edges of drawers as it becomes gummy with heat and causes the drawer to stick. Wax is best for all points of contact between drawer and frame.

Appendix C

RESEARCH IN RESIN IMPREGNATED FIBER FOR LOW-COST FURNITURE (15)

Foundation Scientists Develop A Method of Making Sturdy, Attractive Furniture Rapidly and Economically

By Layton C. Kinney and George G. Ference
Chemical Engineer   Associate Chemical Engineer
Armour Research Foundation

It has long been evident that present methods of furniture manufacture are not adaptable to mass production techniques. Throughout the ages the only improvement which has been made has been to motorize what were previously hand methods of cutting, shaping and finishing. Although this has somewhat reduced the amount of manpower required per unit of furniture, it has not decreased the number of parts nor changed the fact that these parts must be assembled and integrated manually by means of various joining procedures. As the design of a piece of furniture becomes more complex, the amount of manpower required per unit of furniture becomes correspondingly greater.

The use of wood lumber in the manufacture of furniture is wasteful. First, only straight trees may be used for the lumber. This lumber must also be straight grained, free of knots, and be carefully cured before it is suitable for use. Then, in the shaping process sawdust, shavings, and odds and ends are produced which, in most cases, cannot be utilized and have been the bane of many furniture manufacturers' existence. As the design of the furniture attempts to deviate from the angular contours dictated by the limitations of the material, the amount of rejects increases sharply.

As a general rule, the life of a piece of wooden furniture is not terminated by failures of the wood but by failures of the joints used in holding the furniture together. As joints are improved, costs go up.

For the foregoing reasons, furniture having a reasonable degree of aesthetic appeal, durability, and comfort has become increasingly expensive. Consequently, although the volume of sales is large, most manufacturers are forced to operate with only a narrow margin of profit.

EXPLORE NEW METHODS

From a general consideration of the shortcomings of materials and methods now used in furniture manufacture, Armour Research Foundation decided to explore the possibilities of devising a method of furniture manufacture conducive to mass production operations which would use low cost materials with little or no waste and which would minimize or entirely eliminate the use of joints in holding the furniture together.

Since Armour Research Foundation has had broad experience in felting pulp of various materials into desired contours, it was thought that wood pulp could be felted into the contour of certain designed chairs. The Chemical Engineering Department undertook the development of a plastic impregnated wood pulp to meet these needs. The resultant form could be strengthened by impregnating it with resin and then the whole could be compression molded or could be cured unpressed as desired. Accordingly, a pilot plant was set up to explore the possibilities of this approach.

Wood pulp can be and was obtained from paper mills since paper mills are in a position to recover all cellulose portions of a tree regardless of whether it is crooked, cross-grained, knotty or defective in other ways which would make it unsuitable for lumber. This pulp as obtained in sheets of unbleached northern kraft paper, was broken down in a water suspension by means of a paper beater. The action of the beater is such that physical changes were brought about in the pulp fibers -- one such characteristic being the rate of drainage of water through the mats made from the fiber.

This drainage rate is known as freeness, and is a critical factor in controlling the characteristics of the felted preform.

PREPARE PREFORM

The beaten pulp was then placed in a felting tank where water was added as needed to bring the pulp to the desired consistency. The tank was equipped with an agitator to keep the pulp in uniform suspension. The consistency of the suspension was such that approximately 50 gallons contained only one pound of pulp. This is to insure that the fibers will be free to orient themselves in an interlaced structure without matting or balling.

A preform was made by lowering a felting die into the pulp in felting tank. The felting die was a hollow casting conforming to the contour of the under side of the body of a chair, which combines the seat and back in one piece. The felting portion of the die was drilled with drainage holes which were interconnected on top by grooves. Over this was attached a copper screen. The die was fastened to a metal plate having connections to a vacuum system. The principle employed was that used in paper making except that a contoured die was used instead of a flat screen. The vacuum pulled the pulp suspension to the felting tank, the preform was blown water was drawn through the screen and holes into a surge tank where it was stored for refuse while the pulp fibers adhered to the surface of the screen forming a mat which became progressively thicker as the cycle continued and which conformed to the exact contour of the die.

When the die was withdrawn from the felting tank, the preform was blown free of the die with compressed air. The preform was then dried free of water in an oven. A flow diagram of the preparation of the preform and felting is shown.

After drying, the preform was impregnated with resin by dipping into a solvent solution of the resin until it was completely saturated. The amount of resin pickup was controlled by adjusting the concentration of the resin solution. The solvents in the preform were driven out and the resins in the preform were pre-cured by heating the impregnated preform in an oven. This preform was then finished under heat and pressure in a mirror polished die which was operated by a hydraulic press. The use of the die and press was obtained through the courtesy of the General American Transportation Corporation.

If it was not desired to press the preform, the resin in the preform was thoroughly cured in an oven. The resin impregnation and pressing of the chair body are outlined in a flow diagram.

FELTING, DRYING EASY

No trouble was had in felting this chair body design, and preform thicknesses of as much as $1\frac{1}{2}$ inches could be obtained easily. The thickness and felting time was dependent upon the freeness of the pulp. In normal felting operation, the thickness of the preform is uniform throughout; however, by inhibiting the felting action of sections of the felting die thickness variations of about 10 per cent can be obtained if required.

The side of the preform next to the felting die was smooth with the exception of having the texture of the screen design imprinted on its surface. This texture can be varied dependent upon the screening material used. The side of the preform away from the die had a slightly wrinkled or bark-like appearance. Experimentation has indicated that this bark can be prevented if desired by covering the felt with a rubber diaphragm while the die is still immersed.

Drying of the preform was easily accomplished. Although an oven was used in the pilot plant, in industrial practice a transfer die could pick up the preform by means of vacuum and hot air drawn through the preform thus drying it in a fraction of the time required for oven drying.

Resin impregnation of the preform was simply a matter of immersing the preform in the proper solution. The choice of resins used was determined by whether the chair was to be pressed or unpressed since some resins require pressure in addition to heat for setting. Water soluble or dispersible resins were not tried, but there is a definite possibility that these could be added to the felting tank and thereby complete the felting and impregnation operations at one time.

MATERIAL IS ATTRACTIVE

The preforms when pressed were reduced to a thickness of approximately 3/16 inch. The resultant chair bodies were smooth in texture and required no additional finishing operation except to buff off a small amount of flash from the edges. The material had a warmth to touch similar to that possessed by wood instead of the cold feeling exhibited by metals and plastics. The color was rich in appearance. Chair bodies in which the resin was cured without pressing were not as smooth in texture or as rich in color, but they were quite presentable. Both pressed and unpressed chair bodies, with legs attached, are shown.

Physical tests such as tensile strength, transverse strength, impact, abrasion, and shear hardness were run on the pressed and unpressed chair bodies; the results showed the materials were as good or better than wood. These tests, however, mean little in a complex structure such as a chair. Hence, a repeated blow test was run in which a 42 pound weight was dropped repeatedly on the back of the chair body until failure of the chair occurred.

Some chairs were tested up to 250,000 blows without failure. This would amount to a life of well over 100 years if the chair had been in actual service.

Nails could be driven into and screws could be attached to chairs which had not been pressed, thus indicating that they could be used as excellent understructures for upholstered furniture.

Color possibilities are unlimited in the finished chair. Pulp was dyed with satisfactory results, and also the color of the resin was allowed to dominate with equally pleasing effects.

COSTS AMAZINGLY LOW

Although in the course of the investigation no particular effort was made to obtain the cheapest materials, the materials used were amazingly low in cost. The average cost of materials for the two types of chairs was about 25 cents per pound. The pressed chairs were made with materials costing as little as 16 cents per pound, whereas the unpressed chair required somewhat more expensive resins resulting in a cost per pound of about 33 cents. This higher cost for unpressed chairs is readily offset, however, by the elimination of the extremely costly dies and presses required for compression molding. It should be emphasized, however, that while the material costs are phenomenally low in either case, due to the virtual elimination of waste and rejects, the primary economy is to be found in the revolutionary reduction of hand labor through the applicability of the process to straight-line mass production techniques.

By using automatic controls and conveyor systems no direct manpower would be necessary for fabrication. Such manpower as would be required would be only for the maintenance of equipment and the handling of raw materials and finished products. In a production setup, the number of chairs which could be made would be limited to the speed of the felting die for the unpressed chair or to the speed of the finishing presses for the pressed chair. Thus, one unpressed chair per minute for each felting die in operation could be made and one pressed chair per seven minutes could be made for each pressing die in operation.

MANY ITEMS POSSIBLE

The limited studies undertaken upen a wide scope of investigation in the use of the felting process for many types of furniture which could be made out of innumerable pulp and resin formulations. Chairs could be made in one piece thus eliminating all joints -- the designs only being limited to those capable of being pulled from a die. Others items brought to mind are undercarriages for upholstered furniture, desk and bureau drawers, coffee tables, end tables, childrens furniture, etc.

Thus the felting process could contribute greatly to the furniture business by reducing manpower required per unit of furniture through mass production methods and by reducing costs through elimination of waste and rejects and use of lower cost materials. The process would contribute to the public by reducing the price of furniture while increasing the comfort, range of design, and life of wear of the furniture.

FOOTNOTES

1. Aronson, Joseph. Furniture Encyclopedia, Crown Publishers, New York, 1947.
2. Appendix A - 1, 2.
3. Who Wants What in Dining Rooms? A Consumer Research Study by House Beautiful Magazine, 1945.
4. The American Home, Oct., 1948, Vol. XL, No. 5, p. 39.
5. Appendix A - 1, 2, 4, 5.
6. Furniture, Its Selection and Use. U. S. Dept. of Commerce, Wood Utilization Report, 1931, p. 52.
7. Appendix A - 7.
8. Ibid.
9. Patton, A. B., and Vaugh, C. L. Furniture Finishing, Decoration, and Patching, Fred J. Drake & Co., Chicago, 1944.
10. Practical Evaluation of Tim-ber-lox as a Dimensional Stabilization Treatment for Wood, Timber Engineering Co. Laboratory Report, R. B. Blumenstein, Washington, D. C., July 9, 1948.
11. Wood, April, 1949, Vol. IV, No. 4, p. 16.
12. Wood Veneer Product Development Report by L. A. Patronsky.
13. Appendix A- 2.
14. Same as Footnote 9.
15. The Frontier, Armour Research Foundation, 1949.

BIBLIOGRAPHY

Courtenay, E. H. Something New in Functional Furniture. National Hardwood Magazine, Dec. 1947, p. 78.

Graham, Paul H. How Good Drawers Are Made. National Hardwood Magazine, March, 1949, p. 48.

Hyler, John E. Wood Products Parade. Woodworking Digest, March, 1948 and November 1946.