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EXPERIMENTS WITH TUBULAR
STEEL FRAMED SCENERY

Thesis for the Degree of M. A.
MICHIGAN STATE UNIVERSITY
Ralph L. Vanderslice, Jr.
1955

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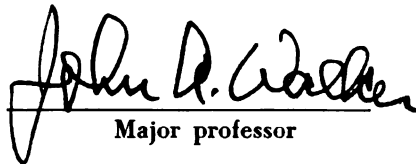
Experiments with Tubular Steel Framed Scenery

presented by

Ralph L. Vanderslice, Jr.

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Major professor

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By

Ralph L. Vanderslice, Jr.

AN ABSTRACT

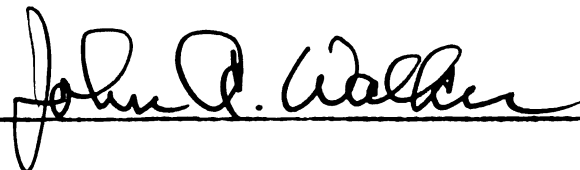
**Submitted to the School of Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
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MASTER OF ARTS

Department of Speech

1955

Approved

A handwritten signature in cursive script, reading "John D. Walker", is written over a horizontal line.

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The purpose of the study was to design and test a system of framed scenery capable of easy and rapid construction and of compact storage. Through the use of standardized, prefabricated, re-usable parts, this system would eliminate handicraft operations in the assembly of flats and facilitate dismantling them for storage. One-inch by two-inch rectangular lock-seam steel tubing was chosen for the basic framing members because of its rigidity and twist resistance.

Telescoping corner pieces were fabricated to join framing members. These permit some adjustment of the frame dimensions without cutting the tubes. To facilitate removal and re-use of canvas a mechanical means of attaching it to a tubular frame was designed. Hardware differs little from conventional stage hardware. Special problems such as sill irons for door flats, non-rectangular flats and attachment of profile were considered.

Although imperfect in its present state of development, the system appears capable of obviating some of the generally recognized limitations of wood scenery and the handicraft system of constructing it. The most significant advantages would apparently lie in (1) saving of time through use of prefabricated parts, (2) less dependence on skilled workmanship through reduction in opportunity for errors, and (3) greater efficiency of storage and re-use through disassembly and preservation of standard members.

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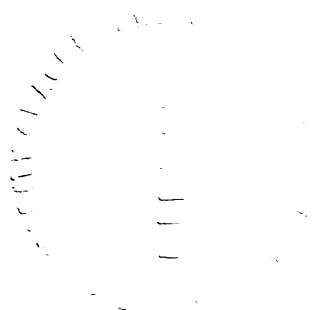
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The writer wishes to express his gratitude to Dr. John A. Walker, whose guidance and criticism were so valuable to this study, and to Mr. Virgil D. Godfrey, Professor Donald O. Buell, and Dr. Charles P. Pedrey for their helpful suggestions and assistance.

Professor Orvil McMurray of the Michigan State University Mechanical Engineering department, who contributed much technical advice, and Professor R. L. Vanderslice, Sr., who photographed the experiments, deserve special thanks.

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CHAPTER I

The representation of walls and other surfaces on theatrical stages by means of suitably painted fabric-covered frames is a practice of long standing. Such covered frames, or flats, have been used since the Renaissance¹ when they may have developed from the canvas covered frames used by artists for paintings. No significant changes have affected the building of flats in the intervening centuries, and the materials and methods used today are essentially the same as those referred to in 1545 by Sebastiano Serlio in Book II of his Architecture when he wrote, "I made all my scenes of lathes covered with linen..."²

This time honored approach to construction of scenery for the stage, which has been termed a wood-handicraft system,³ involves building permanently joined frames after performing a series of operations on each piece of lumber to prepare it for joining, and covering the frame with fabric held permanently by adhesives.

¹Harold Burris-Meyer and Edward C. Cole, Scenery for the Theatre, (Boston; Little, Brown; 1951), pp. 3-4.

²Quoted by Lee Simonson, The Art of Scenic Design, (New York, Harper, 1950), p. 5.

³Robert Baron, A Plan for the Use of Prefabricated Aluminum Sectional Units as a Means of Rendering More Effective the Construction and Use of Framed Scenery for the Stage, (Unpublished Master's thesis, Smith College, Northampton, Mass., 1949), p. 15.

There is no question that effective stage settings are built by the wood-handicraft system. Where skilled personnel are available the complexity of the wood-handicraft system presents no problem, and, if storing flats is not contemplated, the fact that they are permanently joined is not a disadvantage. In certain theatre situations, however, the wood-handicraft system may be regarded as a definite handicap to the production of plays. Speaking of amateur stagecraft in The Art of Play Production, John Dolman says:

...building another complete set every now and then...is the kind of chore that makes unpaid stage workers wonder why they do it.⁴

Another writer states that "one indication of the difficult nature of building scenery in the non-commercial theatre is the tendency to use draped sets instead of rigid scenery and set pieces instead of full-sized flats and platforms."⁵

That storage and re-use of scenery is an important factor in its economy is indicated by this statement of Burris-Meyer and Cole:

Between one fifth and one half of the cost of a production is represented by the scenery. Materials and labor of scene construction constitute a large percentage of this cost. Producing organizations with limited budgets may save a considerable portion of this scenery cost by salvaging and storing sets when productions close.⁶

⁴Rev. ed., New York and London, Harper, 1946, p. 366.

⁵Baron, p. 16.

⁶Op. cit., p. 455.

The reference here is to storing whole scenic units, such as flats. The component parts of a typical flat could be stored in about one-tenth the space required for the whole flat, and the parts would in addition be available for more efficient re-use. However, dismantling wood-framed flats for storage is not feasible because the joints are of a relatively permanent nature whether screws or nails are used, and frequent assembling and dismantling would not only take too long, but would soon cause the lumber to split and crack.

Because of variations in producing situations and conditions under which stage scenery is used, a definitive list of criteria is difficult to establish. Samuel Selden and Hunton D. Sellman in Stage Scenery and Lighting suggest these practical requirements:

First, scenery must be capable of easy and rapid construction. ...

Second, scenery must be capable of economical construction. ...

Third, scenery must be capable of quick and silent shifting. ...

Fourth, scenery must be strong. ...

Fifth, scenery must be well assembled. ...

Sixth, scenery must be capable of storage.⁷

The purpose of this study was to design and test a system of framed stage scenery capable of easy and rapid construction and of compact storage through the use of standardized, prefabricated, reusable parts which would eliminate handicraft operations in the assembly of flats and facilitate dismantling them for storage.

Two previous studies have proposed the use of metal scenery frames. They are Robert Baron's previously cited work, and Francis

⁷New York, Crofts, 1936, pp. 79-80.

Sidlauskas' Aluminum Framed Scenery.⁸

Sidlauskas gives a detailed analysis of the limitations of wood as a framing material. In his experiments he employed 1½"

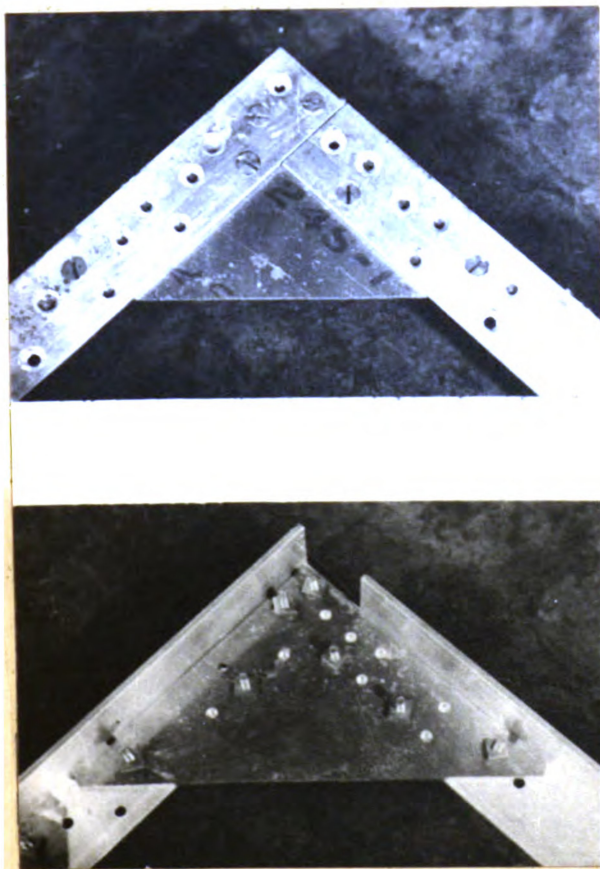


Figure 1. Corner construction employed by Sidlauskas with angle aluminum frames. Top: front view; Bottom: rear view. Reproduced from Aluminum Framed Scenery, courtesy Yale University.

aluminum equal-angle stock drilled through both faces in a somewhat complex pattern to permit joining by means of triangular aluminum plates closely resembling conventional corner blocks (Figure 1). He emphasized the versatility of these members and presented blueprints illustrating their use in flats, platforms, stairs, curtain tracks, and lighting bridges. The flats were covered with canvas attached with a rubber base cement. Large paper clips were used to hold the canvas until the adhesive set.

Baron chose the aluminum

⁸ Unpublished Master's thesis, Yale, New Haven, Conn., 1949.

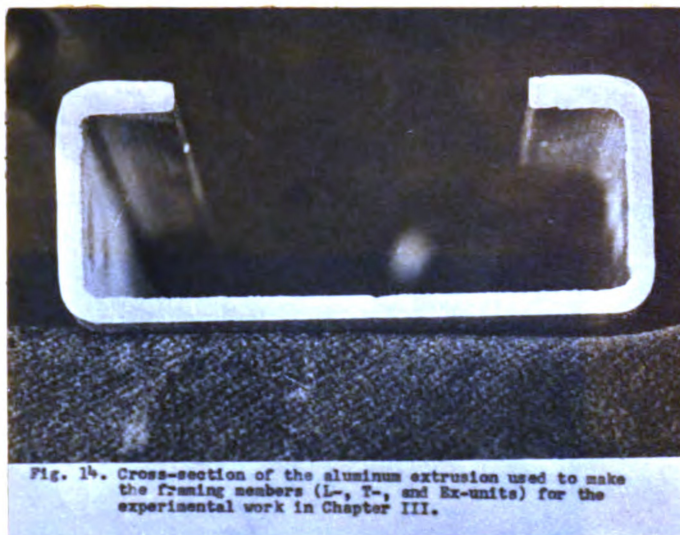


Fig. 14. Cross-section of the aluminum extrusion used to make the framing members (L-, T-, and Ex-units) for the experimental work in Chapter III.

Figure 2. Special channel aluminum used by Baron. Reproduced from A Plan for...Scenery for the Stage, courtesy Smith College.

stock shape shown in Figure 2. He described the disadvantages of the wood-handicraft system as an operating procedure and proposed to abandon not only the conventional material for scenery frames but also the conventional method of fabricating them. He emphasized the need for standardized, prefabri-

cated units which could be joined together quickly and dismantled easily for storage. The scenery cost for a producing organization using such a system would be substantially reduced because the purchase of permanent re-usable metal parts would be a capital expenditure rather than an operating expense.⁹ To attach canvas to his flats, Baron also used an adhesive. He further presented plans for several mechanical methods of attaching the canvas, but he did not actually experiment with them.

Baron discovered that unless his flats were braced on both sides, the unsupported side tended to lean or twist away from the

⁹Baron, p. 83.



Fig. 21. Prefabricated aluminum book-flat. This photograph illustrates the need for more internal bracing than that furnished by a single toggle. The flat on the right is supported by a rectangular wood brace.

Figure 3. Aluminum two-fold showing twist possibly due to lack of twist resistance in open channel shape. Reproduced from A Plan for... Scenery for the Stage, courtesy Smith College.

vertical (Figure 3). He attributed this to a need for more internal bracing, although he says at another point, "It is very possible that the 'twist' is a combination of the lack of adequate internal support; a weakness in the design of the basic cross-section, and inadequately designed joints."¹⁰

Both studies of aluminum framed scenery made contributions toward technological advancements in scenery construction. The specific contributions of the present study to the fund of knowledge about metal framed scenery

are: the investigation of steel as the basic framing material, the use of a tubular rather than an open shape, the development of a mechanical means of attaching fabric as opposed to the use of adhesive, and certain refinements in joining and hardware.

¹⁰Baron, p. 81.

Steel is approximately three times as heavy per volume as aluminum, and about twice as strong.¹¹ Aluminum alloys generally cost five times as much per weight as steel.¹²

Steel, like most metals, can be formed into shapes to suit the purpose for which it is intended, and the shape can be duplicated thousands of times with such accuracy that variations can be distinguished only with special instruments. This is in direct contrast to wood, which is naturally non-uniform and subject to such defects as knots, warping, and grain variations.

The formability of steel and other metals is used to advantage in common structural shapes such as "I" beams, channels, and angles. The result of forming a length of solid bar into one of these open cross-sections is a great increase in its resistance to bending, that is, in flexural strength.

Another shape which increases the flexural strength of a material is tubing. Tubing is formed by the disposition of metal or other material in a closed shape laterally surrounding a hollow center, usually with a uniform wall thickness and with a constant cross-section throughout its length. There are two principal types of tubing, depending on the method of manufacture: seamed and seamless. Seamless aluminum or magnesium tubing is usually extruded,

¹¹Eric Oberg and F. D. Jones, Machinery's Handbook, (12th ed., New York, Industrial Press, 1944), pp. 332 and 1580.

¹²Information supplied by Mr. Orvil McMurray in an interview.

while steel, being difficult to extrude, is generally pierced.¹³ Seamless steel tubing is quite expensive and the walls cannot be made very thin. Cheaper and thinner-walled tubing is produced by rolling a flat strip into the tubular shape and electrically welding or mechanically locking the seam.

The next chapter of this study deals with development of a system of steel scenery, describing experiments which led to the choice of tubing for basic framing members; and with the experimental fabrication of parts to illustrate how this system might work if such parts were available or could be fabricated. Chapter Three is concerned with experiments using the completed parts as they would be received by a scene shop using this system, and illustrates how certain problems of scenery construction might be solved.

¹³Seamless Steel Tubes, (Michigan Seamless Tube Company, South Lyon, Michigan), p. 7.

CHAPTER II

In any system of framed scenery the material and design of the framing members affects almost every other factor. For example, in the wood-handicraft system the traditional use of 1" x 3" white pine lumber permits a limited choice of right-angle joints, the most common of which are the butt joint and the mortise and tenon. The nature of wood also influences the method of attaching canvas, the strength, rigidity and weight of the scenery, and its capacity for compact storage. Hence, the design of framing members is of great importance in any system of scenery.

The first experiments in the present study attempted to determine in what form or shape metal would best meet the requirements of a scenery framing material. These requirements appear to be: light weight, rigidity or flexural strength, and twist resistance. The shape should also facilitate joining and covering.

Solid bars or rods, whether of steel, aluminum or magnesium alloys, proved impracticable because a solid shape large enough in cross-section to have sufficient rigidity is far too heavy. Sheet steel of various gauges, formed into angle or channel shape, appears to have adequate flexural strength without excessive weight, but its twist resistance in these forms is insufficient. Increasing

the thickness of the sheet stock increases the twist resistance only in proportion with the weight.

Due to the nature of sheet metal working facilities available, fabrication of tubing was difficult; however, a crude sample with protruding seam was made for testing. Spot welding this

seam at intervals resulted in a startling increase in twist resistance, which appears to be an integral characteristic of closed-seam tubing.

Round tubing, although the most readily available form, posed serious problems of joining, covering, and applying hardware to the frames. Rectangular tubing was therefore chosen to avoid these problems.

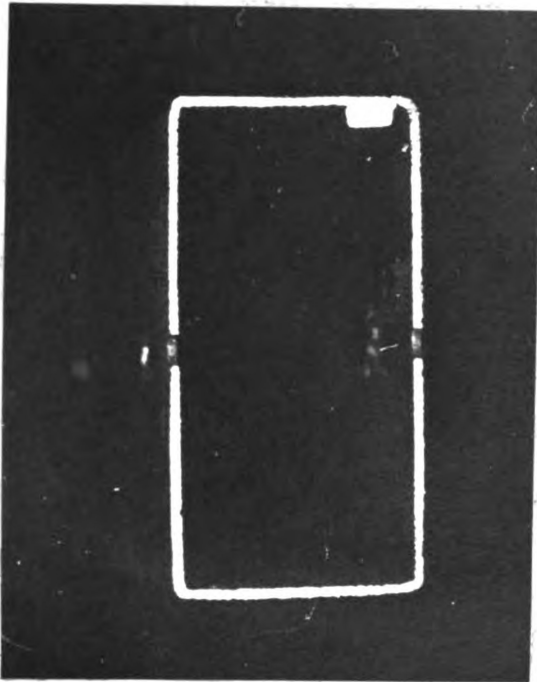


Figure 4. Cross-section of 1"x2"x.035" rectangular lock-seam steel tubing.

Tubing used in this study.

Sixty feet of tubing was donated for this study by the Van Huffel Tube Corporation of Warren, Ohio, through the John A. Koch Company of Detroit. This 1" x 2" rectangular lock-seam steel tubing with .035" wall thickness (Figure 4) is very strong and rigid but fairly heavy. A thinner-walled tubing could be used to advantage, making scenery lighter yet sufficiently



Figure 5. Twelve foot lengths of 1"x2" steel tubing and nominal 1"x3" white pine.

strong; this particular tubing was used for reasons of expediency in that this was what the tubing company donated. Apparently the tube mill was set up for a large order of tubing in this size and weight and ran the extra 60' along with it. Rectangular tubing is not standard warehouse stock; it is produced only after an order is received, and the cost of set up must be included in the charge. In small quantities such tubing costs much more per foot than in larger runs.

One-by-three white pine weighs approximately .375 pounds per linear

foot, although it varies in weight as in other characteristics. The tubing used in this study weighs .730 pounds per foot, or slightly less than twice as much. New twelve-foot lengths of each material are shown in Figure 5. A test of their comparative rigidity is

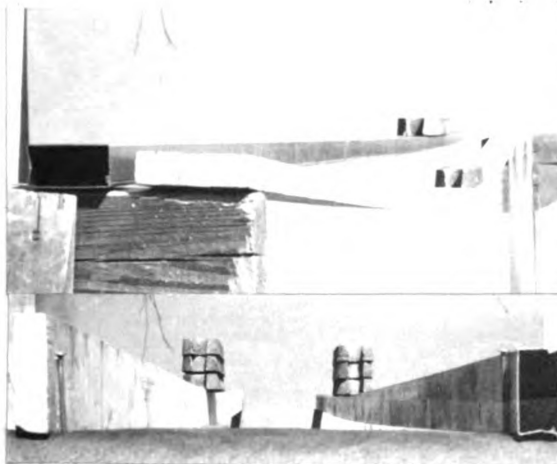


Figure 6. Comparison of flexural strength of steel tubing and white pine. Weights are 10 pounds each.

illustrated in Figure 6. The tubing also has more twist

resistance than wood.

One-eighth inch holes, drilled at one-inch intervals along the center of both two-inch faces of the tubing, provided for joining and application of hardware by accomodating #10 self-tapping sheet-metal screws. After drilling, the tubing was sprayed with Rustoleum to prevent rust. If this system of scenery were adopted by a theatrical supplier in a position to order tubing in efficient quantities and to have it punched and sprayed, the tubes would come to the scene shop in this form, with screw holes accurately prepunched and with rust preventative paint already applied.

Design of corner pieces. Because most scenery frames are rectangular, a basic problem in scenery construction is that of joining two framing members at right angles. It is at this point in the construction of wood flats that the problems inherent in the handicraft system most frequently manifest themselves, and the finished joint, even if it is a mortise and tenon joint, is far weaker than the rest of the frame. A problem of major importance in this study was to provide a means of joining tubular members at right angles in such a way that strength of the joint would closely approach that of the members themselves and which would permit rapid and easy joining by eliminating the measuring, marking, and cutting operations of the handicraft system.

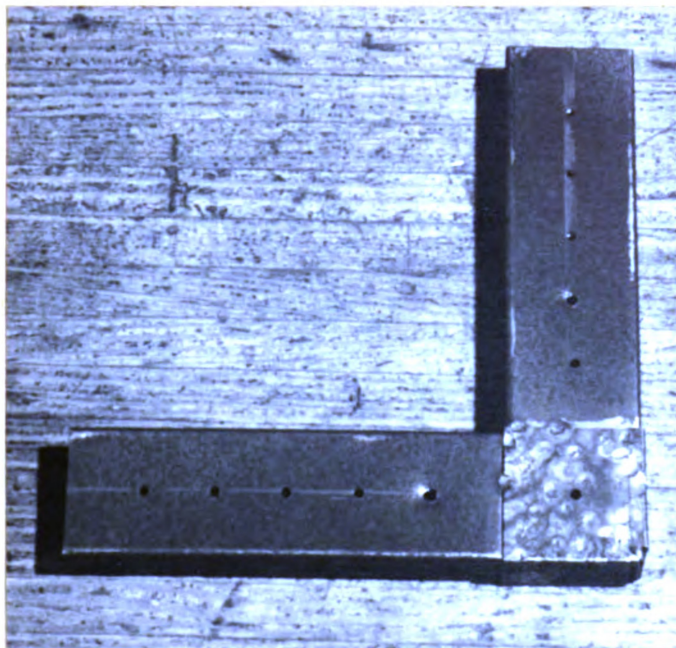


Figure 7. Ninety-degree corner piece designed to telescope into framing tubes.

The right-angle corner piece shown in Figure 7 employs rectangular tubing just enough smaller than the tubular framing members to telescope readily inside. This smaller tubing has an open seam to accomodate the internal protrusion of the lock-seam tubing.

The corner piece was fabricated by joining

the mitred ends of two eight-inch lengths of this open-seam tubing, and spot-welding interlocking plates across the joint on each side. These interlocking plates strengthen the joint and increase the thickness of the exposed portion of the corner piece to match that of the basic tubing.

While a preponderance of flats are rectangular, there is frequently a need to join framing members at angles other than ninety-degrees. To provide a means of making such joints in tubular steel frames without resorting to handicraft, a special corner piece was designed and fabricated. It will adjust from a



Figure 8. Adjustable corner piece.



Figure 9. Steel clip for attaching canvas to frames.

thirty degree outside corner all the way to a 120-degree inside corner (Figure 8).

Method of fastening canvas to frames. The conventional method of covering a wood flat is to tack or staple canvas to the frame and adhere it with gelatin glue or wheat paste. The excess canvas is then trimmed off at the edges of the flat.

Partly because these conventional adhesives will not hold on

steel, but primarily to facilitate removal and re-use of canvas coverings, a mechanical method of attaching canvas to steel

frames was devised, employing channel-shaped clips illustrated in Figure 9. These clips were fabricated from very thin (28 gauge) sheet steel and are designed to fit snugly over canvas pulled around the outside edge of the frames, holding it by friction.

Toggle rails. In conventional wooden flats the stiles are

braced apart at intervals of four or five feet by internal horizontal members called toggle rails. Steel tubes, being more rigid than wooden stiles, do not require as much bracing, however at least one toggle rail is necessary in taller flats to facilitate handling and prevent the stiles from bowing inward under the tension of the canvas covering. A toggle rail was made from half-inch electrical metallic tubing, the ends of which were crimped and drilled to accomodate a single sheet-metal screw. There is no provision for expanding or adjusting the size of this toggle.

Another purpose served by toggle rails in wood flats with internal openings, such as door, window, or fireplace flats, is to support and partly form the inside framing. The round tubular toggle is inadequate for this purpose, and a means of attaching a toggle rail of the basic rectangular tubing had to be provided. Standard, commercially available T-plates with new holes drilled at one-inch intervals were used for this purpose and for attaching the internal stiles to the toggle.

Sill iron. Most door and fireplace flats have openings all the way to the floor, preventing the use of a bottom rail. A thin band of steel, called a sill iron or saddle iron, is usually screwed to the short rails on either side of the opening. Since the tubing is not provided with holes in its one-inch face, and the thickness of the strap steel would raise the flat off the floor about $3/16$ ", it was necessary to attach the sill iron by some

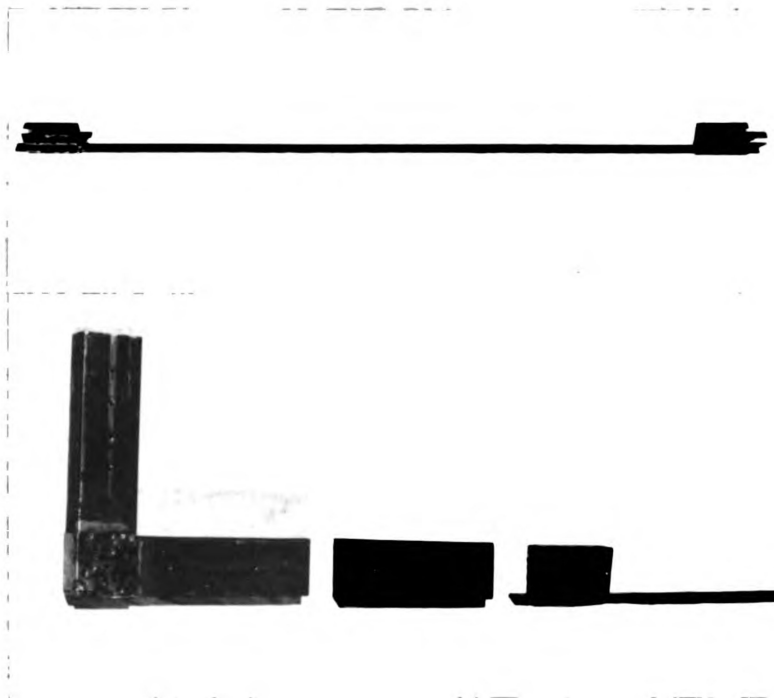


Figure 10. a. Sill iron unit. b. Detail of bottom rail assembly.

means more compatible with the rest of the system; one which would obviate the drilling of new holes and preferably be somewhat adjustable. The sill iron unit in Figure 10a was fabricated by welding two short pieces of open-seam tubing onto the ends of the strap steel

with the strap inside so they could telescope into the lock-seam tubing. Figure 10b shows the expanded bottom rail assembly with ninety-degree corner piece, short length of lock-seam tubing, and one end of the sill iron unit. Corner plates with new holes at 1" intervals are used to join the inside stiles to the short bottom rails because T-plates would extend into the opening.

Hinges and hardware. When two wood flats are hinged together on the face side, the hinges, at least in professional practice, are countersunk into the stile to prevent shadows under stage lighting. The leaves of the hinges and the crack between the flats are

then concealed by application of a dutchman, or strip of cloth, painted to match the flats.

Hinges cannot be countersunk into steel tubes, and even if they could it would be a handicraft operation contrary to the pur-

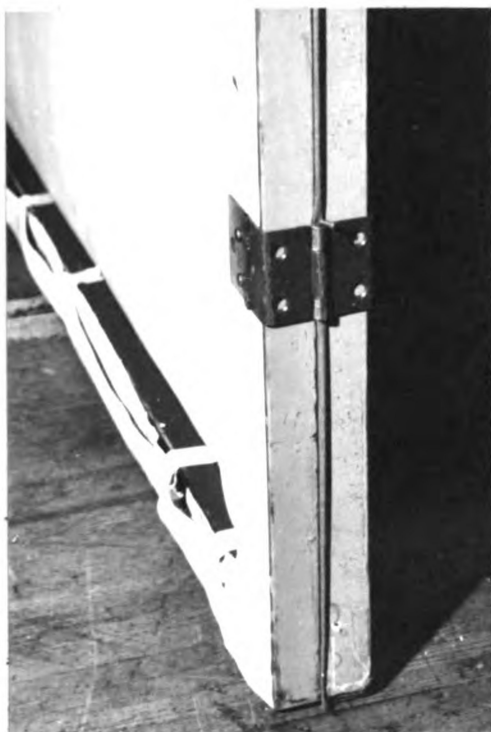


Figure 11. Detail of L-shaped hinge with flats folded.

pose of the system. A special hinge with L-shaped leaves was designed to take the place of countersunk back-flaps (Figure 11). The leaf of this hinge is applied with two screws on the back of the stile. It extends around the edge of the stile through the crack between the flats, and engages a mating leaf at a point approximately flush with the front surface of the flats. Actually, the hinge must protrude enough to bring the center of the hinge pin in line with the front of the flats so they can fold without straining the hinge.

The L-shaped hinges in this study were fabricated from standard theatrical two-inch loose-pin back-flaps by bending the leaves and welding on an extension. Stock back-flaps were also used in the experiments, after being equipped with new screw-holes to

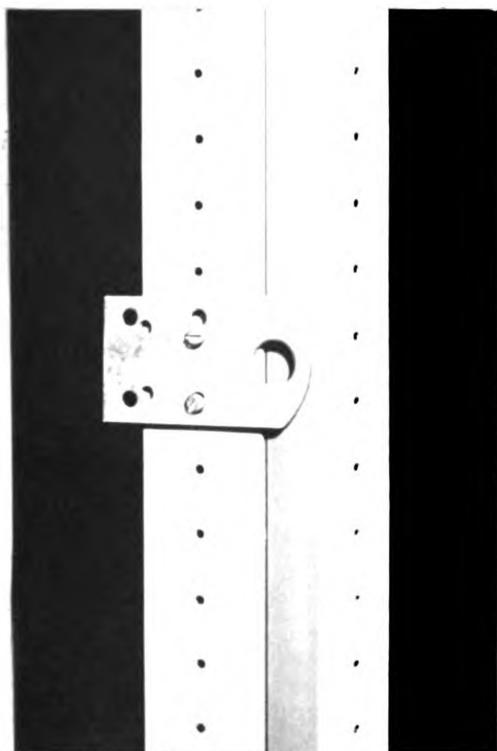


Figure 12. Special all-purpose cleat shown as stop cleat.

permit application to the tubing.

Most standard stage hardware can be used in the tubular steel system without modification other than re-spacing of screw holes. One type of cleat served as lash cleat, lash line eye, tie-off cleat, brace cleat, and stop cleat. (Figure 12). It was also used to attach profiles to the frames.

So much for the design and prefabrication of parts for this system of scenery. They were made as carefully as possible in an

effort to simulate the results of machine production for which they were ultimately planned. The next phase of the experiments involved building flats with the prefabricated parts to simulate the procedure which would be followed in a scene shop employing the system. This phase is described in the next chapter.

CHAPTER III

Constructing a plain flat. Under the wood-handicraft system, plain flat construction involves selecting, measuring, marking, and cutting two stiles, two rails, one or more toggle rails, and two corner braces. The parts are laid out on a bench or floor and checked for errors. Four plywood corner-blocks and six or more keystone are needed to support the joints. The joints are squared with a framing square and fastened with nails or screws driven into the framing members through the plywood blocks. Roughly one hundred screws or nails are used in joining a large plain flat.

The procedure in constructing a tubular steel flat is somewhat simpler, because the parts are ready to assemble. First, tubes are selected for the stiles and rails. They must be at least four inches shorter than the height or width of the flat, because each corner piece adds two inches or more to each dimension. Cutting the tubing to fit a particular flat is unnecessary if tubes are available in lengths of six-inch increments since the corner pieces can be adjusted to make any size in between as long as it is in even inches. Tubes of appropriate length are arranged in a rectangle roughly the size and shape of the frame. They must be placed with the seam of each tube on the inside edge of the frame so as to permit insertion of the corner pieces. If welded



Figure 13. Insertion of corner piece into rail and stile.

instead of lock-seam tubing were used, this minor inconvenience would be avoided.

Four right-angle corner pieces are next placed in position as illustrated in Figure 13a. Two of these can be inserted into either the stiles or rails first. When one end of the flat is thus assembled, the other corner pieces must be joined to the rail (Figure 13b), and both inserted into the stiles simultaneously. Figure 13c shows the assembled corner before the application of sheet-metal screws. The corner piece is inserted the full six inches into the rail, but only five inches into the

stile. Similar adjustment at other joints, using five and one-half and eleven and one-half foot tubes for rails and stiles, makes

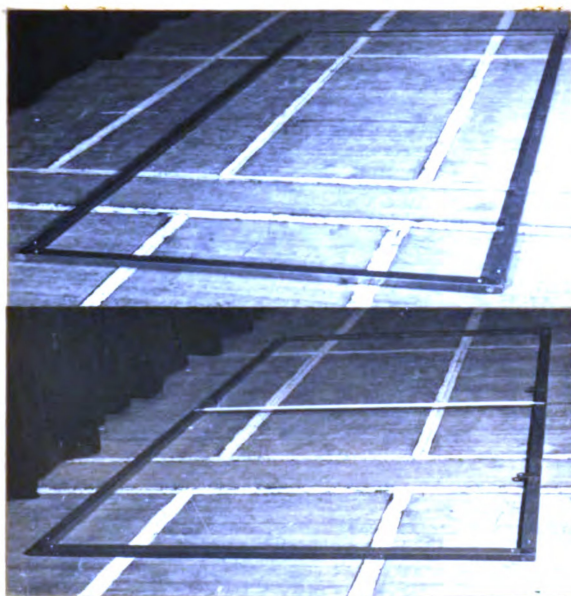


Figure 14. a. 5' 10" x 12' tubular steel frame.
b. Toggle rail and hardware added.

a 5' 10" x 12' frame (Figure 14a). With the addition of a toggle rail and hardware (Figure 14b), the frame is ready for covering. Assembly of the entire frame took only five minutes.

A 1' 4" x 12' jog, which was built to demonstrate methods of joining two flats, is shown in Figure 15. This jog was constructed with butt joints and triangular steel corner blocks (Figure 16), a method

which proved rather unsatisfactory. The corner blocks take longer to apply, permit the frame to twist and flex a

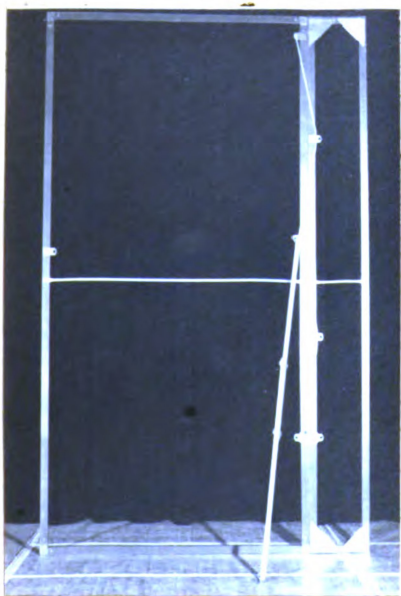


Figure 15. Two scenery frames lashed.



Figure 16. Detail of two methods of making right-angle joints.

good deal, and prevent adjustment of frame dimensions.

Covering a plain flat. When the tubular steel frame was assembled, it was laid face up on saw horses so that the fabric covering could be unrolled across its face (Figure 17a). The steel clips discussed in Chapter II were used to attach the canvas to the frame. They were applied across one rail first, then alternately along the stiles. The canvas was stretched while the clips were pushed over both canvas and tube (Figure 17b). Finally, clips were applied on the remaining rail (Figure 17c and d). At the corners the canvas was folded in three layers, and the steel clips were mitered in order to meet smoothly (Figure 17e). No difficulty was encountered in covering a corner piece that was inserted only part way into the tubing, and the canvas appeared perfectly smooth.



Figure 17. Steps in stretching a painted canvas on a tubular steel frame.

These pictures show how a painted canvas was returned to its frame after it had been removed and rolled up for storage. A very slight amount of touching up with matching paint was necessary.



Figure 18. Applying gauze dutchman over L-hinge.

Applying a dutchman. Figure 18 shows the application of a dutchman over the crack in a two-fold hinged with the L-shaped hinges described in Chapter II. This dutchman is a strip of two-inch surgical gauze applied with the base-color scene paint. The appearance of the two-fold with the dutchman dry and spattered is shown in Figure 19. The joint is barely discernible.



Figure 19. L-hinged two-fold with dutchman painted and spattered.

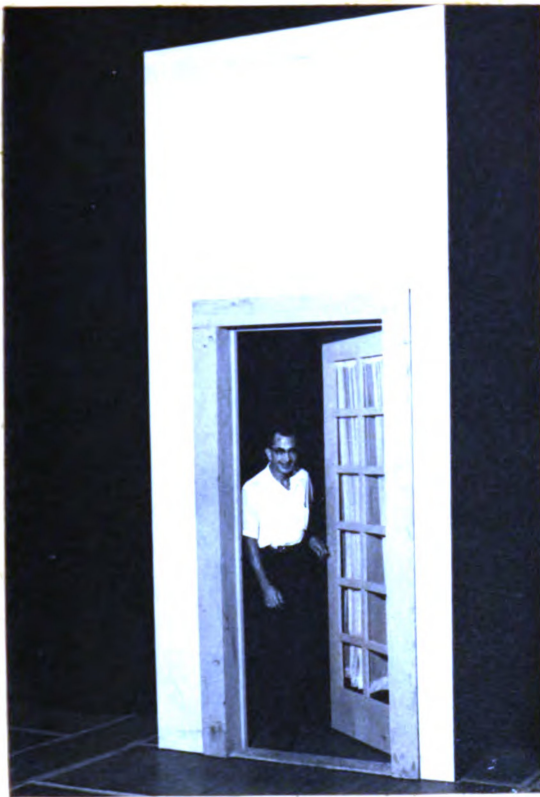


Figure 20. A door flat with door unit installed.

Building and covering a door flat. A door flat (Figure 20) presents most of the problems encountered in any flat with an internal opening. The procedure in constructing this flat was as follows: The top rail and the outside stiles were assembled just as for a plain flat. A toggle rail of rectangular tubing was fastened to the stiles with T-plates, high enough to clear the top of the door unit. T-plates were also used to attach the internal

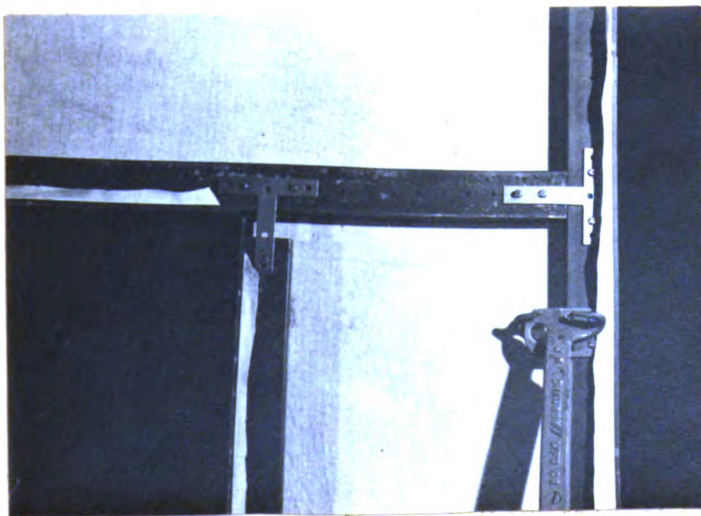


Figure 21. Detail of internal framing.

stiles to the toggle rail (Figure 21). The four-inch T-plates used in the experiments were too small, but were used because six-inch T-plates to match the six-inch corner plates were unavailable.

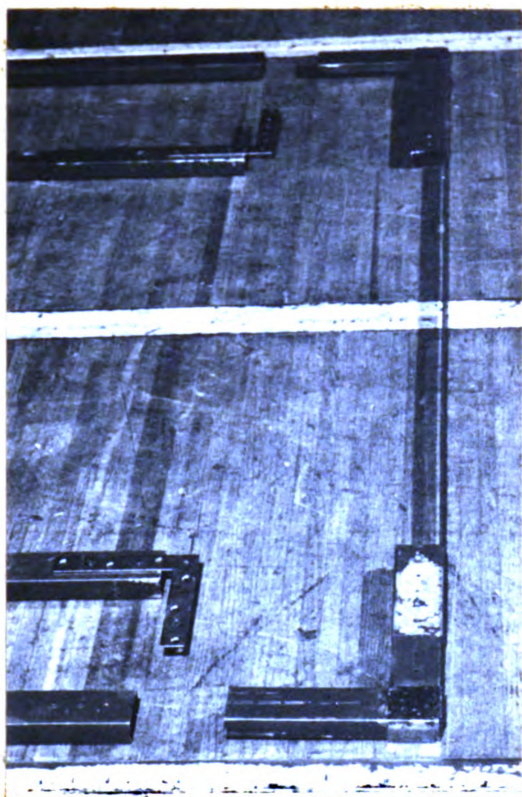


Figure 22. Sill iron and bottom rail assembly about to be joined to door flat.

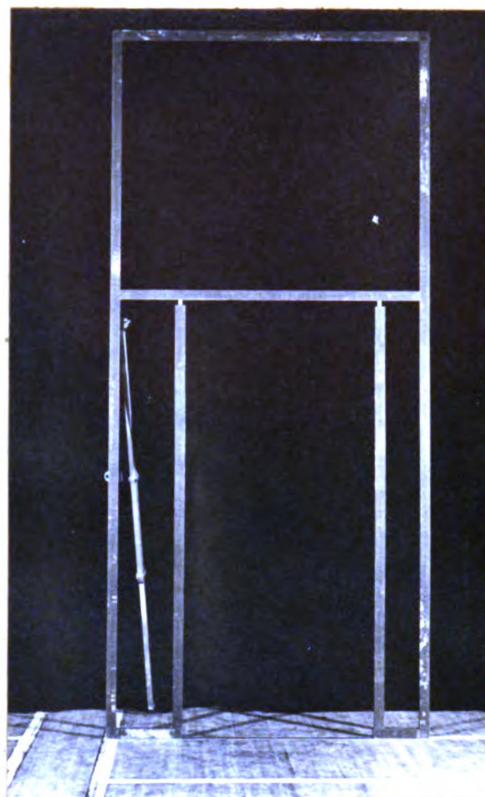
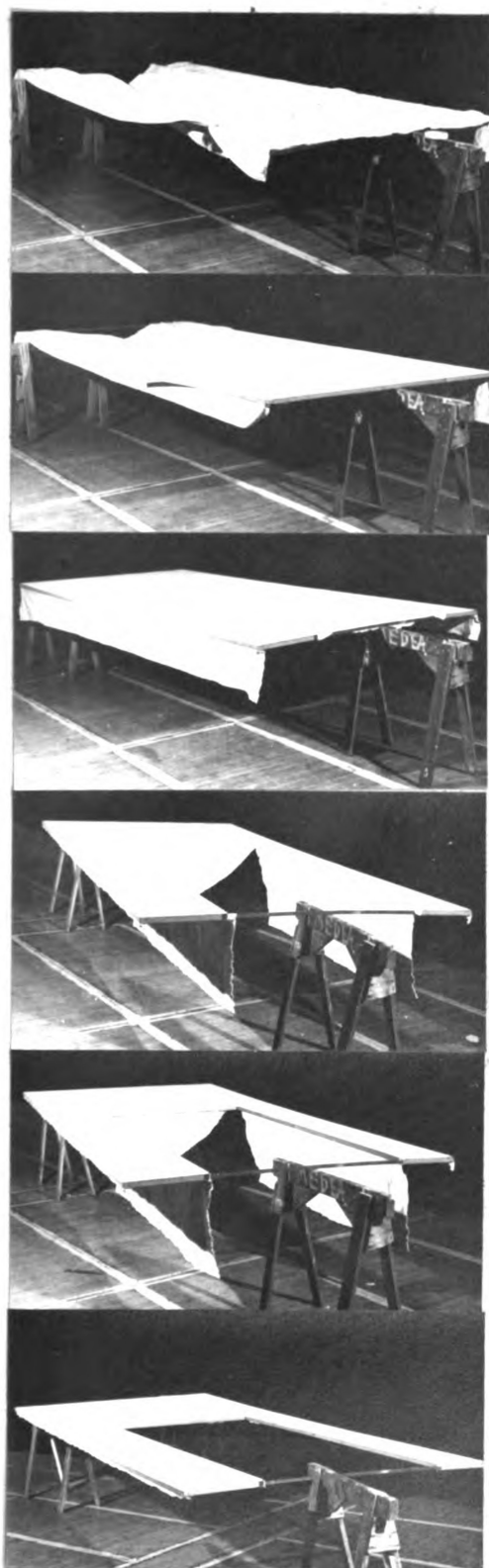


Figure 23. Uncovered frame for door flat.

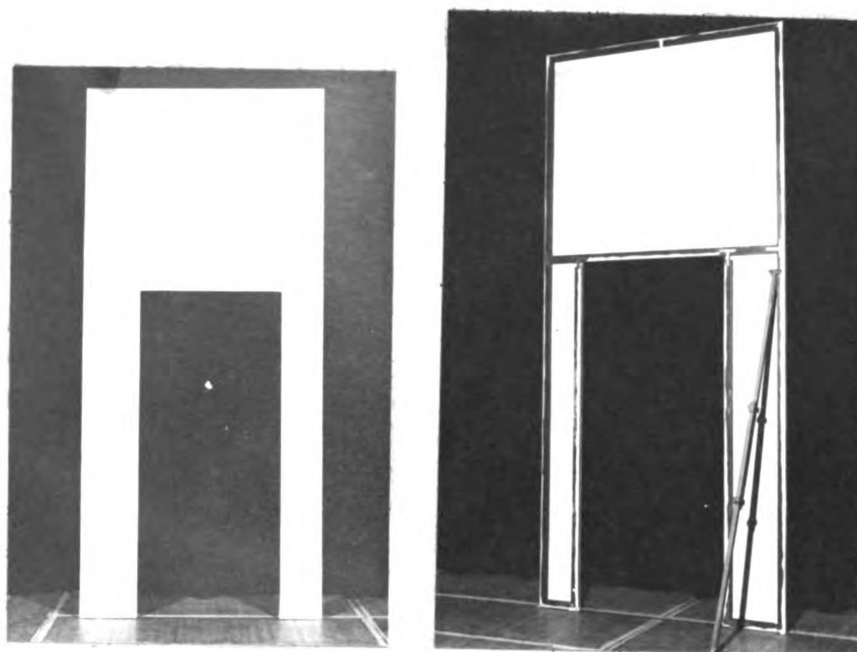
The sill iron unit described in Chapter II was joined to the bottom corner pieces with short lengths of tubing, and this whole assembly (Figure 22) was then joined to the rest of the flat by inserting the corner pieces into the outside stiles and applying corner plates to butt joints between the short rails and the inside stiles. In Figure 22 the corner plates are positioned on the inside stiles. Figure 23 shows the completed door flat frame.



The procedure for covering a door flat also begins like that used with a plain flat: The frame was placed face up on horses, and the canvas spread out and taped temporarily in place with masking tape (Figure 24a). The cloth was clipped to the top rail first, then clips were placed alternately along the outside stiles (Figure 24b). Figure 24c shows the flat turned around with clips holding the canvas on the bottom rails up to the opening, where the sill iron starts. The canvas across the opening was cut so that it hung down as illustrated in Figure 24d. In Figure 24e the stretching of the canvas is completed with clips on inside framing tubes, and Figure 24f shows the flat with excess canvas trimmed.

Figure 24. Steps in covering a door flat.

Figure 25.
Front
and
rear
views
of a
door
flat.



Two views of the finished door flat are shown in Figure 25. A stock door unit can be locked into the opening by the conventional method using strap hinges, as illustrated in Figure 26.

Non-rectangular flats.

Designs calling for flats with framing members joined at angles other than ninety-degrees require the use of the adjustable corner discussed in Chapter II. A non-rectangular

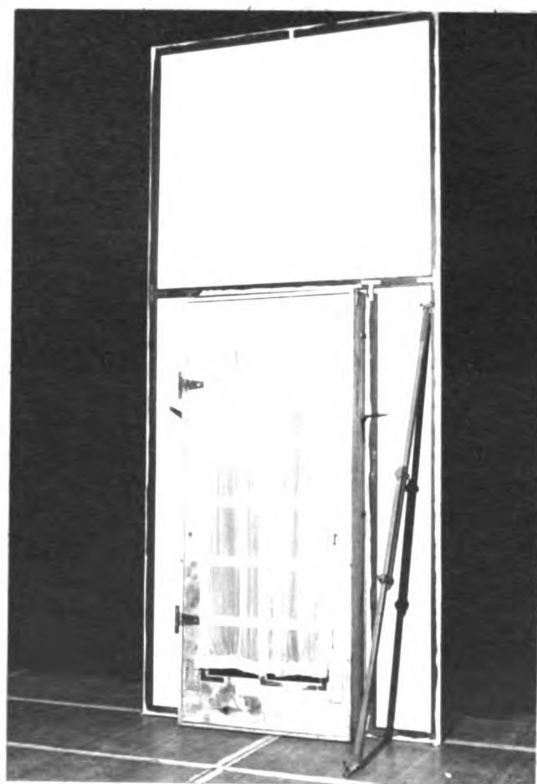


Figure 26. Door flat showing door unit locked in place.

frame employing two such joints is shown in Figure 27. The acute angle at the top (Figure 28a) was strengthened with a short brace of round tubing. The inside corner (Figure 28b) is not readily subject to additional bracing, and flexes considerably when the flat is raised or moved.

Application of profiles.

Quite frequently irregular flats must be built so that their outline is neither rectangular or rectilinear.

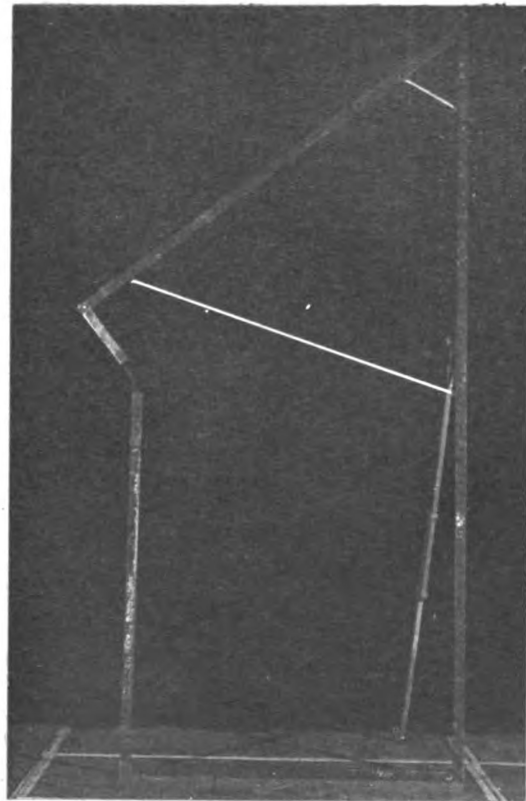
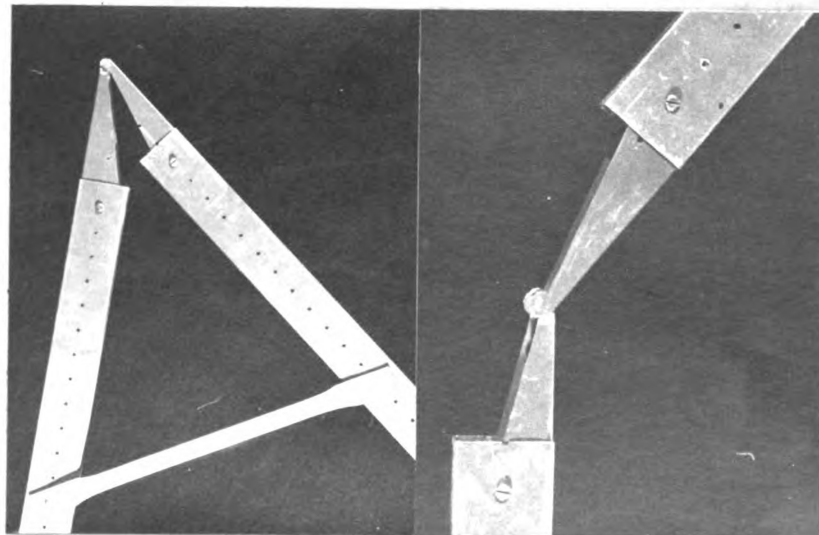


Figure 27. Non-rectangular frame with adjustable corners.

Figure 28.
Detail
of
flexible
corners.



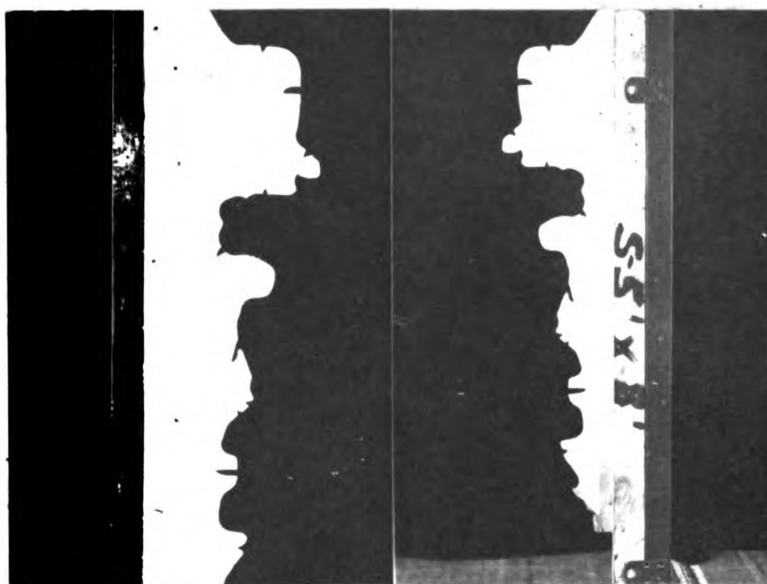


Figure 29. Profile attached to steel tube;
a. Front view b. Rear view showing
cleats.

In such cases the conventional solution is to build a rectilinear frame to support the profile board cut out according to the design.

Figure 29 shows a segment of such profile work and

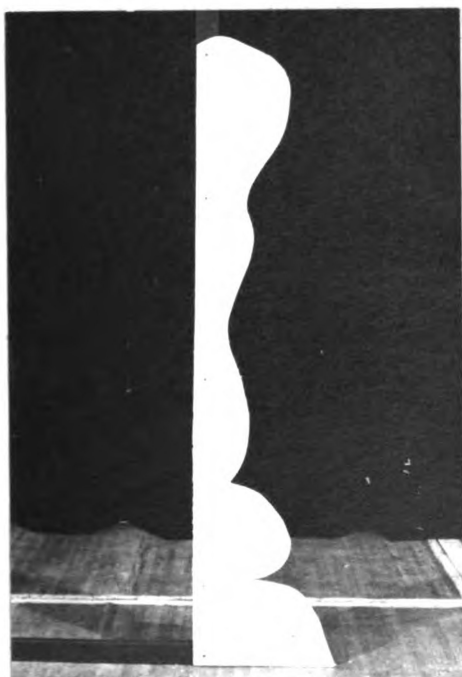


Figure 30. Alternate method
of attaching profile.

how it is attached to the tubular steel frame using the cleats discussed earlier. Nails were driven through special holes in the cleats into a short wooden batten attached to the profile. The thickness of the profile and the batten just equals that of the tube. Another method of attaching profile board is shown in Figure 30. Three-quarter inch #8 sheet-metal screws were used to hold the profile board on the front face of the frame.

A tubular steel frame with profile attached by either method could be covered by the conventional method using staples or tacks and glue. The first method can also be used to apply profiles to a steel frame already covered with the use of clips. A narrow dutchman might be needed to conceal the crack.

Shifting tubular steel framed flats. This study is concerned with the design of a system of scenery which differs from the conventional wood-handicraft system primarily in matters of construction and storage. An exhaustive comparison of the systems is not warranted by this purpose; however certain questions concerning the feasibility of the system are treated tentatively where the results of the experiments seem to cast some light on them. One such question is whether the scenery is capable of quick and silent shifting. The flats built in this study have not been used in an actual stage production, and the results noted here derive from experiments and from handling the units during construction, painting, and photography.

One important consideration in shifting scenery is its weight. A 5' 10" x 12' tubular steel framed flat, covered and painted, weighs slightly over 40 pounds. A newly constructed wood framed flat of the same dimensions weighs approximately 30 pounds. A typical stock flat of roughly the same size, which was taken out of storage for comparison and which has had numerous adaptations, weighed 44 pounds.

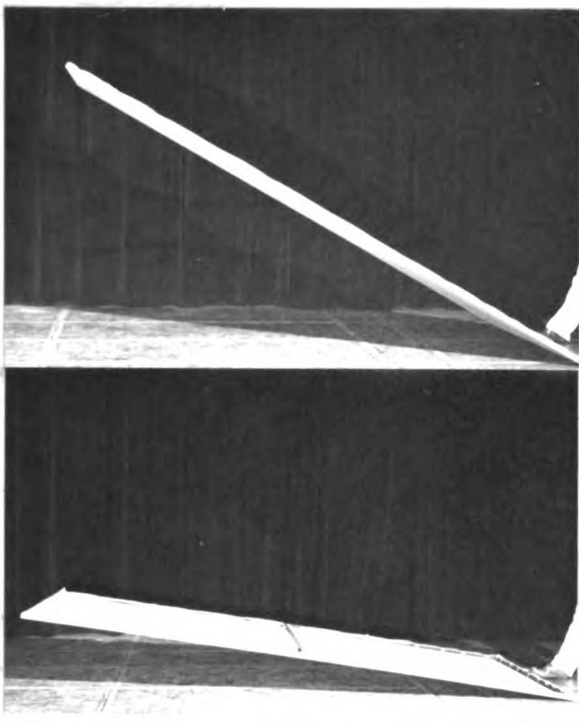


Figure 31. Floating a steel framed flat.

The weight of the steel framed flat does not prevent it from being raised by one man, floated (Figure 31), or run (Figure 32).

Rigidity of the frame appears to be a useful factor in shifting or handling flats. Figure 33 shows the 5' 10" x 12' and the 1' 4" x 12' steel frames hinged to support each other on one side. The unsupported side shows no tendency to lean or twist.



Figure 32. Union stage manager running steel framed flat.

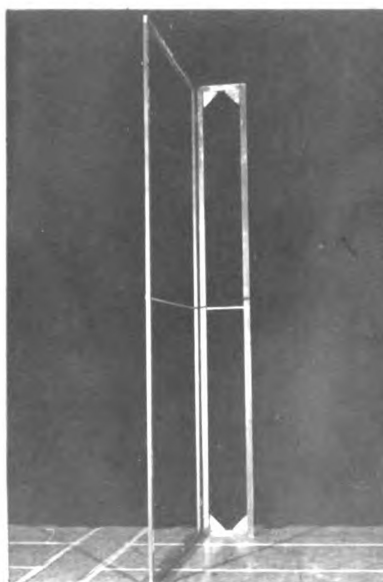


Figure 33. Uncovered frames showing absence of twist.

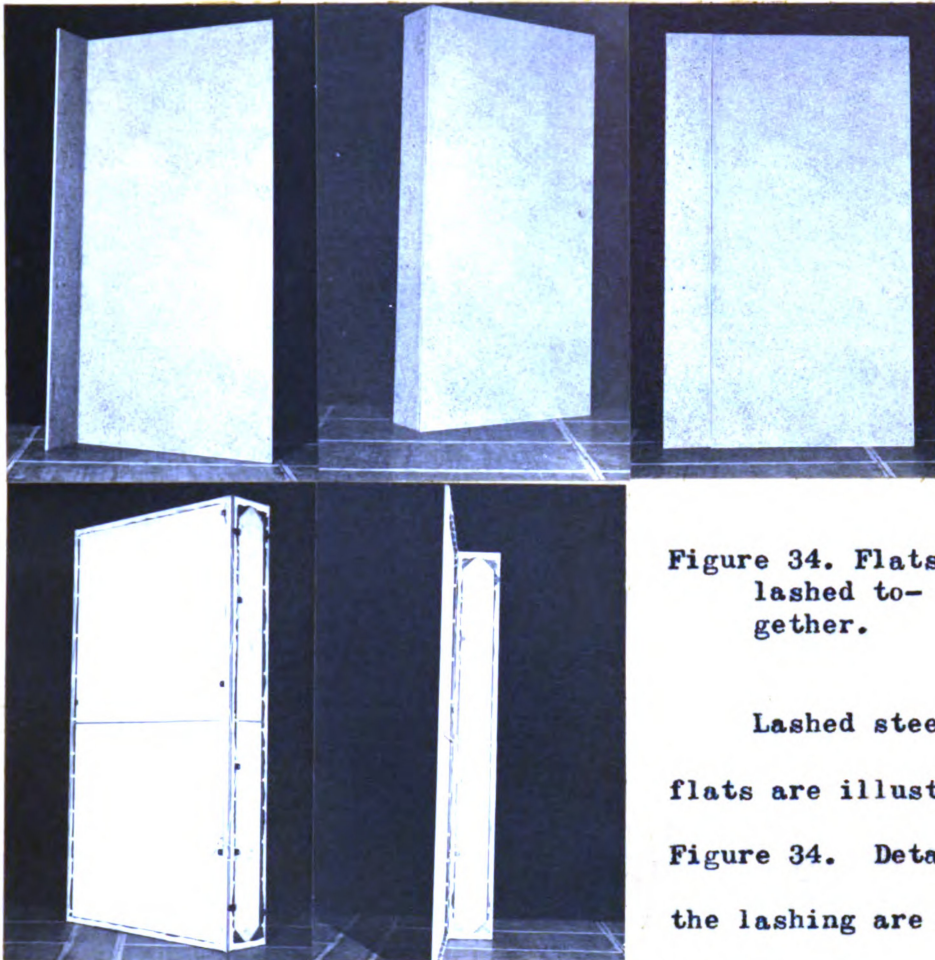


Figure 34. Flats lashed together.

Lashed steel framed flats are illustrated in Figure 34. Details of the lashing are shown in Figure 35.

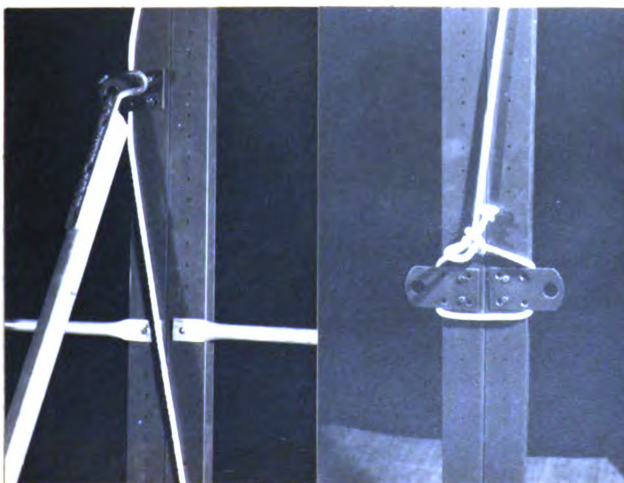


Figure 35. Details of lashing.

Dismantling and storing tubular steel framed flats. The capacity of tubular steel framed flats for storage is important to this study because it was one of the purposes underlying the design of the system. Fully

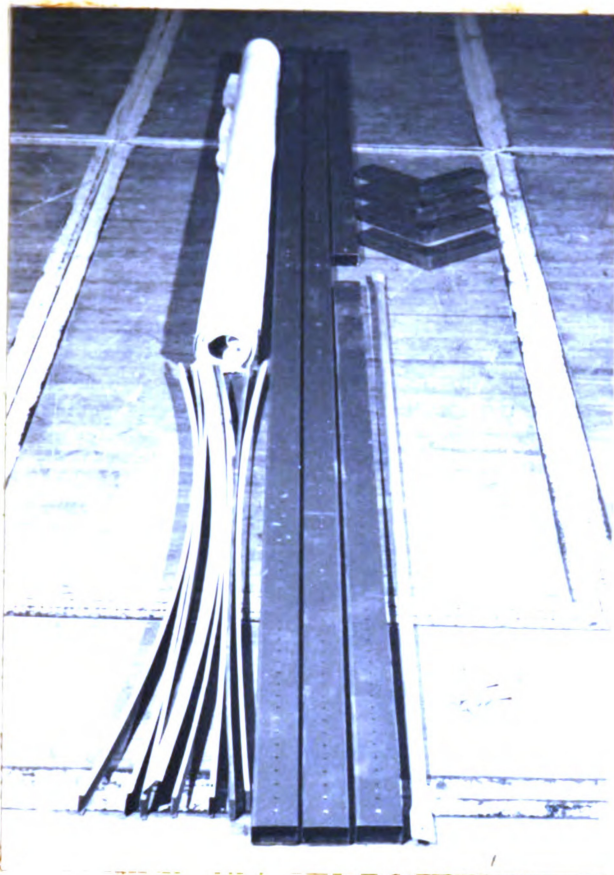


Figure 36. Parts for a 5' 10" x 12' flat.

assembled steel framed flats can be stored in approximately the same amount of space as would be occupied by equivalent wood flats. A far more compact method of storing them is possible because the units were designed to come apart. Figure 36 shows all the parts from a dismantled 5' 10" x 12' plain flat. These parts can be stored in roughly one-tenth the space occupied by the assembled flat,

and they are readily available for re-use in other combinations. Disassembling the flat involves merely removing the steel canvas clips and the canvas, taking out ten screws, and sliding the corner pieces out. It is done by the reverse of the procedure used in assembly. The tubes could be stored either vertically or horizontally with others the same length. Special racks or bins could be provided for corner pieces and for steel clips. The canvas could be rolled as shown and stored to preserve the painting,

or it could be laundered before re-use, thus avoiding any need for scrubbing the framed flat.¹⁴

The experiments in this chapter were undertaken to test whether the system and the parts described in Chapter II would work, and to demonstrate graphically how that system and those parts would operate. The next chapter deals with the conclusions which appear to be warranted by the results of these experiments.

¹⁴At the time of this writing, commercial laundries charge about 15¢ per pound for washing such canvas.

CHAPTER IV

Although imperfect in its present state of development, the tubular steel framed scenery system appears capable of obviating some of the generally recognized limitations of wood scenery and the handicraft system of constructing it. The most significant advantages would apparently lie in (1) saving of time through use of prefabricated parts, (2) less dependence on skilled workmanship through reduction in opportunity for errors, and (3) greater efficiency of storage and re-use through disassembly and preservation of standard members.

The tests in this study did not include use of the scenery in actual productions. Adequate evaluation of the system would require its use in productions over a period of years. Such investigation might reveal shortcomings in the system not recognized in this study, and it might reveal further advantages. The rigidity of steel tubes and their freedom from warping might prove advantageous in handling and shifting. Possibly the steel parts would prove sufficiently durable that their continued re-use over a period of years would result in greater economy despite their higher initial cost.

Most of the engineering problems encountered in this study

were problems not of design but of execution. Slight inaccuracies in spacing the holes in the tubing would not have occurred in a production set-up, where the holes could be punched within .005" tolerance. Similarly, variations in the steel clips, which caused difficulties in covering the flats, could be obviated by machine production.

The problem of weight in steel framed scenery deserves further attention. The tubing used in this study appeared to have strength and rigidity to spare insofar as this was put to test. Similar steel tubing with thinner walls might be practicable.

The adjustable corner piece failed to give adequate rigidity to non-rectangular flats. Possibly a redesigned unit would be strong enough. Rigid units of various angles on the pattern of the ninety-degree corner pieces might fill much of the need for adjustable corners, but unless a very wide range of angles were available, they would seriously limit the designer. Perhaps the best solution would be to use the tubular steel system for constructing rectangular flats and retain the wood-handicraft system for irregular pieces.

The system of tubular steel frames for scenery set forth in this study would be feasible for ordinary producing groups only if a metal-working shop could be persuaded to prefabricate the special pieces, or if an organization with sufficient capital to produce the parts in efficient quantities should enter the field as a supplier. The difficulty of working up steel would prevent

the great majority of scene shops from fabricating their own parts.

The multiplicity of factors which would affect the production and distribution of such parts makes an estimate of their cost impossible. The initial cost of tubular steel frames would probably be at least twice that of conventional wood frames.

If tubular steel framed scenery parts were available, the system would probably have its most effective application in amateur theatres which depend on volunteer labor for scenery construction and which produce plays with sufficient regularity to make purchase of tubing and parts economically feasible.

Touring companies might regard the weight of steel framed scenery as an obstacle unless lighter tubing could be used. The possibility of removing the painted canvases and disassembling the frames for every move on a tour could be investigated, although the space saved probably would not justify the work and time involved.

The possibility of storing and re-using painted canvases might prove valuable in repertory production. If the implications of these experiments are valid, the painted scene canvas from many productions using tubular steel framed flats could be removed from the frames and rolled up for compact storage. The frames, or their component parts, would be released for use in other productions. Restoring a set for re-use would involve merely assembling frames of the dimensions originally used and clipping the painted canvases in place. The front edges of the steel canvas clips would need to

be retouched with matching paint to prevent their being visible to the audience.

In the area of educational theatre the tubular steel system might make possible greater concentration on aesthetic considerations by releasing students and staff from much of the routine and time consuming effort of construction under the wood-handicraft system, and permitting a larger proportion of the available time to be spent on painting and decor. The possibility of efficiently storing and re-using steel framed scenery is another factor which might appeal to school and university theatres.

Use of tubular steel framed scenery in commercial combination production would presumably depend on the scenic construction company contracted to build scenery for the show. This company might arrange to lease the scenery to the producer or to re-purchase it at the end of the run, similarly to lighting equipment. Possible union opposition to use of steel framed scenery would have to be considered.

The results of this study suggest that a system of tubular steel framed stage scenery using prefabricated, standardized parts could be established in certain situations to supplement the wood-handicraft system. The feasibility of such a system appears to depend on machine production of the parts, and hence on its adoption by a manufacturer or distributor in a position to produce or purchase the parts in economical quantities. Further research into the problems suggested in this study seems to be warranted.

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