

THE DEVELOPMENT OF A LABORATORY
TECHNIQUE FOR
MODEL CONSTRUCTION

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THE DEVELOPMENT OF A LABORATORY TECHNIQUE
FOR MODEL CONSTRUCTION

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Introduction

The author wishes to express his appreciation to Professor
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INTRODUCTION

Present day structural design is based upon theory composed of numerous assumptions, some of which have been proved rigidly by experimental data while others have been shown to be adequate only so long as a large enough safety factor is introduced. The strength and stability of the majority of our structures which have been built in the last thirty years attest the overall adequacy of the theory being used. However, as stated above, this theory is padded in numerous places with high safety factors to insure adequacy in instances where experimental data is lacking. Of course, information which is lacking could be obtained by trial and error -- building a structure, loading it, and observing whether or not the structure supported the loads to which it was subjected. If a person lived long enough and had unlimited resources, he might obtain some very important information in this way. However, as has been done in the past and as will probably be done in the future, designers have attempted to make models of the structures they wished to investigate and, by subjecting those models to loads which simulated the actual loading, learn something about the action of the prototype. Model analysis has proved very useful in some instances.

In the field of rigid frames, for example, little is known about the stresses at the knees. Practically all the information we have at this time came from the results of some full and quarter scale tests conducted several years ago by the U. S. Bureau of Standards, Lehigh and Columbia Universities,

and the University of Illinois. These tests were very expensive, and are not likely to be repeated for checking purposes in the near future. The results of these tests disagreed radically with the stresses predicted by theory. Although a new theory was evolved, to date it has not been checked. The small scale testing that has been done up to this time has not yielded, in general, satisfactory results.

In an effort to help solve this problem, E. J. Scullen designed and constructed at Rensselaer Polytechnic Institute in 1950, as a master's thesis, a model testing frame which could accommodate intermediate scale models (approximately one twenty-fifth to one fifteenth scale.) It was hoped that by testing intermediate scale models, accurate information could be obtained at much less expense than by testing large scale models.

The object of our thesis, then, was to develop a technique for constructing the intermediate scale models. The prime requirement of any technique would be to produce a model which could be expected to simulate the action of its prototype. The technique should be inexpensive. It should be simple, so that master craftsmen are not required to build the model. The technique should facilitate rapid construction of a model. Last of all, the technique should be flexible, lending itself to the fabrication of models of varied shapes.

In the attainment of the object as presented above, the authors constructed many different models and tested these models by various means to determine their suitability for model analysis.

and the University of Illinois. These three have very re-
sults and are not likely to be repeated for several
months in the near future. The results of these three
experiments indicate that the stimulus strength of energy,
Although a low energy was used, it was found that the
number. The total weight lifted was not more than 25
pounds. This was not lifted, in general, satisfactory results.
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study of the study to the University of Illinois.

I. CONSIDERATION OF MATERIALS TO BE USED

The problem of building a suitable model for laboratory analysis is a matter not only of the techniques and methods that might be used, but also a matter of what material should be used. Therefore, it is necessary first of all to look at the various materials readily available, and from these, to pick one or two that seem to possess the greatest possibilities for success.

Those materials which seemed to us to offer the best possibilities were: aluminum, steel, plastic, and wood.

An understanding of the problem of using the loading frame with the high loads which it will be desirable to apply will bring to mind a question about the feasibility of using wood and plastic. Wood, of course, is readily available, but the difficulty of fabricating suitable models such that reasonable values could be predicted for their prototypes is a major problem. Also, knowing that eventually it will be desirable to build welded structures, the making of suitable joints with wood that would resemble welded joints presents a problem of questionable solution. The possibility of using plastic is equally as difficult as using wood, not only because of the problem of putting joints together and the low loads plastics are capable of carrying, but of great importance is the fact that residual, stress free models are very difficult to make.

This then brings us to aluminum and steel. These two metals were chosen in preference to other metals due to the

great deal of information that is known about them, such that the problem of making models might be simplified by using techniques already recognized as acceptable. It was decided to use aluminum first, primarily because of a ready supply on hand, along with the fact that the equipment available was best suited for handling that material. The most recognized characteristics of aluminum are its light weight, resistance to corrosion, and high strength, which make it highly desirable for this work. However, there are several properties of aluminum which tend to hinder the possibility of success. These are: (1) the fact that the melting point of aluminum is very close to the welding temperature such that great care is needed to avoid melting the parent material while welding, and; (2) the coefficient of thermal expansion of aluminum is slightly more than twice that of cast iron or steel with the resulting effect that care must be taken to consider expansion and to control it carefully in order to avoid distortion. Secondly, we decided to try steel as a material for a possible second method even if aluminum should work out. This would prove to be very helpful, if successful, since with the higher strength of steel it would be possible to build models which would be capable of carrying the full load of the loading frame.

Thus, with this in mind we started with aluminum as our first material and proceeded as the following pages indicate.

II. ALUMINUM MODULUS CHECK

In the fabrication of models from aluminum by brazing, soldering, or welding it is necessary to heat the aluminum, the temperature required depending upon the method used. Aluminum alloys which derive their strength from alloying and subsequent tempering* are annealed by reheating (if the reheating temperature is high enough) and lose their strength. Aluminum alloys which derive their strength from alloying alone are not appreciably changed by heating them to temperatures below their melting points. Of the alloys tested, 61ST6 is one of the former, while 5250 is one of the latter. We were interested in finding out what happened to these alloys, with respect to their structural strength, specifically their moduli of elasticity, when they were heated to temperatures required for brazing, soldering, or welding. As stated in The Aluminum Company of America's literature, "Alcoa Aluminum and Its Alloys," and "Welding and Brazing Alcoa Aluminum," the results of heating these alloys could be determined for each case only by individual tests. We, therefore, elected to test various heated and unheated samples by using electric strain gage equipment.

A. Electric Strain Gage Equipment**

1. General

The electric strain gage equipment used was

* Engineering Physical Metallurgy (Chapter 4) - Meyer

** For a detailed description and for operation procedure, see Baldwin instruction book, bulletin 312, entitled "Type L Portable Strain Indicator."

composed of, essentially, bonded wire strain gages, type SR-4, and an electric indicating device for measuring strains, in micro-inches, produced in those strain gages by some type of loading applied to the material upon which the gages were mounted. The indicating device, Baldwin Type L, indicates strains resulting from the loading by measuring the change in electrical resistance produced in the bonded gages.

Leading to the indicator are two sets of wires, one set from the active gage and one set from the compensating gage. The active gage is mounted on the test piece or model which is to be loaded; the compensating gage is mounted on a piece of the same material as that on which the active gage is mounted, is placed near the active gage, but is not loaded. The purpose of the compensating gage is to correct the strain reading for temperature prevailing in the vicinity of the active gage.

2. Operating Procedure

- a. Check calibration of indicating device if equipment is being used for the first time.*
- b. Check batteries; if the pointer remains in the red part of the dial, new batteries are needed.
- c. Connect leads from compensating and active gages to their respective terminals.

* See Calibration Check Procedure below.

1. The first step in the process of...
 2. The second step is to...
 3. The third step is to...
 4. The fourth step is to...
 5. The fifth step is to...

6. The sixth step is to...
 7. The seventh step is to...
 8. The eighth step is to...
 9. The ninth step is to...
 10. The tenth step is to...

3. Operating Instructions

- a. Check condition of... before use.
- b. Check... in the... before use.
- c. Check... before use.
- d. Check... before use.
- e. Check... before use.
- f. Check... before use.
- g. Check... before use.
- h. Check... before use.
- i. Check... before use.
- j. Check... before use.

- d. Turn battery switch to ON position, and allow 10 seconds for tube warm-up.
- e. Set the correct value of gage factor, as supplied by the gage manufacturer, on the gage factor dial.
- f. Bring the pointer to zero, and read the indicator dial. This is the zero reading.
- g. Load the test piece, bring the pointer to zero, and read the indicator dial. This is the loaded reading. The difference between the zero reading and the loaded reading is the strain produced in the test piece by the load, in micro-inches.

For best results, use hot soldered joints in connecting lead wires to gages, and make both lead wires to any one gage the same length. Also, place the compensating gage as near as possible to the active gage.

3. Calibration Check

If the indicating equipment is being used for the first time, it is best to check its calibration before using it. A brief check procedure follows:

- a. Connect the active and compensating gages to the equipment as above, and set the gage factor dial.
- b. Take a zero reading.
- c. Connect a resistor of known value, (R_c), in parallel with the active gage. A resistor of

1. Connect the positive and compensating leads to the equipment as shown, and set the gain factor.

2. Connect a resistor of known value, R_0 , in parallel with the active lead. A resistor of

3. Calibration check

If the indicating equipment is being used for the first time, it is best to check the calibration before using it. A check procedure follows:

4. Connect the positive and compensating leads to the equipment as shown, and set the gain factor.

5. Take a zero reading.

6. Connect a resistor of known value, R_0 , in parallel with the active lead. A resistor of

7. Take the compensating lead to zero, and note both lead errors.

8. For best results, use an oil-immersed potentiometer for the zero reading. Also, place the compensating lead to zero as possible on the active lead.

9. Read the zero reading. Also, place the compensating lead to zero. The difference between the zero readings and the loaded reading is the error.

10. Load the active lead, raise the potentiometer zero, and read the indicated value. This is the zero reading.

11. Repeat the reading as zero, and then the indicated value.

12. Load the active lead, raise the potentiometer zero, and read the indicated value. This is the zero reading.

13. Repeat the zero reading.

14. Repeat the zero reading as the potentiometer is raised.

about 500,000 ohms is satisfactory.

d. Read the indicator dial, and subtract the zero reading from this second reading to obtain a value in micro-inches which we will call "e".

e. If R_g designates the resistance of the active gage, which is approximately 120 ohms, then R_c referred to in "c" above equals R_g divided by e times the gage factor, G.

$$\text{ie, } R_c = \frac{R_g}{(e)(G)}$$

This computed value of R_c should equal the value of the known resistor.

B. Preparation of Samples

Strips of 61ST6 aluminum about 9 inches long and about 1 inch wide were cut from sheet aluminum 0.091 inches thick. The cutting was done on a metal cutting bandsaw. The edges of the pieces were sanded to remove cutting burrs. Similar strips 0.271 inches thick were cut from 5280 stock. Two samples each of 61ST6 and 5280 were then heated with an oxy-acetylene torch, with an effort being made to simulate the welding and soldering temperatures. As an index to the correct temperature, the pieces were heated until the flame impinging upon the aluminum became tinted with yellow. This was an arbitrary temperature measuring index (which later proved inaccurate) adopted after observing the flame while actually joining pieces of aluminum. The heated pieces were then air cooled.

Another strip of 61ST6 was heated in an electric furnace to the actual temperature required for welding, then allowed to cool in air.

An electric strain gage of the SR4 type was then mounted on the centerline of each piece at about its mid-length.

C. Explanation of the Gage Mounting Procedure

1. Clean the surface upon which the gage is to be mounted. For this purpose, light grinding or sanding with emery cloth may be employed.

2. Degrease the surface with carbon tetrachloride (acetone may be used).

3. Mount the gage:

a. Scribe lines to indicate gage orientation.

b. Coat test surface with a layer of Duco household cement and allow it to dry about 20 minutes.

c. Coat test surface with a second liberal coat of Duco cement and allow it to dry until it becomes slightly tacky.

d. Press gage into position with proper orientation and gradually press out the excess cement with the fingers. Watch the corners of the gage particularly.

e. Keep a slight pressure on the gage until the cement will hold the gage to the surface (about 3 minutes required).

f. Cure the gage:

(1) Cure gages under a slight pressure - about

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7. Description of the data processing procedure

1. Data are sorted according to the
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(2)

1 pound will be sufficient.

(2) Directly on top of the gage, place a layer of waxed paper, then a piece of sponge rubber, then the weight. This combination allows the slight pressure of the weight to hold the gage in place while curing.

(3) Allow gages to cure at room temperature for at least 24 hours. If curing is taking place in an atmosphere of high humidity, allow a longer curing time.

(4) As an alternative to (3) above, an infra-red heating bulb may be placed near the gages, such that a temperature of 150° is maintained, in which case only about 5 hours curing time is required.

4. Cover gages with a light coating of Ceresin wax to keep out moisture. (If testing is being conducted in a laboratory, in all probability no wax coating will be required.)

D. Check of Mounted Gages

After gages have been cured, it is necessary to check them before straining them. The resistance of a strain gage should be about 120 ohms. The leakage resistance to ground should be infinite. By using an ohmmeter, check the above resistances. The gage resistance, in order to be satisfactory, should be within 2 ohms of 120 ohms. The resistance to ground should be at least 50 megohms.

1. The test shall be conducted as follows:

(a) The test shall be conducted on a piece of paper of standard weight, size and color, and the test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C.

(b) The test shall be conducted on a piece of paper of standard weight, size and color, and the test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C. The test shall be conducted for at least 24 hours. The test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C.

(c) The test shall be conducted on a piece of paper of standard weight, size and color, and the test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C. The test shall be conducted for at least 24 hours. The test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C.

(d) The test shall be conducted on a piece of paper of standard weight, size and color, and the test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C. The test shall be conducted for at least 24 hours. The test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C.

2. Check of moisture loss

After the test has been carried out, it is necessary to check the moisture loss. The test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C. The test shall be conducted for at least 24 hours. The test shall be conducted in a dry atmosphere. The test shall be conducted at the temperature of 23 ± 0.5°C.

E. Testing of Samples and Results (See Figures 1 and 2)

The samples were loaded as cantilevers, one end being held with a "C" clamp to a rigid support while the other end received the load.

Loading was accomplished by suspending an empty beer can, into which shot was placed, from a knife edge which rested in a deep scribe mark at the end of the test piece. Loads were varied by varying the amount of shot placed in the can. The shot was weighed on a laboratory balance for accuracy.

Representative results of these tests are shown on the next few pages.

1. Journal of the American Medical Association, Vol. 100, No. 1, p. 100.

The committee was composed of the following members:

Dr. J. H. ...

Dr. ...

The committee was organized to investigate the ...

and, also, to determine the ...

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Modulus Check

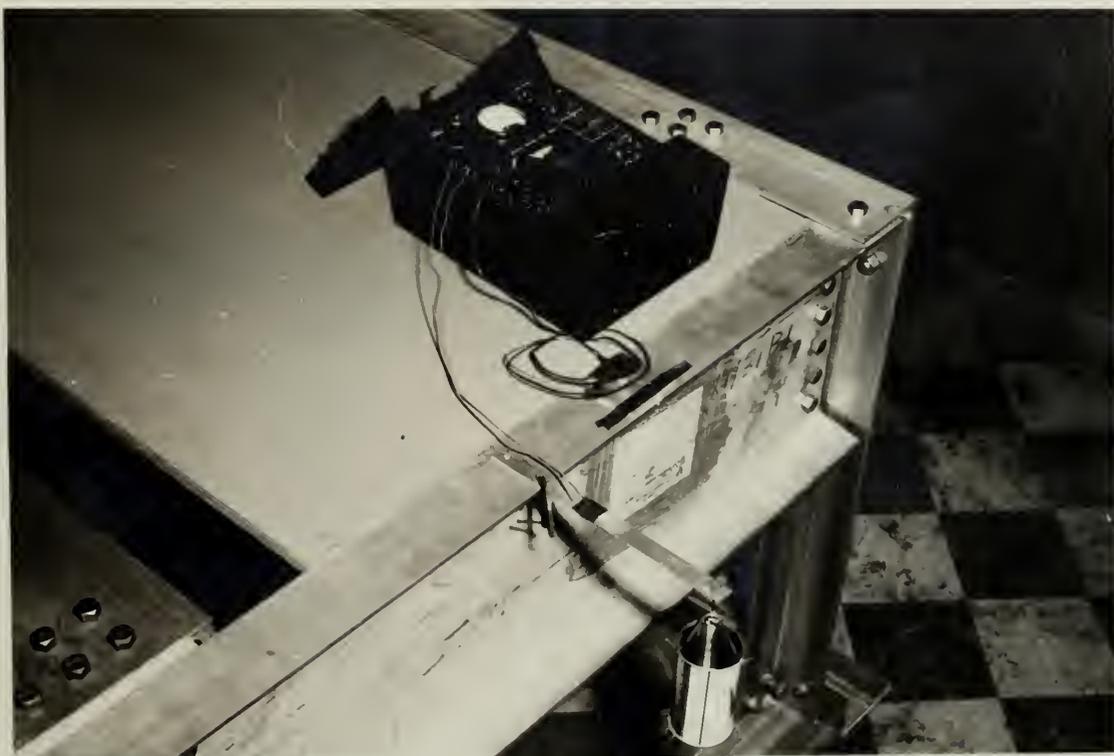


Figure 1



Method of Loading For "E" Check

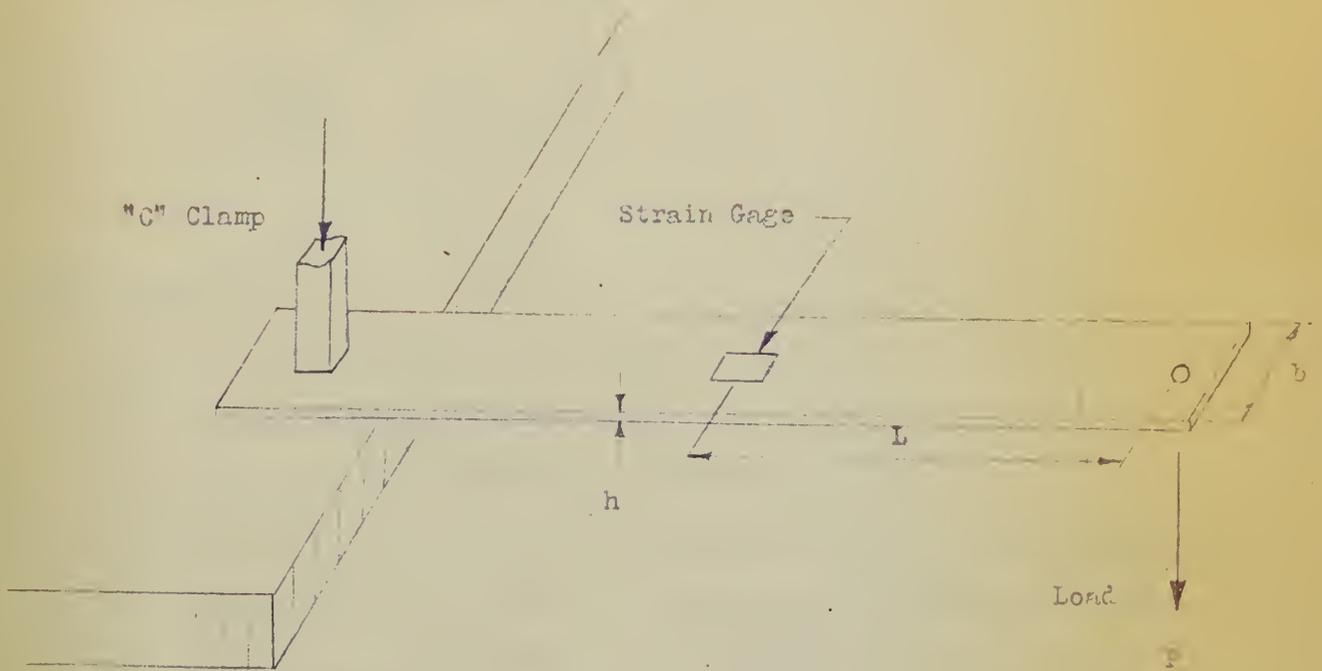


Figure 2



Form of Computations for "E" Check

Computations:

$$I = \frac{bh^3}{12}$$

$$f = \frac{Mc}{I} = \frac{(P)(L)(h/2)}{\left(\frac{bh^3}{12}\right)} = \frac{6 PL}{bh^2}$$

$$E = K \frac{\text{Stress}}{\text{Strain}} = K \frac{f}{e} = \frac{6 PL}{6 \frac{h^2}{e}} K$$

Terms Defined:

I, moment of inertia, inches⁴

b, width of test piece, inches

h, thickness of test piece, inches

f, bending stress in extreme fiber of test piece, lbs/inch²

e, unit strain indicated by SR-4 gage, micro-inches/inch

E, a number proportional to the modulus of elasticity

L, distance from point of application of load to the center of the strain gage, inches

M, bending moment, inch lbs.

K, a constant which corrects the strain indicated by the SR-4 gage to the value actually existing at the extreme fiber of the test piece.

P, load applied, pounds

Form of Equations for *1* Case

Equations:

$$I = \frac{dQ}{dP}$$

$$I = \frac{dQ}{dP} = \frac{d(\frac{Q}{P})}{d(\frac{Q}{P})} = \frac{dQ}{dP} = \frac{dQ}{dP}$$

$$I = \frac{dQ}{dP} = \frac{dQ}{dP} = \frac{dQ}{dP}$$

Form of Equations:

- 1. Amount of output, output
- 2. Rate of change, output
- 3. Measure of total output, output
- 4. Measure of change in output, output
- 5. Unit price, indicated by $\frac{dQ}{dP}$, indicated by $\frac{dQ}{dP}$
- 6. A higher percentage in the number of elasticity
- 7. Measure of the price, output
- 8. Elasticity, output
- 9. A constant value between the elastic indicated by the
- 10. Rate of the price, output
- 11. Total output, output

Heated 618T6 Aluminum

Dimensions of Test piece:

$$b = 0.817 \text{ inches}$$

$$I = 5.21 \times 10^{-5} \text{ inches}^4$$

$$h = 0.091 \text{ inch}$$

$$L = 5.34 \text{ inches}$$

$$E = \frac{P}{e} (.00466)$$

P, lbs.	Strain Reading				
	Zero	Loaded	e	E	f
.25	0924	1043	119	9.78	1165
.50	0924	1161	237	9.82	2330
.75	0923	1281	358	9.78	3490
1.00	0923	1400	477	9.78	4660
*1.25	0923	1519	596	9.78	5840
*1.50	0923	1637	714	9.80	7000

* Strains recorded are those existing 10 minutes after the load was applied. Immediately upon applying the load, the strain was somewhat higher, but gradually decreased to the above values. After 10 minutes, there was no significant change in the strain reading.

Unheated 61ST6 Aluminum

Dimensions of test piece:

$$b = 0.837 \text{ inches}$$

$$I = 5.33 \times 10^{-5} \text{ inches}^4$$

$$h = 0.0915 \text{ inches}$$

$$L = 5.375 \text{ inches}$$

$$E = \frac{P}{e} (.00457)$$

Strain Reading

<u>P, lbs.</u>	<u>Zero</u>	<u>Loaded</u>	<u>e</u>	<u>E</u>	<u>f</u>
.25	1498	1617	119	9.60	1143
.50	1497	1735	238	9.60	2281
.75	1496	1853	357	9.60	3430
1.00	1494	1970	476	9.60	4570
*1.25	1493	2086	593	9.62	5700
*1.50	1493	2201	708	9.68	6860

* Strains recorded are those existing 10 minutes after the load was applied. Immediately upon applying the load, the strain was somewhat higher, but gradually decreased to the above values. After 10 minutes, there was no significant change in the strain reading.

TABLE 1. Results of the tests.

$\sigma = 0.007$ inches
 $\sigma = 0.001$ inches
 $\sigma = 0.001$ inches
 $\sigma = 0.001$ inches
 $\sigma = 0.001$ inches

TABLE 1. Results of the tests.

σ	σ	σ	Load	Time	σ
0.001	0.001	0.001	1000	1000	0.001
0.001	0.001	0.001	1000	1000	0.001
0.001	0.001	0.001	1000	1000	0.001
0.001	0.001	0.001	1000	1000	0.001
0.001	0.001	0.001	1000	1000	0.001
0.001	0.001	0.001	1000	1000	0.001

The results of the tests are shown in Table 1. It is seen that the load capacity of the material is very low. This is due to the fact that the material is very soft and the load is applied very slowly. The results of the tests are shown in Table 1. It is seen that the load capacity of the material is very low. This is due to the fact that the material is very soft and the load is applied very slowly.

F. Conclusions on "E" Check

As shown on the preceding pages, the torch heating of the 61ST6 strips changed their value of "E" about 2%. Consistent, stable strain readings were obtained as long as the stresses were below about 5000 psi. For stresses above about 5000 psi, strains fluctuated with time.

Stressing of the 52S0 strips, heated and unheated, produced strains which varied radically with time, even at low values of stress. As shown on figures 3 and 4, this variation appears almost linear on a semi-log graph plot. This action appears similar to creep, only in a reversed direction, the test piece seeming to gain strength (i.e., become strained less) the longer the load of constant value remains on it. The authors consulted with members of the Metallurgy Department in an effort to explain this action, but were unable to find a satisfactory answer.

The authors concluded from the results of the above tests that 52S0 definitely would not be suitable for a model material, but that 61ST6 would probably be satisfactory.

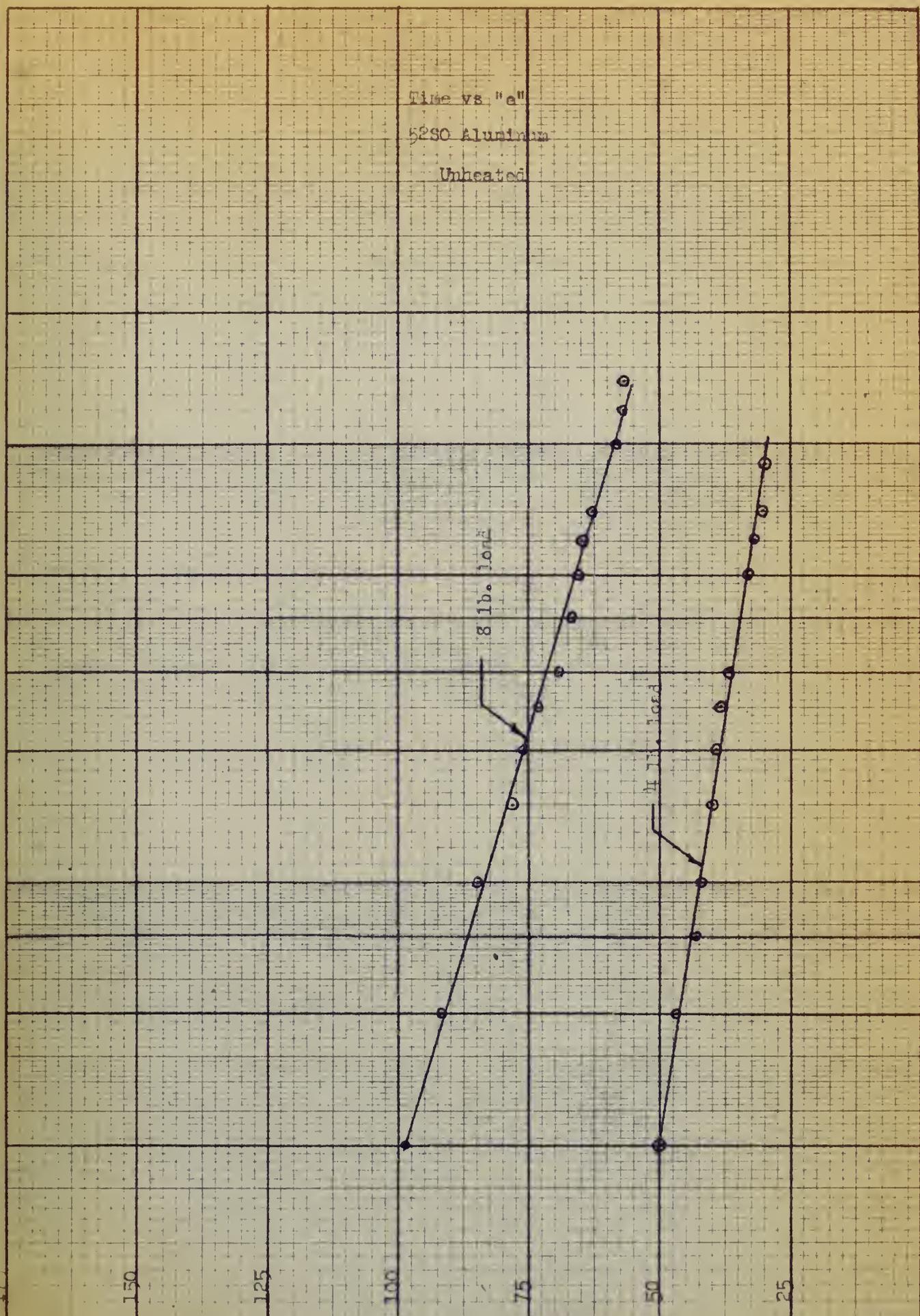
In an effort to determine the cause of poor results in beams #1 through #7, strips of 61ST6 were placed in an electric furnace to find out the actual temperature required for fusion. It was determined that 1125° F. was required for fusion of the parent metal with the eutecrod filler. The temperature left the metal in a very soft distorted condition after being heated for about 15 minutes. When an effort was made to subject a strip to a flexural load, it collapsed.

7. *Experiments with*

is shown in the following table for the series
of the first eight groups with values of 75, 80, 85, 90,
95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150,
155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205,
210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260,
265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315,
320, 325, 330, 335, 340, 345, 350, 355, 360, 365, 370,
375, 380, 385, 390, 395, 400, 405, 410, 415, 420, 425,
430, 435, 440, 445, 450, 455, 460, 465, 470, 475, 480,
485, 490, 495, 500, 505, 510, 515, 520, 525, 530, 535,
540, 545, 550, 555, 560, 565, 570, 575, 580, 585, 590,
595, 600, 605, 610, 615, 620, 625, 630, 635, 640, 645,
650, 655, 660, 665, 670, 675, 680, 685, 690, 695, 700,
705, 710, 715, 720, 725, 730, 735, 740, 745, 750, 755,
760, 765, 770, 775, 780, 785, 790, 795, 800, 805, 810,
815, 820, 825, 830, 835, 840, 845, 850, 855, 860, 865,
870, 875, 880, 885, 890, 895, 900, 905, 910, 915, 920,
925, 930, 935, 940, 945, 950, 955, 960, 965, 970, 975,
980, 985, 990, 995, 1000.

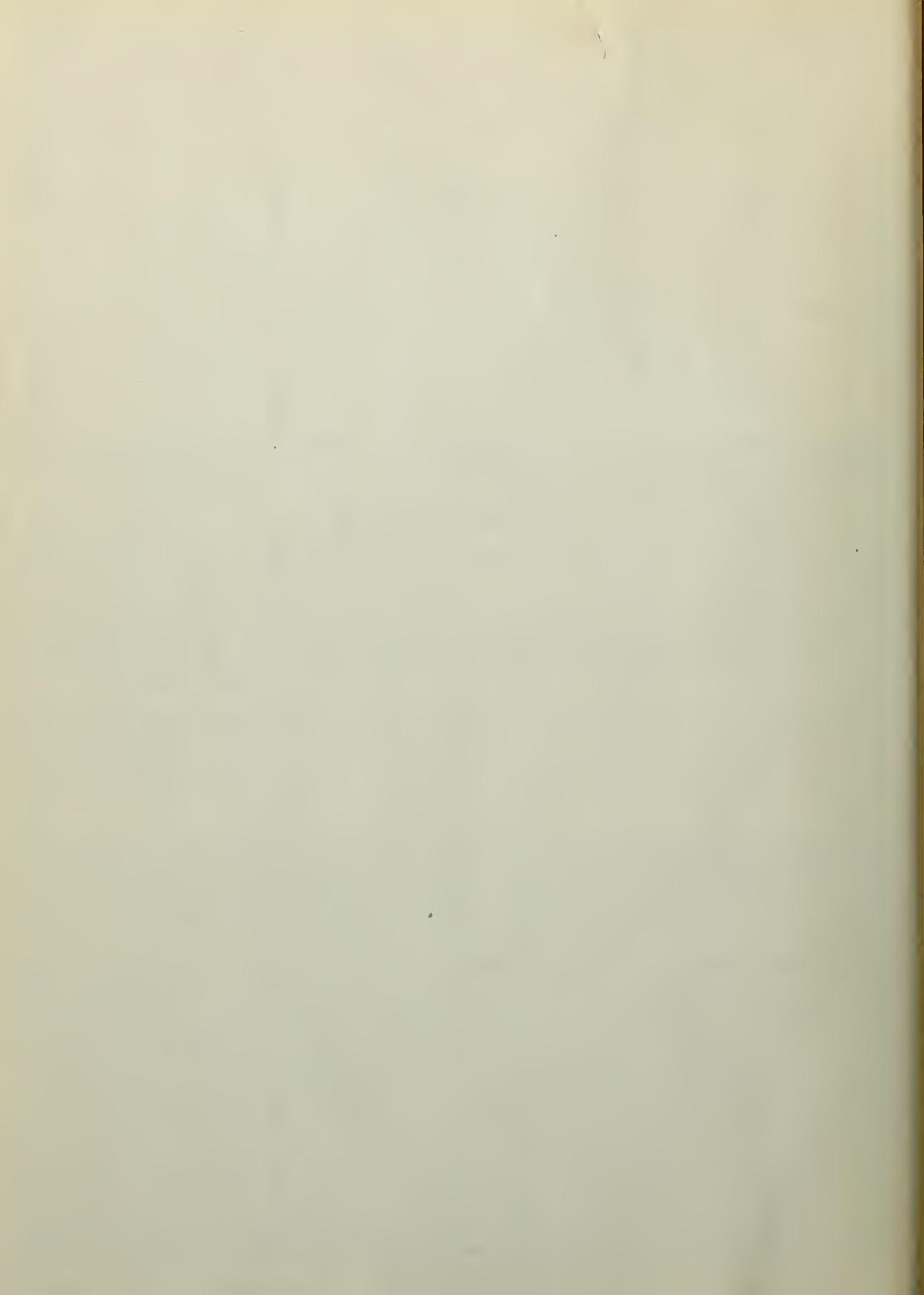
Time vs "e"
5250 Aluminum
Unheated

Figure 3



Time after applying load, minutes

"e", Micro-inches per inch



Time vs. ϵ''
5250 Aluminum
Heated

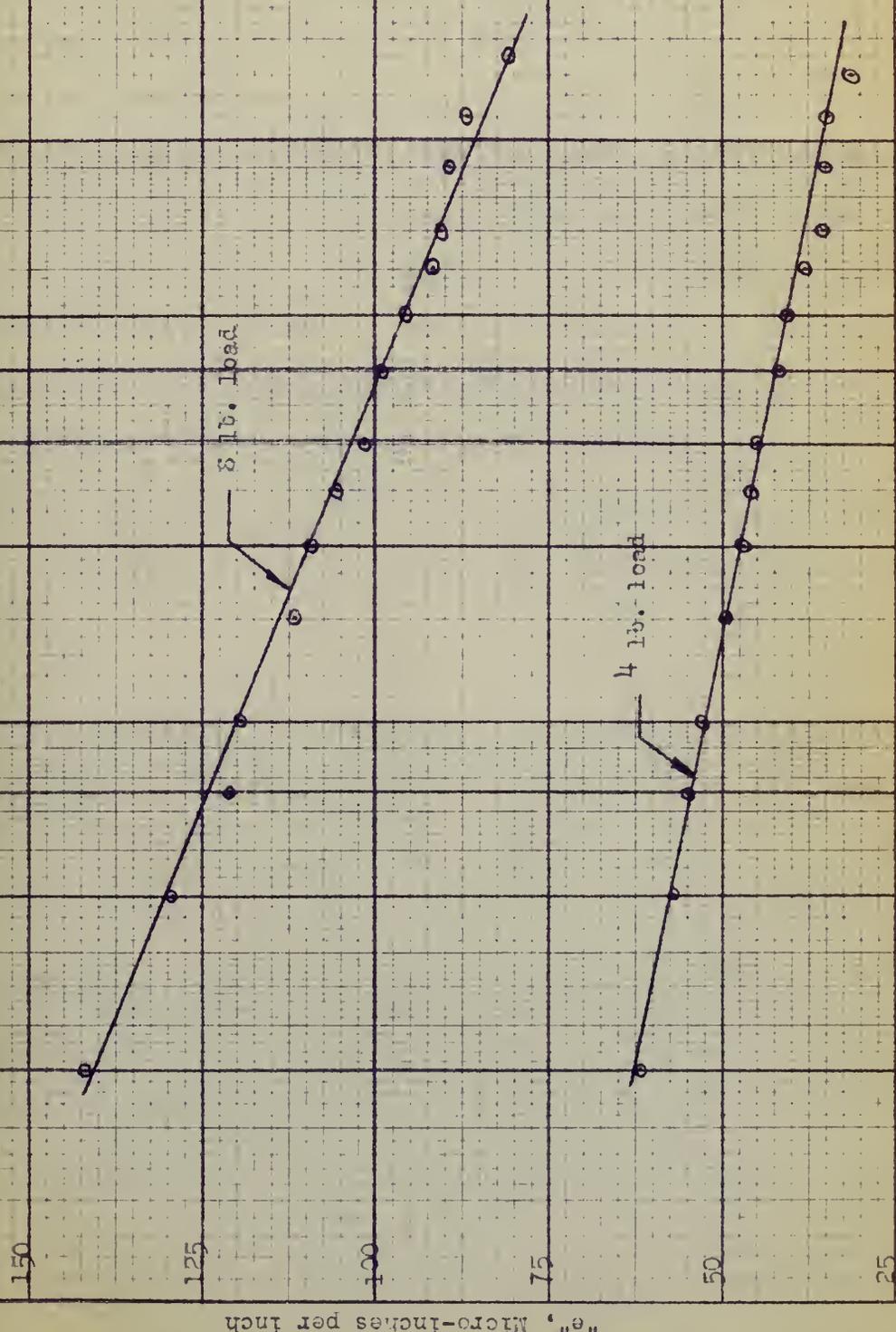
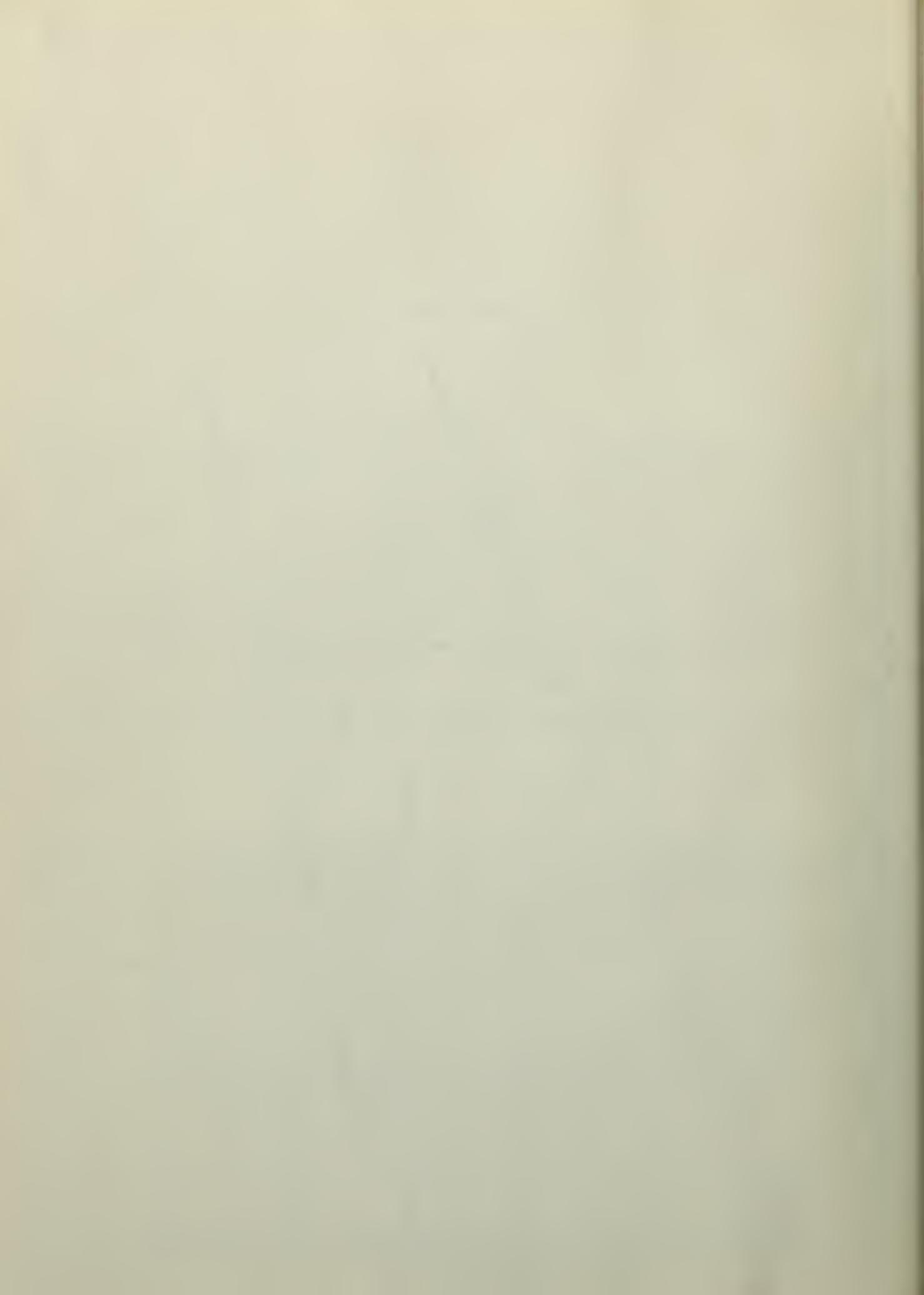


Figure 4

Time after applying load, minutes

ϵ'' , Micro-inches per inch



Thus, it was impossible to get strain reading with any meaning from these pieces. The authors concluded that, since these strips had been rendered useless for structural purposes by the temperature required for fusion, at least in the vicinity of the weld when a torch was being used to supply the heat, a similar condition of softness and distortion existed. It was seen, then, that the amount of torch heating given the 61ST6 strips, as determined arbitrarily by the slight discoloration of the flame as it impinged upon the surface of the aluminum, was in reality considerably below the temperature required for fusion during welding with eutecrod. This accounts for the closeness of the valves of "E" as determined in the previous test. (The actual temperature was probably near that required for soldering with the alladin rod.) Welding was then discarded as a method of making aluminum models, and our efforts were concentrated upon the lower temperature alladin soldering method.

III. FABRICATION OF TEST BEAMS

The two materials used for the making of the test beams were steel and aluminum, with the reasons for this choice as dictated in part I. This section is dedicated to the methods and techniques used, and the problems encountered in the fabrication of the test beams. It is divided into two sub parts based on the material used.

A. Aluminum

Aluminum was our first choice for the reasons previously explained. It is best perhaps to begin with the ways the material was prepared.

1. Preparation of Material

The aluminum for the beams was obtained from sheet aluminum of the 61ST6 type, and of varying thicknesses. A metal cutting bandsaw was used to obtain the desired sizes, with great care being taken to insure that straight pieces were obtained. Of interest at this point, would be the fact that it is necessary to be certain that a sharp blade is used in the saw if a straight cut is to be obtained. The sawed edges were next ground down to a smooth finish on a disc sand-wheel and burrs left from this sanding were taken off with a belt sander. This process insured that the extreme edge was not only clean, but also smooth such that close fitting tolerances were obtained when joining pieces. In the making of wide-flange beams in which the web of the beam is butted against the middle of the flange, it is felt by the authors

LII. PREPARATION OF PURE ALUMINA

The two materials used for the purpose of the test were very pure and aluminum, and the process was carried out as detailed in part I. This section is devoted to the methods and techniques used, and the procedure recommended in the section of the test report. It is believed that the test results obtained in the laboratory were.

A. Aluminum

Aluminum was not used in the test as the amount of material required was negligible. It is best practice to begin with the purest material available.

1. Preparation of material

The aluminum for the test was obtained from the aluminum of the B.I.U. type, and of varying degrees of purity. A special cabinet furnace was used to obtain the desired purity with great care being taken to insure that the desired purity was obtained. Of interest at this point, would be the fact that it is necessary to be certain that a sharp line is seen in the test if a sharp line is to be obtained. The same method was used to obtain down to a sharp line on a test wheel and to test the results. The process involved the same steps as the test itself. The test results were also obtained with the same method. In the case of the test, it is believed that the test results obtained in the laboratory were in the case of the test, it is believed that the test results obtained in the laboratory were.

that even the thin aluminum oxide present at the joint should be cleaned off. This was accomplished by using a fine emery cloth and cleaning the center of the flange along which the web would touch. The surfaces of the web near the edges were also cleaned up for a short distance, using emery cloth, to insure that the fillet of joining material would have a good surface on which to adhere.

2. Jigs

Making a jig to hold the pieces together while joining them was one of the most difficult problems encountered. We will explain not only the most successful method used, but also the others that were tried. It can be easily understood that the problem of jiggling is not just one of holding the materials, but also a problem of holding them extremely accurately in their correct relation to each other. For example, in the making of wide-flange beams it is necessary that the web be held exactly in the center of the flange. The problem of jiggling is applicable to all the different methods of joining the materials; therefore, it is only necessary to present it once.

At the beginning, the most important problem of jiggling seemed to be one of being able to insure that the pieces were held in exact alignment. It was with this in mind that the first jig was made.

This jig was constructed using three pieces of aluminum angle, lined with asbestos along the outside against

which the main material would be held, as shown in Figure 5. Angle A and angle B were clamped together to hold the flange securely. Then angle C, which was a cut down angle to give the maximum torch clearance, was used in conjunction with angle A to hold the web securely. As can be seen in the sketch, this method not only gave assurance that the web and the flange were at right angles, but also afforded clear access for measurement to insure that the web was at the midpoint of the flange. The several disadvantages that became apparent in using this method were as follows: (1) in spite of the asbestos lining, too much heat was lost through contact with the metal jig, such that the heating of the piece was irregular and thus the welding temperature, which is very critical, was hard to regulate; (2) the two pieces which were to be joined were both held clamped together, and although of the same material, they warped because of the unequal expansion due to localized heating; and (3) most important, as there was no support for the upper part of the flange, there was a tendency for it to distort to one side or the other due to the concentrated heating near the centerline. Therefore, in the method of welding using eutecrod, as will be explained later, the temperatures required are too high; however, in the soldering method, with the slightly lower temperatures, it might be possible to use the above procedure. The method finally used, as will be explained, seems to be a much more practical way of solving the problem.

which the main essential point is that, it is not in the
 sense of a new principle from classical mechanics in the sense
 accuracy. The angle θ , which was a very small angle in the
 the maximum force element, was used in the classical
 angle θ to find the force element. At the same time in the
 angle, this method not only gave a more accurate result than the
 the force was in the angle θ , but also showed that
 excess for measurement in finding that the force was in the
 point of the force. The average displacement was found
 element in the angle θ was used as a result. It is also
 of the element θ , for which the force was found to be
 part of the angle θ , which was the result of the
 the element and was the result of the element, which is very
 element, was used as a result. It is also shown that the
 to be found was that the force was found to be
 the same result, that is, the force was found to be
 the same as the result of the element, as
 there was no change in the angle θ of the force, there
 was a constant in it to show that the force was
 to the constant result near the element. Therefore,
 in the result of the element, which will be explained
 later. The element was found to be
 the element, which is the result of the element,
 it will be possible to use the above procedure. The result
 finally was, as will be explained, which is to be a
 practical way of finding the element.

Jig # 1

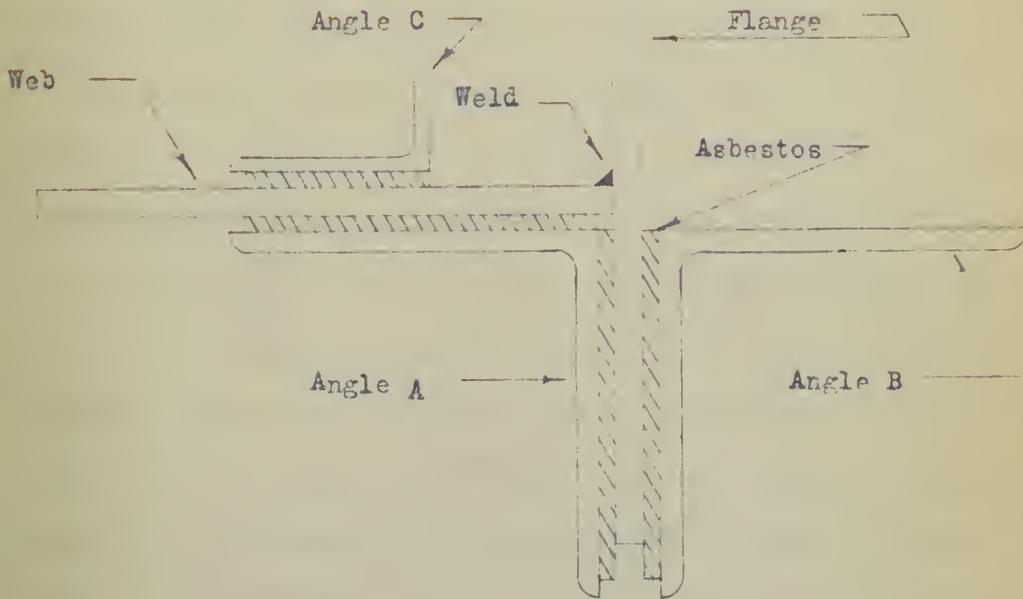
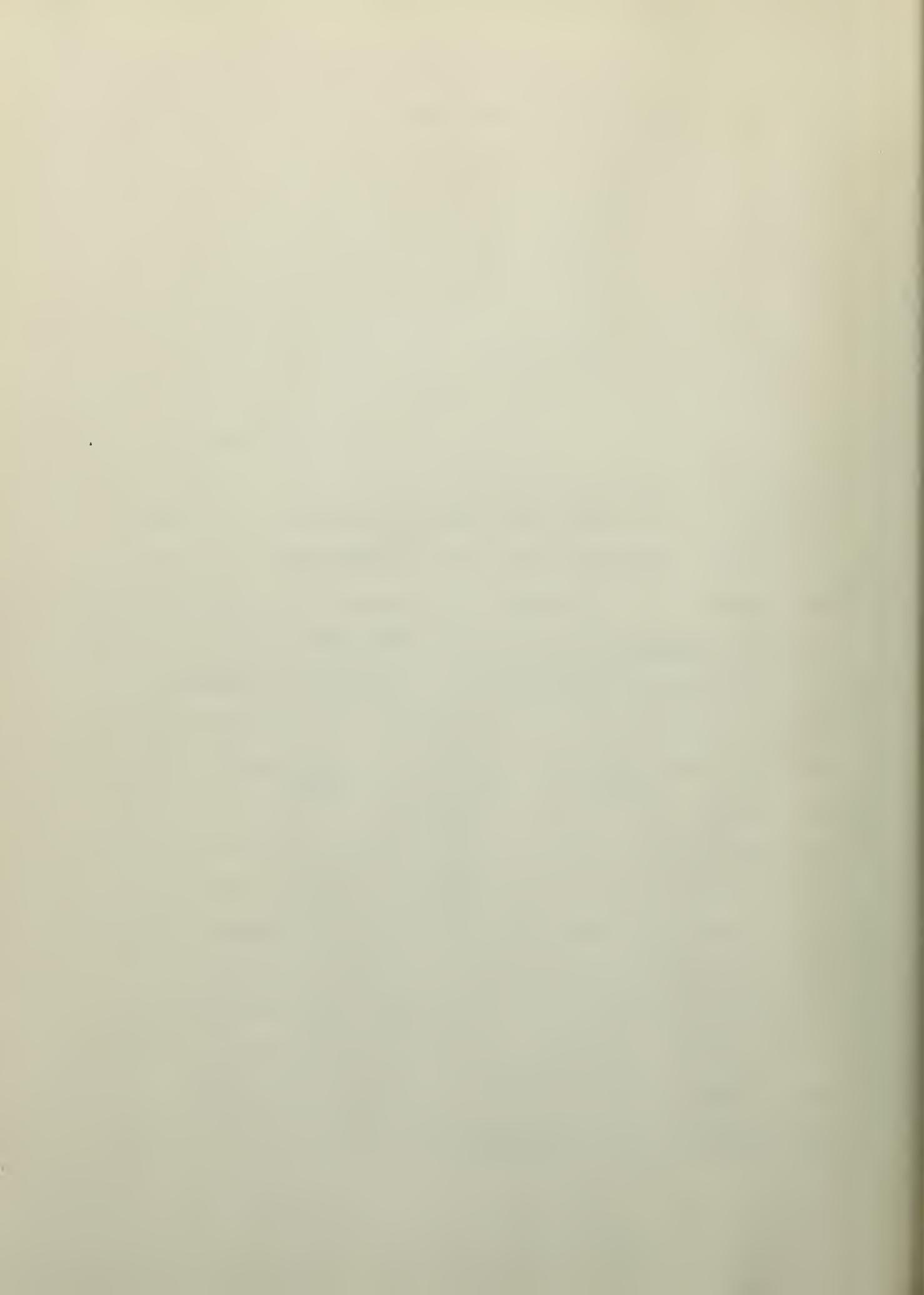


Figure 5



The second jig was made with the idea in mind of being able to support both flanges and the web at the same time to overcome any tendency of these members to warp due to lack of support. We then constructed a jig, the cross section of which is shown in Figure 6. The two angles were made about 30 inches long, which of course limited the length of beam it was possible to make. The angles were lined with asbestos and one was fixed to a base plate to prevent movement. The other angle was made a sliding variety which was held in place by clamping it to the fixed angle with "C" clamps to provide the pressure needed to hold the beam while welding it. The correct location of the web was obtained by using a piece of sheet aluminum bent on a brake such that it held the web up between the two flanges as shown in the sketch. In the process of welding, the two upper welds were placed, the beam was turned over, and the two other welds were placed. This method, at first, seemed to be the solution to all jiggling problems; however, one of the problems encountered in the first jig was present along with a new one. The old problem was that of controlling the heat, and still hadn't been solved. The new problem was as follows. In clamping the two angles together we tried to put just enough pressure to cause the joints to be tight, but not really forced together. This appeared fine from the standpoint of expansion, but still proved inadequate. From the sketch it can be seen that there is no easy way to provide support on top of the web, and still leave room in

Jig # 2

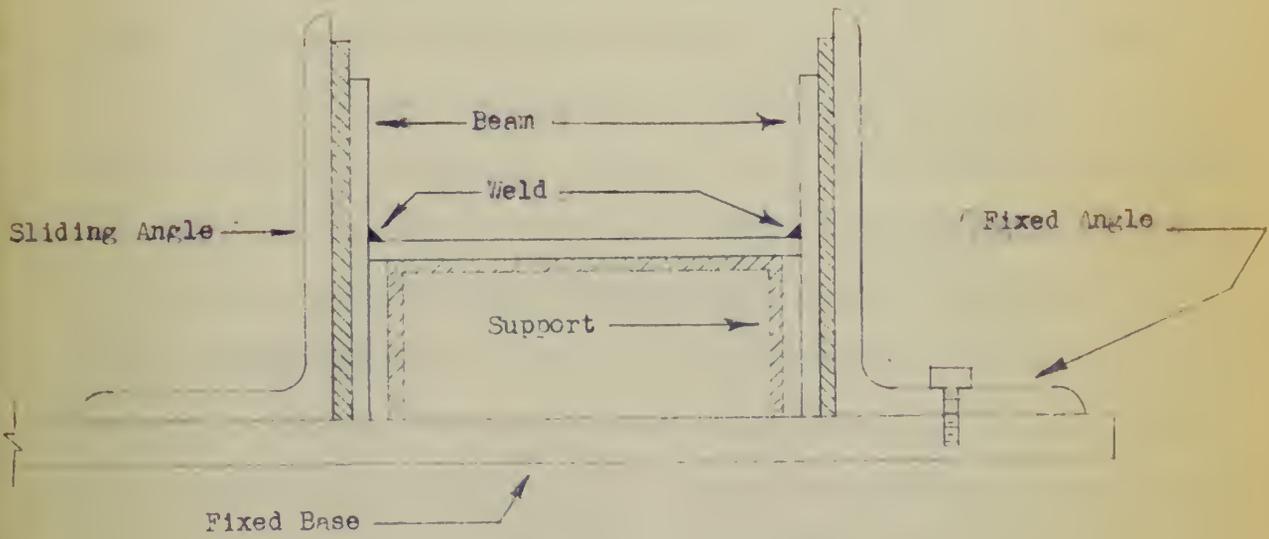


Figure 6



which to use the acetylene torch. Therefore, due to no top support, and the fact that the web was bound to be held by the flanges with more pressure in some places than others, there was a definite tendency for the web to rise off its support and buckle upwards when the heat was applied. The flanges seemed to stay in line, but the method resulted in a beam whose web was not exactly centered between the flanges. Therefore, this beam could not be expected to check according to the deflection theory being used.

Our third design, which eventually led to our final and very successful method, came as an effort to eliminate the defects that were noted in our previous jigs. First of all we wanted to eliminate the heat loss due to contact of other materials with those we were welding. It was also necessary to find some way to support the flanges and web such that they would be held in the proper orientation with respect to each other. These problems were solved by using 1-inch by 1-inch steel angle cut in 3/4-inch lengths. The flange and the web were held at right angles by clamping pieces of the angle to both the web and the flange along one side leaving the other free for welding. Then by adjusting the location of the angle on the flange the web could be placed in the proper location. This arrangement of angles was made along the whole length of the beam, the weld being placed down the free side. However, the flange and the web, which were clamped rigidly together, distorted due to the heating. This resulted in beams which would not check out.

which he used the analysis before. Therefore, due to the
 nature, and the fact that the test was found to be valid by
 the Linnet at 10 with reference to some other cases,
 there was a definite tendency for the test to give all the
 support and weight towards the test was applied. The
 Linnet seemed to stay in line, but the weight received in a
 form that was not exactly identical between the Linnet.
 Therefore, this case could not be applied in some countries
 to the solution being used.

On this matter, which is possibly not to be

that was very important matter, was it an effort to find
 out the details that were taken in the previous line. There
 of all we tried to eliminate the fact that the weight of
 that matter was also in use. It was also
 easy to find some way to weight the Linnet and the
 that they would be held in the present situation with respect
 to each other. That problem was solved by using a
 1-inch steel angle cut in 2 1/2-inch lengths. The Linnet and
 the test were held at right angles by clamping them at the
 angle to hold the test and the Linnet along one side leaving
 the other free for weighing. Then by adjusting the location
 of the angle on the Linnet the test could be placed in the
 proper location. The arrangement of angle was held along
 the angle length of the test, the test being placed down the
 test line. However, the Linnet and the test, with very
 change slightly between, directed due to the weight. This
 resulted in being able to read the test.

Finally, we used the same method as described in the previous paragraph, but clamped one piece of angle to each side of the flange, directly opposite each other, leaving enough clearance between the angles to insert the web and hold it firm and perpendicular. (See Figures 7 and 8.) The pairs of angles were placed about one foot apart.

A clamp preventing the web and flange from separating, but allowing longitudinal movement, was placed along the beam at each set of angles. The whole beam was then supported on pedestals placed at the mid-point between the angles. This was done such that the beam reaction at the support would keep the joint between the web and the flange tight. The welding was done next, welding first on one side of the web for a length of about 8 inches, then on the other side of the web. It is important not to weld any closer than 2 inches to the angles. The purpose of welding on the opposite side immediately was to utilize the heat that had already been put into the pieces. This also minimized distortion, since stresses resulting from heating on both sides of the web tended to be cancelled out. After the whole beam was welded this way, it was necessary to take off the angles and clamps and weld up the remaining spaces. This method gave us consistent results on all beams constructed, as the results in the following sections will indicate.

3. Check of the Loading Device

It was felt by the authors that a check of the vertical loading frame (see Figure 9) was necessary in order

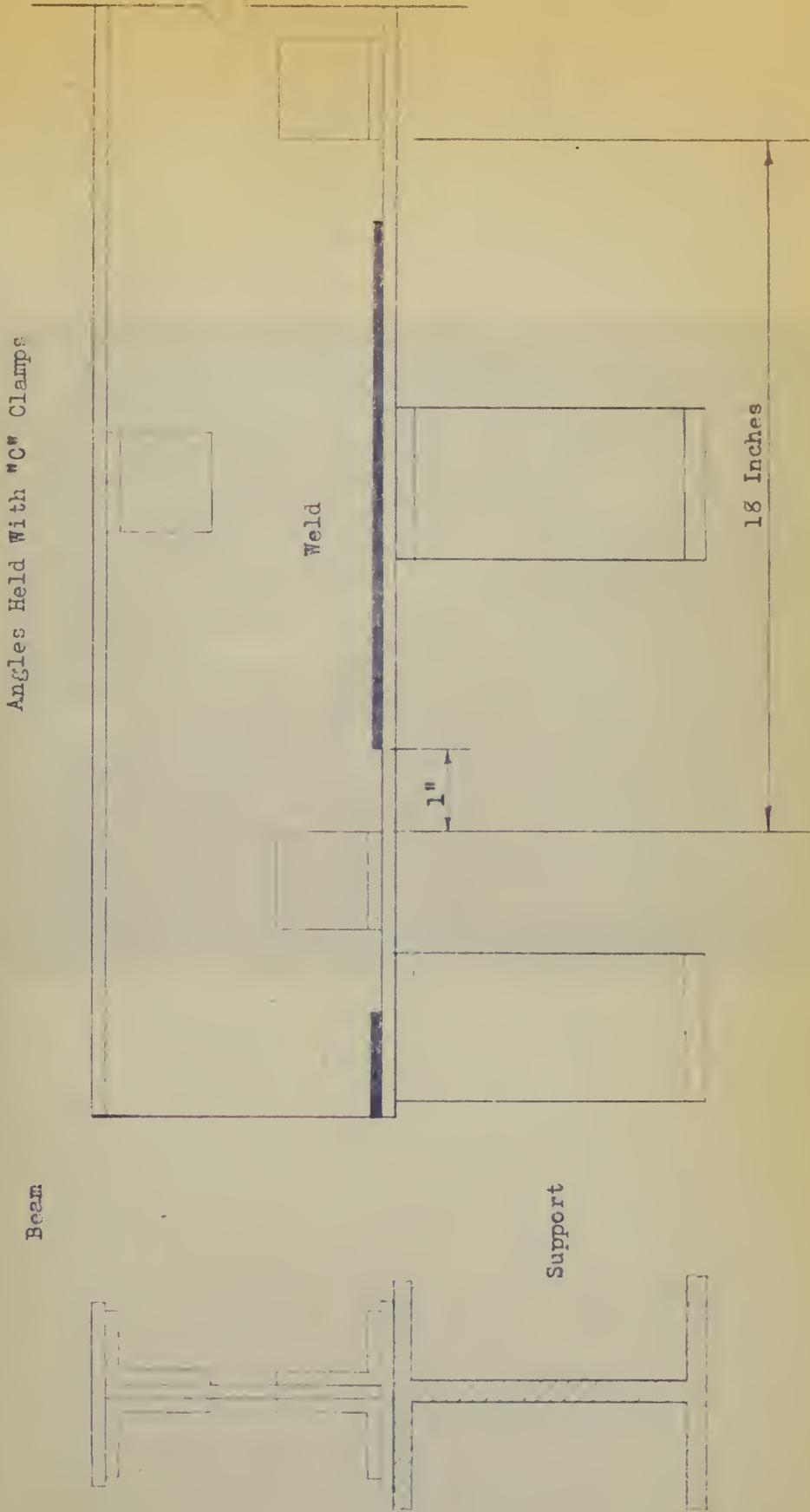
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Angles Held With "C" Clamps

Beam

Support

Weld

1"

18 Inches

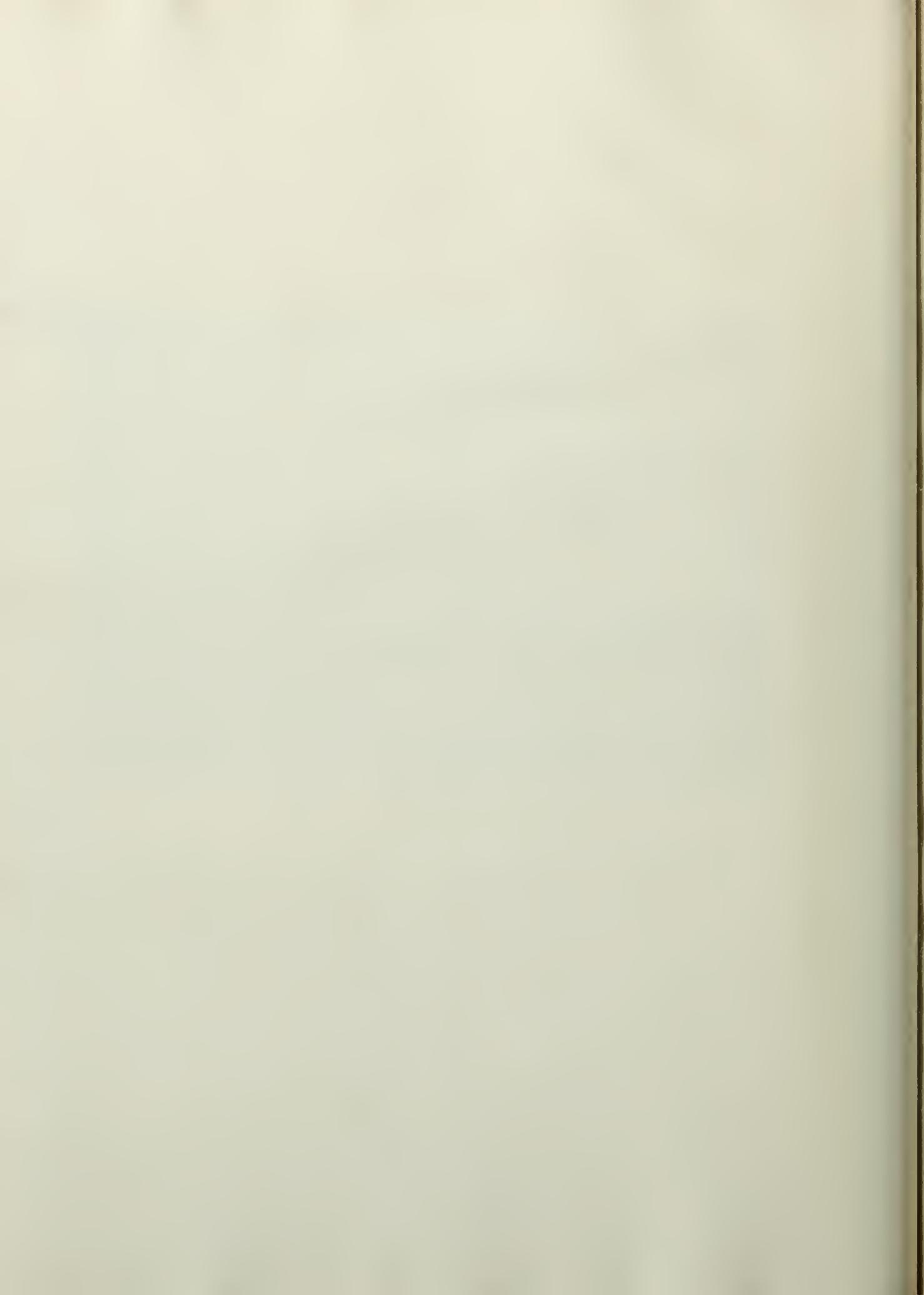
Jig # 3 Modified

Figure 7

Jig #3 Modified



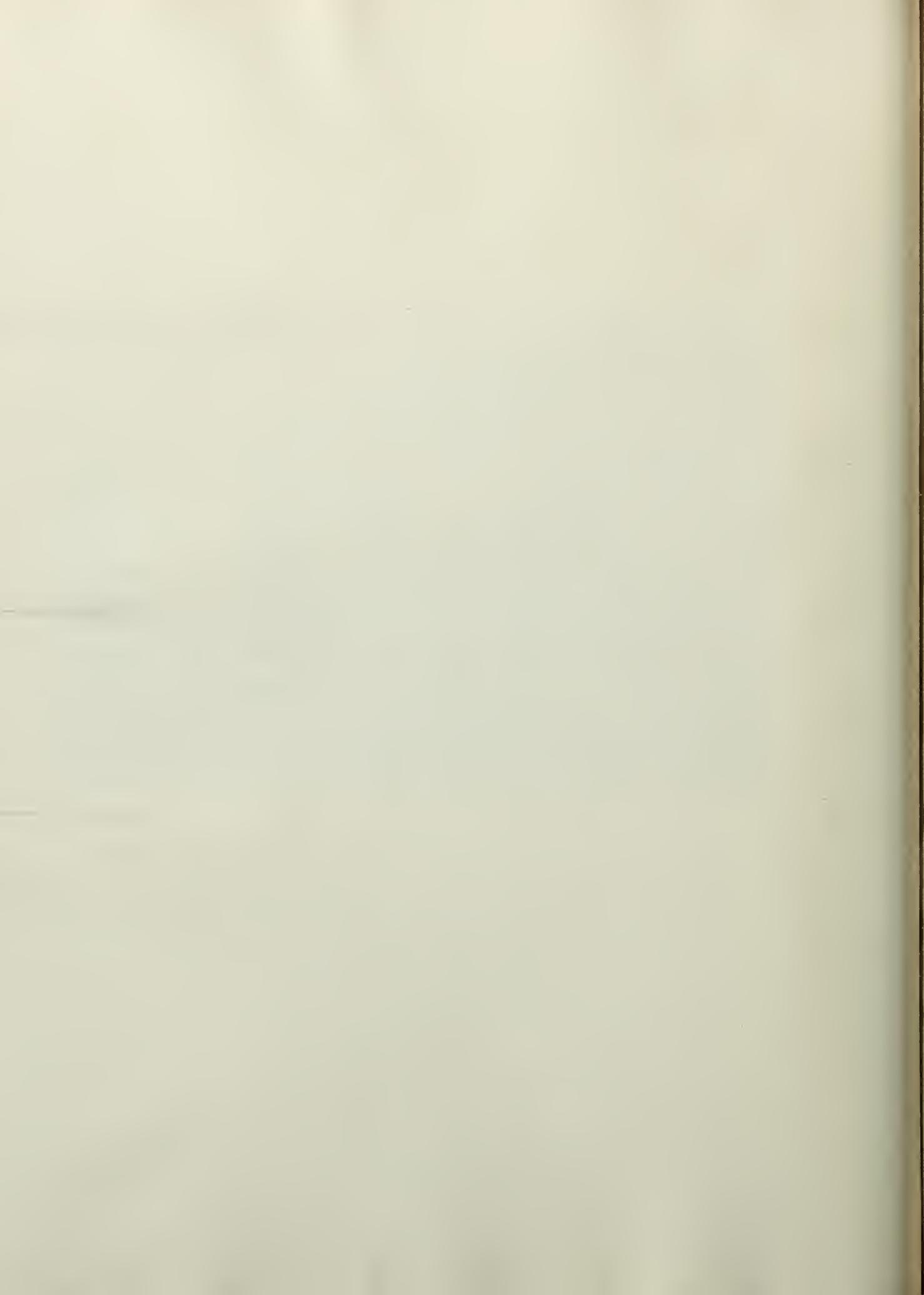
Figure 8



Vertical Loading Frame



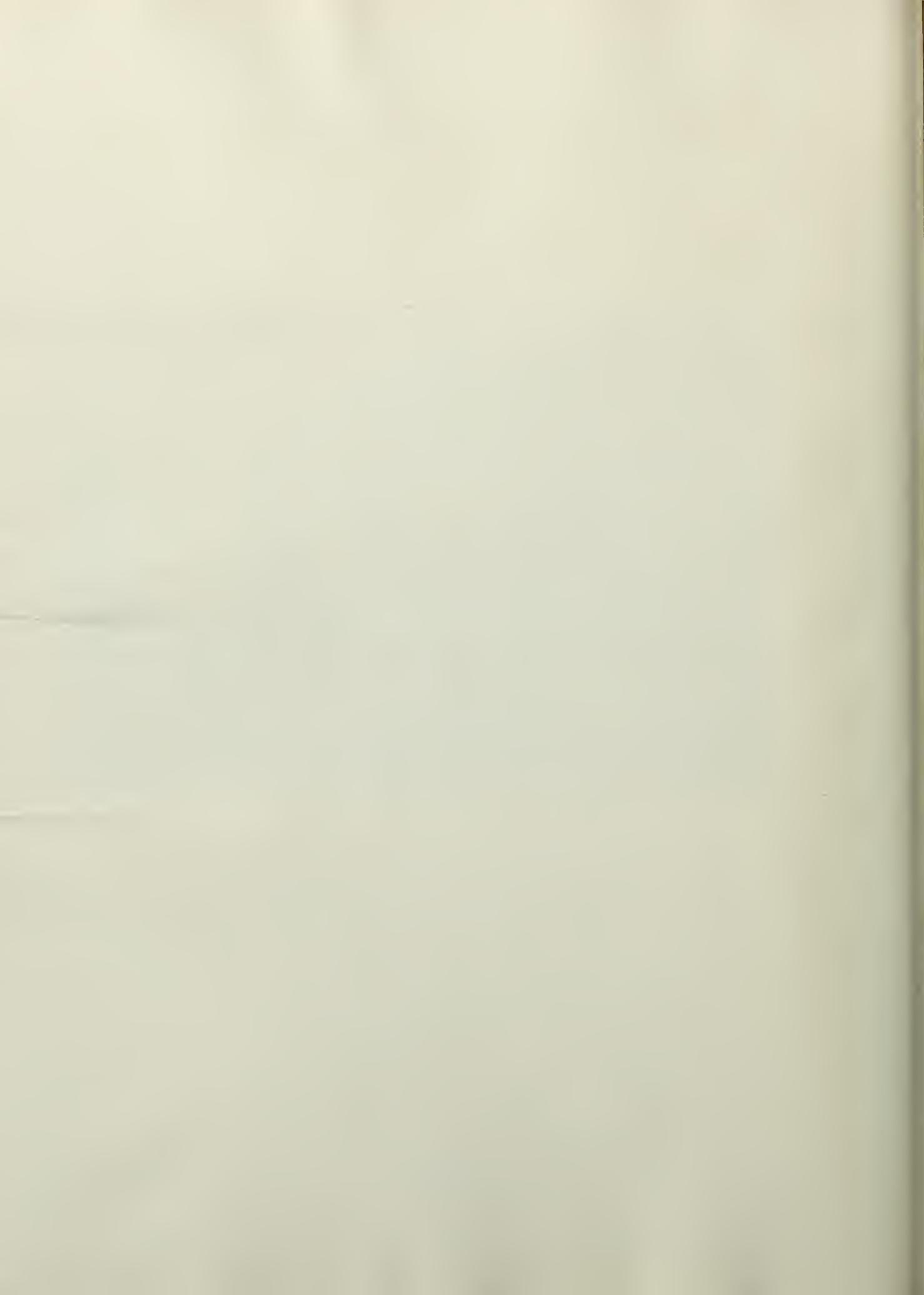
Figure 9



to insure that accurate results would be obtained. Therefore, an extruded "T" beam was obtained and subjected to a load test on the loading frame. The method used to check our procedure consisted of loading the beam and comparing the actual and computed deflections. This set up is shown in Figure 10.

The beam, when in the loading frame, was supported on knife edges which were rounded on the underneath side so that no restraint was placed on them. The load consisted of lead shot placed in a bucket. It was applied to the beam by means of a knife edge, attached to a yoke (see Figure 11) which supported the bucket. The deflection was measured by a $1/10,000$ of an inch direct reading dial, placed underneath the mid-point of the span. The dial holder is shown in Figure 11 and was made such that it would also serve as a dial holder for taking readings on the horizontal loading frame.

A comparison of the actual deflections, under load, with the deflections computed by conventional formulae show an average difference of 1.4%. This check was considered close enough to allow the use of this vertical loading frame for future model tests.



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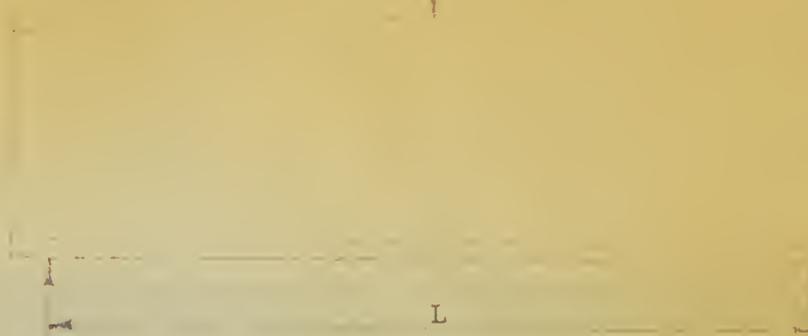
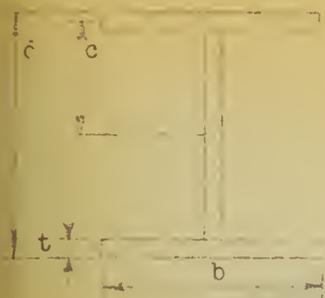
A comparison of the actual deflections, under load, with the deflections computed by conventional formulae show an average difference of 1.4%. This check was considered close enough to allow the use of this vertical loading frame for future model tests.

to insure that accurate results would be obtained. The results
 as obtained were subjected to a test for
 on the loading frame. The method used to check the procedure
 consisted of loading the beam and comparing the actual and
 computed deflections. This test is shown in figure 10.

The beam, when in the loading frame, was supported
 on knife edges which were mounted on the under-ends of the
 ends of the beam and fixed on them. The beam consisted of
 lead shot placed in a bucket. It was applied to the beam by

means of a knife which extended to a point less than 1/16
 inch beyond the point. The deflection was measured by a
 1/16 inch at an inch direct reading dial, fixed underneath
 the mid-point of the beam. The dial pointer is shown in figure
 11 and was used only if the beam was used as a dial pointer
 for testing beams on the bolted loading frame.

A comparison of the actual deflections, when
 used, with the deflections computed by theoretical formulas
 show an average difference of 1.4%. This shows the consistency
 of the method so also for use of this vertical loading frame
 for future model tests.



All Dimensions are in inches.

Computations:

Moment of Inertia,

$$I \text{ flange} = \frac{2(bt^3 + btc^2)}{12}, \quad I \text{ web} = \frac{t(d-t)^3}{12}$$

I Total equals I flange + I web.

Deflection,

$$D = \frac{PL^3}{48 EI}$$

D- Deflection in inches
L- Span length in inches
E- Modulus of Elasticity
I- Moment of Inertia
P- Load in pounds

Stress

$$f = \frac{Mc}{I}$$

f- Stress in psi
M- Moment in inch-pounds
I- Moment of Inertia
c- As shown above

Figure 10

Loading Yoke and Deflection
Dial Holder



Figure 11

Extruded "T" Beam

(Beam #1)

Dimensions of Beam
(See Figure 10)

b = 1.24 inches
t = .128 inches
d = .87 inches
L = 34 inches

Neutral Axis was computed to be .227 inches above the base.

Moment of inertia (I) = .0158 inches⁴

Deflection (D) = 5.18 P (10⁻³)

Stress (f) = 345 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Dif.</u>	<u>Stress</u>
1.6	.07551	.08330	.00801	.00830	0	551.0
2.16	.07566	.08679	.01128	.01123	.45	745.0
3.0	.07555	.09170	.01604	.01555	3.05	1035.0
4.0	.07560	.09708	.02153	.02073	3.72	1380.0
5.0	.07560	.10160	.02600	.02590	.38	1720.0
7.0	.07561	.11201	.03641	.03630	.32	2320.0
9.0	.07561	.12314	.04753	.04670	1.74	3100.0
11.0	.07561	.13320	.05759	.05700	1.02	3800.0
13.0	.07561	.14382	.06821	.06730	1.33	4480.0
15.0	.07561	.15489	.07928	.07775	1.93	5180.0

4. Technique of Joining Flanges to Web

There were three methods used by the authors in fabricating models from aluminum. They were eutecrod welding, soldering, and furnace brazing. It is in this section that we will discuss the three methods and the results of the tests run on the models constructed by each method.

a. Eutecrod Welding

(1) Welding difficulties

The difficulty in welding with eutecrod is the high temperature required for fusion, which approaches the melting temperature of aluminum. In actual practice the two temperatures differ only by about 50 degrees and great care must be exercised not to bridge this differential. The parent material will warp and disintegrate very quickly when the melting point is approached. Another important point to consider is that, in the vicinity of the weld, the yield strength of the material has decreased considerably, resulting in the material no longer being homogeneous. These two facts are very important and must be considered in view of the final results desired.

(2) Flux

The flux used was supplied by the eutecrod company to be used in conjunction with their rod. It is a powder that is mixed with

There were three methods used by the authors in
conducting these tests. They were: (1) the
method of use, and (2) the method of use.
We will discuss the three methods and the results of the tests
run on the models conducted by each method.

a. Method of use

(1) Method of use

The difficulty in relation with the
in the case of the method of use for the
which approaches the method of use of
method. In actual practice the two methods
are only as much as the method and
that the method is not as simple as
the method. The method of use will
with the method of use. The method of use
method of use is approached. The method of use
method of use is not as simple as the method
of the method, the method of use of the method
has been considered, resulting in the
method of use being considered. These
two tests are very important and may be
conducted in view of the final results desired.

(2) Method of use

The first test was conducted by the method
and the method of use in conjunction with
the method. It is a method that is used with

water to form a paste, which is spread on the joint to be welded. Care must be exercised in applying the flux, insuring that only the surfaces at the joint are covered. This is true because, if too much is used, the flux allows the eutectoid to run as it melts, covering a weld area that is too large. This point is not essential in making a good weld but it appears to help.

(3) Method of welding (See Figure 12)

The actual method used in welding is similar to that used in any torch welding, with a modification. The big change adopted was in the way the heat from the torch was applied to the joint. Rather than directing the flame almost perpendicular to the joint, we found it better to shoot the flame parallel to the joint, heating with the side of the flame. Using this method, it was found that there was better control of the heat, giving effective preheating with less chance of overheating. The rest of the welding procedure is the same, i.e., feeding in welding rod as the temperature gets high enough, and moving along fast enough to give an even fillet.

Method of Welding

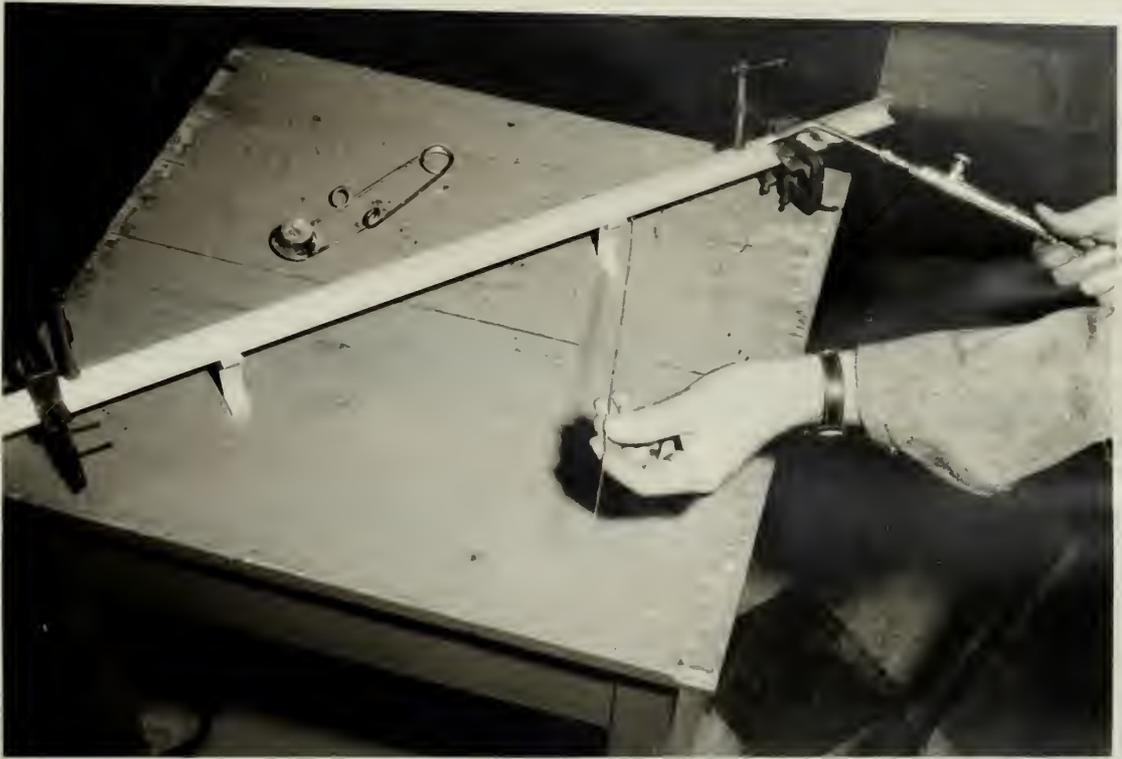
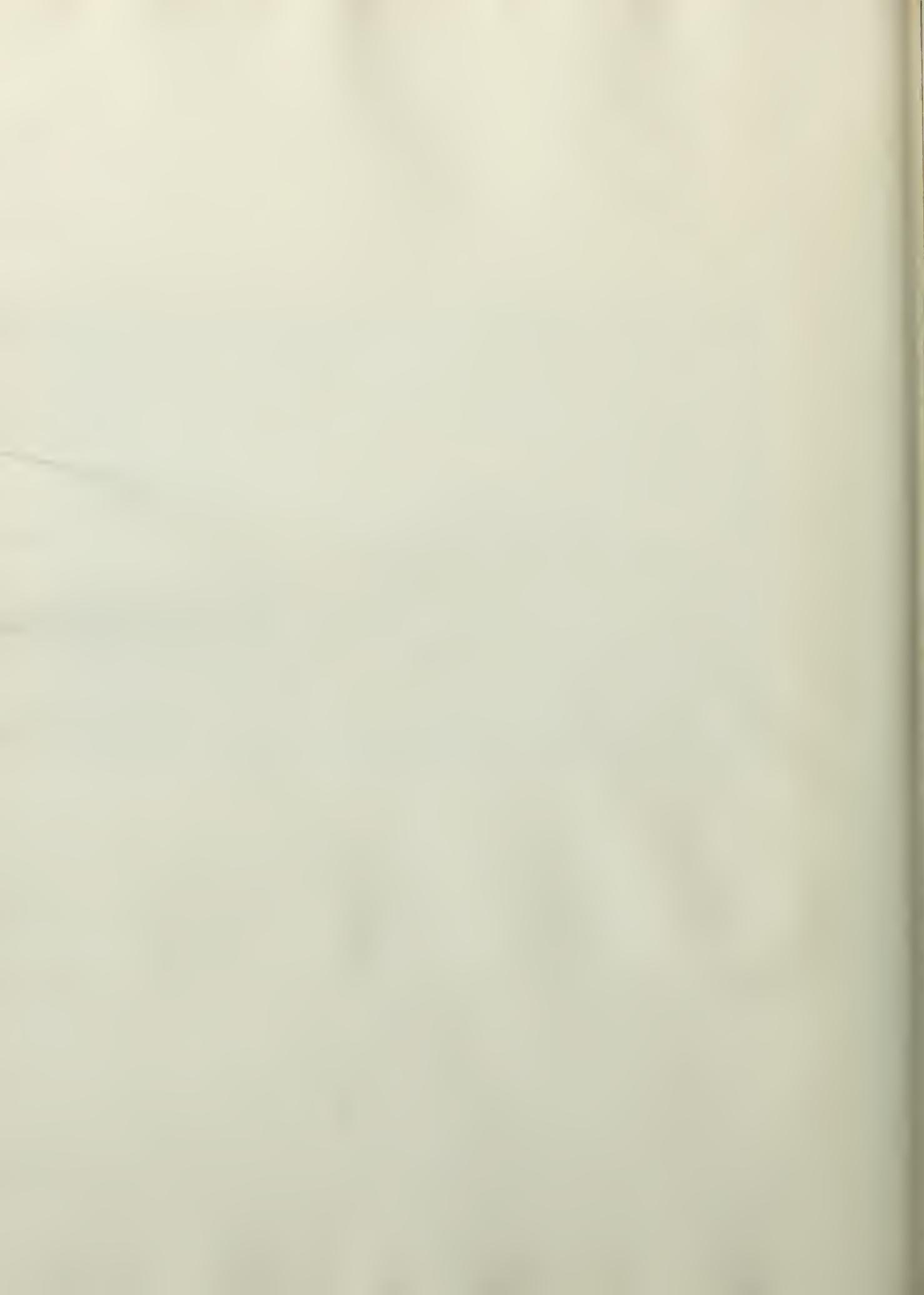


Figure 12



(4) Test Samples and Results

In order to be sure of the amount of load eutecrod welding would sustain, a series of test samples were made. They were of the form as shown in Figure 13 with the dimensions and results as shown below.

Shear test

a = 1 inch
L = 2 inches
b = 3/4 inch
h = .091 inch

Under a load (P) of 1590 pounds, the parent material broke across the 3/4 inch dimension.

Tension test

a = 1 inch
b = 3/4 inch
h = .091 inch

Under a load (P) of 980 pounds, the weld broke.

The results of these tests were definite proof that any welds made with eutecrod were sufficiently strong to withstand more load than the parent material, and therefore, strong enough to carry the loads we would use.

(1) Test results and results

In order to be sure of the amount of load sustained during work, several tests of test results were made. They were of the form as shown in figure 13 and the dimensions and results are given below.

Lower test

Load	$a = 1$
Load	$b = 1$
Load	$c = \sqrt{2}$
Load	$d = 1$
Load	$e = 1$

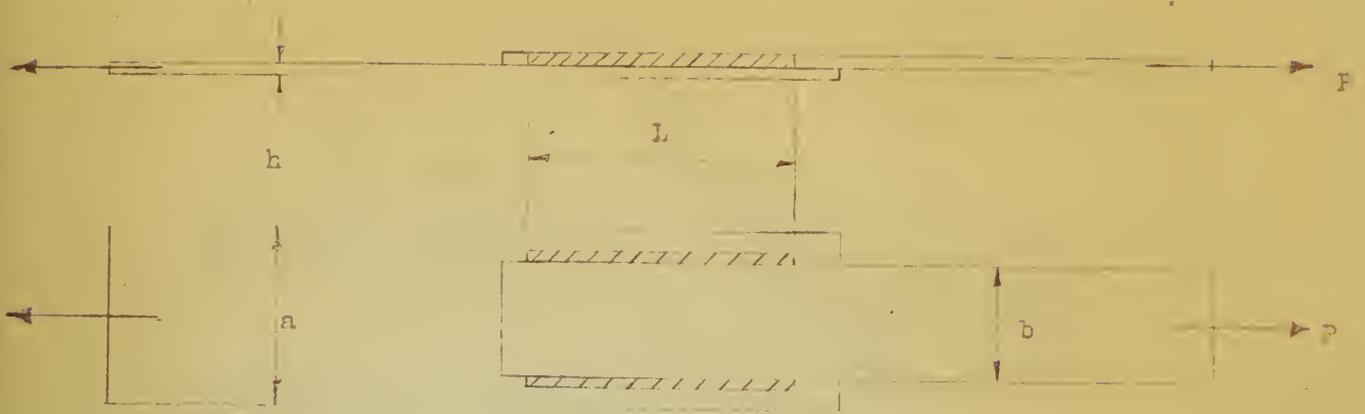
Under a load (1) of 1000 pounds, the average deflection across the $5\sqrt{2}$ inch diameter

Upper test

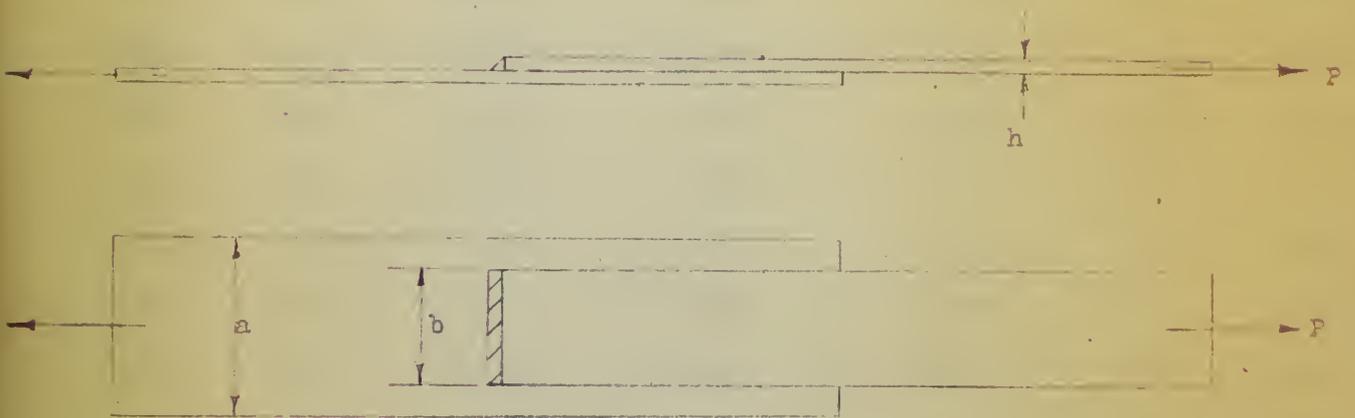
Load	$a = 1$
Load	$b = \sqrt{2}$
Load	$c = 1$

Under a load (1) of 100 pounds, the deflection across the $5\sqrt{2}$ inch diameter was 0.015 inches. The results of these tests were satisfactory and show that the test results were sufficiently accurate to warrant more load tests. The average deflection, and results, are given below.

Shear and Tension Test Specimen

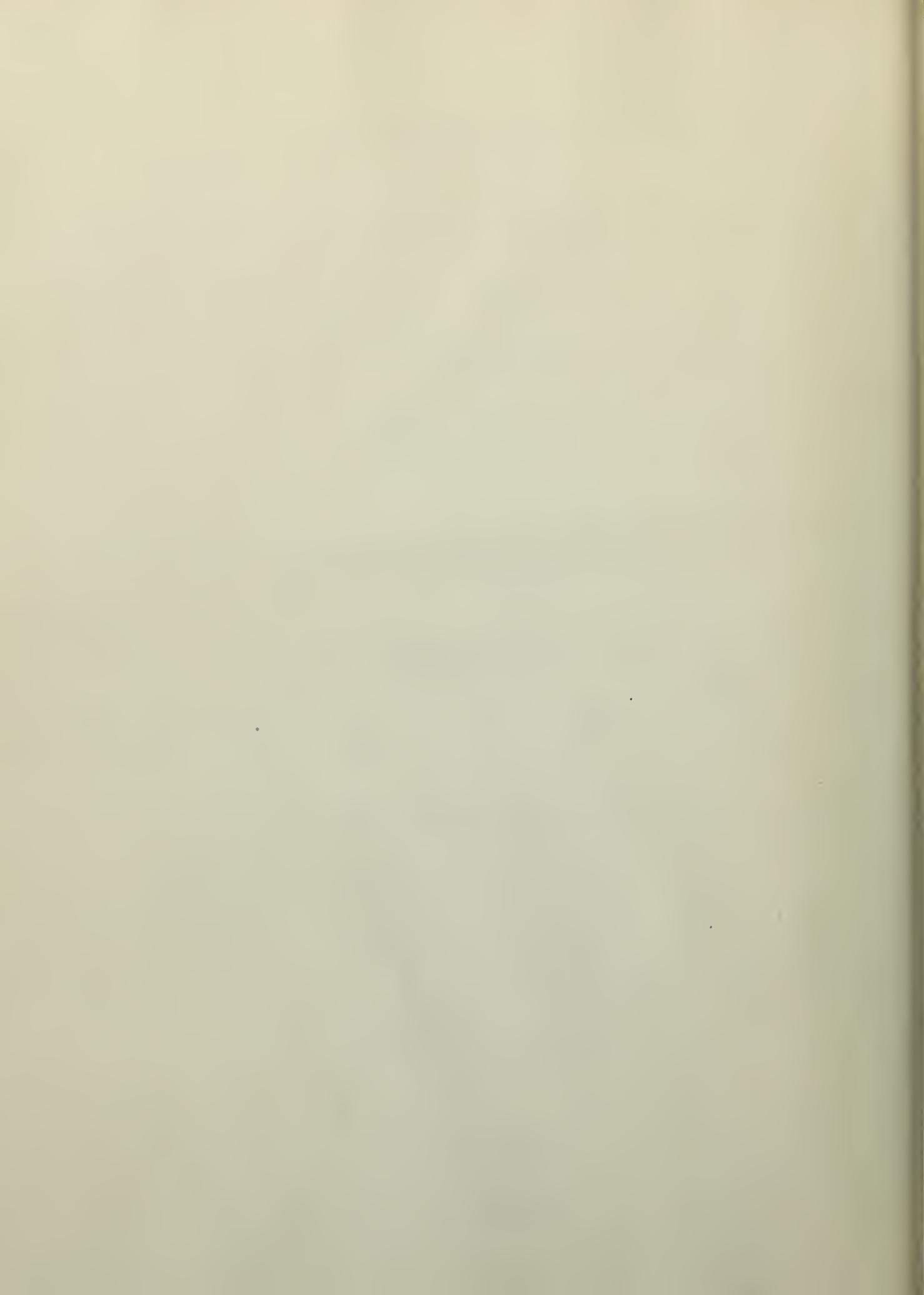


Shear Test



Tension Test

Figure 13



(5) Aluminum welded beam tests and results

Beam #4

Beam #4 was constructed, using the eutecrod welding method, in jig #2. It was tested on the vertical loading frame with the results as given below.

Dimensions of Beam	b = 2.0	inches
(See Figure 10)	t = .093	inches
	c = 1.32	inches
	d = 2.73	inches
	L = 24	inches

Moment of Inertia (I) = .7750

Deflection (D) = $.0371 \times 10^{-3} P$

Stress (f) = 10.2 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
10	.2800	.2831	.0031	.00037	87.0	102.0
26.6	.2800	.2845	.0045	.0010	78.0	272.0
35.0	.2821	.2859	.0038	.0013	66.0	357.0
50.6	.2823	.2875	.0052	.0019	63.0	516.0
60.0	.2826	.2882	.0056	.0022	61.0	612.0
75.6	.2828	.2901	.0073	.0028	62.0	771.0
85.0	.2829	.2916	.0087	.0032	63.0	867.0
100.6	.2831	.2928	.0097	.0037	62.0	1020.0
110.0	.2832	.2936	.0104	.0041	61.0	1121.0
125.6	.2836	.2946	.0110	.0047	57.0	1280.0
135.0	.2839	.2949	.0110	.0050	55.0	1379.0
150.6	.2839	.2976	.0137	.0056	59.0	1537.0

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
160.0	.2844	.2981	.0137	.0059	57.0	1631.0
185.0	.2849	.2997	.0148	.0068	54.0	1889.0
215.5	.2850	.3004	.0154	.0080	48.0	2195.0

Beam #4 was warped and distorted which accounts for the high percentage error. These high errors indicate that the whole method was entirely inadequate for a simple laboratory technique. The next attempt at eutecrod welding was Beam #7.

Year	1911	1912	1913	1914	1915	1916
1911	0.70	0.000	0.010	0.000	0.000	0.000
1912	0.74	0.000	0.010	0.000	0.000	0.000
1913	0.78	0.000	0.010	0.000	0.000	0.000

The data presented in this table shows the results of the various tests conducted during the year 1911. The tests were conducted in accordance with the standard methods of the Bureau of Standards. The results show that the various tests were conducted in accordance with the standard methods of the Bureau of Standards. The results show that the various tests were conducted in accordance with the standard methods of the Bureau of Standards.

Year	1911	1912	1913	1914	1915	1916
1911	0.70	0.000	0.010	0.000	0.000	0.000
1912	0.74	0.000	0.010	0.000	0.000	0.000
1913	0.78	0.000	0.010	0.000	0.000	0.000
1914	0.82	0.000	0.010	0.000	0.000	0.000
1915	0.86	0.000	0.010	0.000	0.000	0.000
1916	0.90	0.000	0.010	0.000	0.000	0.000
1917	0.94	0.000	0.010	0.000	0.000	0.000
1918	0.98	0.000	0.010	0.000	0.000	0.000
1919	1.02	0.000	0.010	0.000	0.000	0.000
1920	1.06	0.000	0.010	0.000	0.000	0.000

Beam #7

Beam #7 was constructed using the autecrod welding method in jig #3. It was tested on the vertical loading frame with the results as follows:

Dimensions of Beam	b = 1.03 inches
(See Figure 10)	t = .063 inches
	c = .55 inches
	d = 1.16 inches
	L = 12 inches

Moment of Inertia (I) = .0455

Deflection (D) = $.0791 \times 10^{-3} P$

Stress (f) = 36.2 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.2337	.2341	.0004	.000127	67.5	58.0
5	.2337	.2347	.0010	.000396	60.4	181.0
12.2	.2337	.2357	.0020	.000963	52.0	442.0
19.85	.2335	.2364	.0029	.00157	48.3	719.0
27.85	.2338	.2373	.0035	.00220	37.0	1005.0
35.7	.2338	.2379	.0041	.00283	31.0	1290.0
42.65	.2340	.2389	.0049	.00337	31.2	1540.0
51.1	.2340	.2400	.0060	.00403	32.8	1850.0
58.85	.2341	.2410	.0069	.00465	32.6	2130.0
66.35	.2343	.2416	.0073	.00525	28.7	2400.0
74.65	.2341	.2428	.0087	.00590	32.2	2750.0
110.00	.2339	.2470	.0130	.00870	33.1	3980.0
160.0	.2340	.2518	.0175	.01265	28.0	5800.0

Table IV

Table IV was calculated using the average welding values in 1945. It was based on the average loading (Table III) and results as follows:

- 1 = 1.15 inches
- 2 = 1.15 inches
- 3 = 1.15 inches
- 4 = 1.15 inches
- 5 = 1.15 inches
- 6 = 1.15 inches
- 7 = 1.15 inches
- 8 = 1.15 inches
- 9 = 1.15 inches
- 10 = 1.15 inches
- 11 = 1.15 inches
- 12 = 1.15 inches

Direction of Load (from reference)

Sum of loads (1) = 0.450
 Deflection (2) = 0.001 x 10⁻³
 Stress (3) = 50.0

Load	Def.	Comp. Def.	Def. Def.	Load	Def.	Load
0.000	0.00	0.0000	0.000	1.000	0.000	1.000
0.100	0.01	0.0000	0.000	2.000	0.000	2.000
0.200	0.02	0.0000	0.000	3.000	0.000	3.000
0.300	0.03	0.0000	0.000	4.000	0.000	4.000
0.400	0.04	0.0000	0.000	5.000	0.000	5.000
0.500	0.05	0.0000	0.000	6.000	0.000	6.000
0.600	0.06	0.0000	0.000	7.000	0.000	7.000
0.700	0.07	0.0000	0.000	8.000	0.000	8.000
0.800	0.08	0.0000	0.000	9.000	0.000	9.000
0.900	0.09	0.0000	0.000	10.000	0.000	10.000
1.000	0.10	0.0000	0.000	11.000	0.000	11.000
1.100	0.11	0.0000	0.000	12.000	0.000	12.000
1.200	0.12	0.0000	0.000	13.000	0.000	13.000
1.300	0.13	0.0000	0.000	14.000	0.000	14.000
1.400	0.14	0.0000	0.000	15.000	0.000	15.000
1.500	0.15	0.0000	0.000	16.000	0.000	16.000
1.600	0.16	0.0000	0.000	17.000	0.000	17.000
1.700	0.17	0.0000	0.000	18.000	0.000	18.000
1.800	0.18	0.0000	0.000	19.000	0.000	19.000
1.900	0.19	0.0000	0.000	20.000	0.000	20.000
2.000	0.20	0.0000	0.000	21.000	0.000	21.000
2.100	0.21	0.0000	0.000	22.000	0.000	22.000
2.200	0.22	0.0000	0.000	23.000	0.000	23.000
2.300	0.23	0.0000	0.000	24.000	0.000	24.000
2.400	0.24	0.0000	0.000	25.000	0.000	25.000
2.500	0.25	0.0000	0.000	26.000	0.000	26.000
2.600	0.26	0.0000	0.000	27.000	0.000	27.000
2.700	0.27	0.0000	0.000	28.000	0.000	28.000
2.800	0.28	0.0000	0.000	29.000	0.000	29.000
2.900	0.29	0.0000	0.000	30.000	0.000	30.000
3.000	0.30	0.0000	0.000	31.000	0.000	31.000
3.100	0.31	0.0000	0.000	32.000	0.000	32.000
3.200	0.32	0.0000	0.000	33.000	0.000	33.000
3.300	0.33	0.0000	0.000	34.000	0.000	34.000
3.400	0.34	0.0000	0.000	35.000	0.000	35.000
3.500	0.35	0.0000	0.000	36.000	0.000	36.000
3.600	0.36	0.0000	0.000	37.000	0.000	37.000
3.700	0.37	0.0000	0.000	38.000	0.000	38.000
3.800	0.38	0.0000	0.000	39.000	0.000	39.000
3.900	0.39	0.0000	0.000	40.000	0.000	40.000
4.000	0.40	0.0000	0.000	41.000	0.000	41.000
4.100	0.41	0.0000	0.000	42.000	0.000	42.000
4.200	0.42	0.0000	0.000	43.000	0.000	43.000
4.300	0.43	0.0000	0.000	44.000	0.000	44.000
4.400	0.44	0.0000	0.000	45.000	0.000	45.000
4.500	0.45	0.0000	0.000	46.000	0.000	46.000
4.600	0.46	0.0000	0.000	47.000	0.000	47.000
4.700	0.47	0.0000	0.000	48.000	0.000	48.000
4.800	0.48	0.0000	0.000	49.000	0.000	49.000
4.900	0.49	0.0000	0.000	50.000	0.000	50.000

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
185.0	.2343	.2540	.0197	.01462	25.8	6700.0
235.0	.2350	.2603	.0253	.01860	26.5	8500.0
259.8	.2362	.2644	.0282	.0205	27.4	9370.0
283.0	.2362	.2680	.0318	.0223	29.9	10,500.0

The readings taken on Beam #7 were consistently better than those on Beam #4, but the percentage error was still much too high to accept this method as a way for building models. It appears that, due to the localized heating, there is a definite zone of softening in the area of the weld which caused the beam to act irregularly.

b. Aluminum Soldering

The method of using aluminum solder as a means of constructing our model beams was investigated at the same time as the eutecrod method. The two methods are very similar, and their similarities along with the differences will be presented in this section.

(1) Characteristics of Solder

Alladin soldering is not as strong as eutecrod welding. However, once the limitations were discovered, it was possible to use it with considerable success. The solder melts at a much lower temperature than does welding rod. This most important characteristic makes it much easier to use since the melting point of the parent material is not approached. However, since there is no direct fusion of material, the strength of the joint is definitely decreased. The sample pull test results will indicate this much more clearly. The rod used was an alladin rod. This particular rod required no flux. Therefore, it was necessary to insure that all oxides were cleaned off the aluminum prior to soldering. In addition, a reducing flame was used to prevent the formation of any oxides while soldering.

B. Aluminum Sulfate

The action of water on aluminum sulfate is a
 reaction of decomposition. The water is split
 into hydrogen and hydroxyl ions. The hydroxyl
 ions combine with the aluminum ions to form
 aluminum hydroxide. The hydrogen ions
 will be converted to free hydrogen.

(1) Characteristics of Al₂(SO₄)₃

Aluminum sulfate is a white crystalline
 substance. It is soluble in water. It is
 a strong electrolyte. It is used in the
 paper industry. It is used in the
 textile industry. It is used in the
 food industry. It is used in the
 pharmaceutical industry. It is used in the
 chemical industry. It is used in the
 agricultural industry. It is used in the
 industrial industry. It is used in the
 domestic industry. It is used in the
 commercial industry. It is used in the
 scientific industry. It is used in the
 medical industry. It is used in the
 military industry. It is used in the
 aviation industry. It is used in the
 space industry. It is used in the
 nuclear industry. It is used in the
 environmental industry. It is used in the
 energy industry. It is used in the
 transportation industry. It is used in the
 information industry. It is used in the
 communication industry. It is used in the
 entertainment industry. It is used in the
 education industry. It is used in the
 health industry. It is used in the
 sports industry. It is used in the
 recreation industry. It is used in the
 leisure industry. It is used in the
 tourism industry. It is used in the
 hospitality industry. It is used in the
 food and beverage industry. It is used in the
 retail industry. It is used in the
 wholesale industry. It is used in the
 manufacturing industry. It is used in the
 construction industry. It is used in the
 real estate industry. It is used in the
 financial industry. It is used in the
 insurance industry. It is used in the
 legal industry. It is used in the
 government industry. It is used in the
 non-profit industry. It is used in the
 religious industry. It is used in the
 cultural industry. It is used in the
 artistic industry. It is used in the
 entertainment industry. It is used in the
 media industry. It is used in the
 advertising industry. It is used in the
 public relations industry. It is used in the
 marketing industry. It is used in the
 sales industry. It is used in the
 customer service industry. It is used in the
 human resources industry. It is used in the
 operations industry. It is used in the
 logistics industry. It is used in the
 supply chain industry. It is used in the
 procurement industry. It is used in the
 inventory management industry. It is used in the
 quality control industry. It is used in the
 safety industry. It is used in the
 security industry. It is used in the
 risk management industry. It is used in the
 compliance industry. It is used in the
 ethics industry. It is used in the
 corporate governance industry. It is used in the
 sustainability industry. It is used in the
 social responsibility industry. It is used in the
 environmental management industry. It is used in the
 climate change industry. It is used in the
 renewable energy industry. It is used in the
 clean technology industry. It is used in the
 artificial intelligence industry. It is used in the
 blockchain industry. It is used in the
 cybersecurity industry. It is used in the
 data science industry. It is used in the
 machine learning industry. It is used in the
 computer vision industry. It is used in the
 natural language processing industry. It is used in the
 robotics industry. It is used in the
 autonomous vehicles industry. It is used in the
 space exploration industry. It is used in the
 biotechnology industry. It is used in the
 nanotechnology industry. It is used in the
 quantum computing industry. It is used in the
 quantum cryptography industry. It is used in the
 quantum communication industry. It is used in the
 quantum sensing industry. It is used in the
 quantum simulation industry. It is used in the
 quantum optimization industry. It is used in the
 quantum chemistry industry. It is used in the
 quantum materials industry. It is used in the
 quantum information science industry. It is used in the
 quantum computing industry. It is used in the
 quantum cryptography industry. It is used in the
 quantum communication industry. It is used in the
 quantum sensing industry. It is used in the
 quantum simulation industry. It is used in the
 quantum optimization industry. It is used in the
 quantum chemistry industry. It is used in the
 quantum materials industry. It is used in the
 quantum information science industry.

The method of cleaning the aluminum was the same as that outlined under eutecrod welding. Of the two size rods available, the 1/16" rod was preferred to the 1/8" rod due to the size of the sections being joined. There was only one difficulty encountered, other than those mentioned under eutecrod welding. It was noticed that the solder already placed tended to ball up in some places along the joint when placing solder on the opposite side. This occurred only in a few locations, however, and was patched up easily by reheating and soldering.

(2) Method of Soldering

The technique of heating the joint in preparation for soldering was the same as outlined under the method of eutecrod welding. Since the solder requires a lower temperature than eutecrod, the size of the flame used was considerably smaller. The pressure settings on the cylinder regulators were 5 lbs. and 2 lbs. for oxygen and acetylene respectively. The main difference in soldering is when the filler rod is added. As the torch is held in position for heating the joint, it is best to hold the filler rod in the outer fringe of the flame to keep it

in a soft condition. Then, when the reflected flame turns orange, quickly remove the torch and wipe the filler rod along the joint. It will be possible only to run the joint for about 1 to 2 inches, as the metal cools quickly. However, in our method of using the torch to preheat as well as weld, it will be necessary just to heat the joint a second or two until it will be hot enough again to make another run. This procedure is continued until the whole length of weld is completed.

(3) Test Samples and Results (See Figure 13)

A series of tests on samples, similar to those run using eutecrod, were run using solder. Since there is quite a range of temperatures at which the solder will flow and still not affect the parent material, we ran two sample tests. The first was on a model soldered at a very high temperature such that there was almost fusion. The second was run at the lowest possible temperature such that there was no fusion. The results of these two tests were considered as limits of the possible strength a soldered joint would take. In all future tests, we kept our horizontal shear definitely below that indicated by the lowest test.

Test #1 (Fusion of material and solder noted)

Shear test a = 1 inch
 L = 2 inches
 b = 3/4 inch
 h = .091 inch

Under a load (P) of 1176 pounds the solder failed in shear

Tension test a = 1 inch
 b = 3/4 inch
 h = .091 inch

Under a load (P) of 85 pounds, the solder failed.

Test #2 (Low temperature)

Shear test a = 1 inch
 L = 2 inches
 b = 3/4 inch
 h = .091 inch

The load built up to 50.5 pounds, then the solder yielded suddenly within the joint, although no cracks were visible. It was impossible to make the specimen take any more load. The horizontal shear was 12.6 lbs./inch.

The authors concluded from these tests that if the alladin solder method were to be used it would be necessary to keep the loads down such that the horizontal shear would be less than 12 lbs./inch, except where we were interested in the beam behavior at higher loads.

Test 18 (continued) - continued

Time	a = 1	Time
Time	b = 2	Time
Time	c = 3	Time
Time	d = 4	Time
Time	e = 5	Time

Order a load (1) of 1000 pounds per cubic

feet of sand

Time	a = 1	Time
Time	b = 2	Time
Time	c = 3	Time
Time	d = 4	Time
Time	e = 5	Time

Order a load (1) of 1000 pounds per cubic

feet of sand

Test 19 (low compressive)

Time	a = 1	Time
Time	b = 2	Time
Time	c = 3	Time
Time	d = 4	Time
Time	e = 5	Time

The load will be 1000 pounds, and

the other factors normally apply to 1000

pounds of sand per cubic foot. It will be

applied as soon as the operator has no more

work. The operator will be 1000 lbs.

The entire procedure will be 1000

lbs of sand per cubic foot. It will be

applied as soon as the operator has no more

work. The operator will be 1000 lbs.

applied as soon as the operator has no more

work. The operator will be 1000 lbs.

applied as soon as the operator has no more

work. The operator will be 1000 lbs.

(4) Aluminum soldered beam tests and results

Beam #2

Beam #2 was constructed using the alladin solder method in Jig #1. It was tested on the vertical loaded frame.

Dimension of Beam (See Figure 10)	b = 1.03 inches
	t = .064 inches
	c = .55 inches
	d = 1.16 inches
	L = 14 inches

Moment of inertia (I) = .0455

Deflection (D) = $.1256 \times 10^{-3} P$

Stress (f) = 42.3 P

Load	Dial Reading		Act. Def.	Comp. Def.	% Diff.	Stress
	Zero	Loaded				
15.1	.600	.5975	.0025	.0019	24.0	640.0
45.75	.600	.5925	.0075	.0057	24.0	1940.0
84.0	.600	.5860	.0140	.0105	25.0	3580.0
100.60	.600	.5835	.0165	.0126	23.6	4260.0
116.35	.600	.5810	.0190	.0146	23.1	4930.0
131.6	.600	.5785	.0215	.0165	23.1	5570.0
156.6	.600	.5742	.0258	.0196	24.0	6640.0
166.35	.600	.5725	.0275	.0209	24.0	7060.0
174.65	.600	.5709	.0291	.0219	24.8	7400.0
188.75	.600	.5684	.0316	.0237	25.0	7999.0
202.75	.600	.5658	.0342	.0255	25.5	8560.0
210.85	.600	.5632	.0368	.0265	27.9	8960.0

The error in Beam #2 was believed to have resulted from the fact that the beam was warped and untrue. We, therefore, constructed beam #3.

(*) Additional conditions have been added

Table 1

Table 1 shows the results of the analysis of variance for the different treatments. The results are given in Table 1. The results are given in Table 1.

1	1.00	1.00
2	1.00	1.00
3	1.00	1.00
4	1.00	1.00
5	1.00	1.00
6	1.00	1.00

Results of the analysis of variance

Table 1 (continued)

Table 1 (continued)

Year	Rate	Label	Label	Label	Label	Label
1940.0	1.00	1.00	1.00	1.00	1.00	1.00
1941.0	1.00	1.00	1.00	1.00	1.00	1.00
1942.0	1.00	1.00	1.00	1.00	1.00	1.00
1943.0	1.00	1.00	1.00	1.00	1.00	1.00
1944.0	1.00	1.00	1.00	1.00	1.00	1.00
1945.0	1.00	1.00	1.00	1.00	1.00	1.00
1946.0	1.00	1.00	1.00	1.00	1.00	1.00
1947.0	1.00	1.00	1.00	1.00	1.00	1.00
1948.0	1.00	1.00	1.00	1.00	1.00	1.00
1949.0	1.00	1.00	1.00	1.00	1.00	1.00
1950.0	1.00	1.00	1.00	1.00	1.00	1.00
1951.0	1.00	1.00	1.00	1.00	1.00	1.00
1952.0	1.00	1.00	1.00	1.00	1.00	1.00
1953.0	1.00	1.00	1.00	1.00	1.00	1.00
1954.0	1.00	1.00	1.00	1.00	1.00	1.00
1955.0	1.00	1.00	1.00	1.00	1.00	1.00
1956.0	1.00	1.00	1.00	1.00	1.00	1.00
1957.0	1.00	1.00	1.00	1.00	1.00	1.00
1958.0	1.00	1.00	1.00	1.00	1.00	1.00
1959.0	1.00	1.00	1.00	1.00	1.00	1.00
1960.0	1.00	1.00	1.00	1.00	1.00	1.00

The results of the analysis of variance are given in Table 1. The results are given in Table 1.

continued from 47.

Beam #3

Beam #3 was constructed using the alladin soldering method in Jig #1. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.03 inches
t = .064 inch
c = .55 inch
d = 1.15 inches
L = 23 inches

Moment of Inertia (I) = .0452

Deflection (D) = $.558 \times 10^{-3} P$

Stress (f) = 73.2 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.1559	.1568	.0009	.0008	11.0	117.0
5.0	.1554	.1601	.0047	.0028	40.3	366.0
12.2	.1554	.1649	.0095	.0068	28.4	893.0
19.8	.1553	.1692	.0139	.0111	20.1	1455.0
27.8	.1555	.1741	.0186	.0159	15.0	2040.0
35.70	.1556	.1789	.0233	.0199	14.6	2610.0
43.50	.1556	.1839	.0283	.0243	14.2	3190.0
51.25	.1563	.1893	.0330	.0286	13.3	3750.0
58.75	.1575	.1978	.0403	.0328	18.5	4300.0
83.75	.1605	.2440	.0835	.0418	49.3	6130.0

Beam #3 was made considerably longer than Beam #2. This, along with the fact that a zero reading was taken after each load, had a noticeable effect on the results. While these results were better, it was decided to try a new method. We next built beam #5.

Item 43 was constructed using the classic spinning method in the US. It was tested on the section testing frame.

Dimension of beam (see Figure 10)	Value
a	1.00 inches
b	0.04 inch
c	0.25 inch
d	1.10 inches
e	0.50 inches

Number of particles (1) = 0.024

Rotation (2) = 0.000 x 10⁻⁴

Force (3) = 7.14 x 10⁻⁴

Final Reading

Load	Time	Force	Ext. Def.	Long. Def.	Strain	Stress
1.0	1.00	0.000	0.000	0.000	0.000	0.000
2.0	1.00	0.000	0.000	0.000	0.000	0.000
3.0	1.00	0.000	0.000	0.000	0.000	0.000
4.0	1.00	0.000	0.000	0.000	0.000	0.000
5.0	1.00	0.000	0.000	0.000	0.000	0.000
6.0	1.00	0.000	0.000	0.000	0.000	0.000
7.0	1.00	0.000	0.000	0.000	0.000	0.000
8.0	1.00	0.000	0.000	0.000	0.000	0.000
9.0	1.00	0.000	0.000	0.000	0.000	0.000
10.0	1.00	0.000	0.000	0.000	0.000	0.000
11.0	1.00	0.000	0.000	0.000	0.000	0.000
12.0	1.00	0.000	0.000	0.000	0.000	0.000
13.0	1.00	0.000	0.000	0.000	0.000	0.000
14.0	1.00	0.000	0.000	0.000	0.000	0.000
15.0	1.00	0.000	0.000	0.000	0.000	0.000
16.0	1.00	0.000	0.000	0.000	0.000	0.000
17.0	1.00	0.000	0.000	0.000	0.000	0.000
18.0	1.00	0.000	0.000	0.000	0.000	0.000
19.0	1.00	0.000	0.000	0.000	0.000	0.000
20.0	1.00	0.000	0.000	0.000	0.000	0.000

Item 43 was constructed using the classic spinning method in the US. It was tested on the section testing frame.

With the test load a zero reading was taken after each load, and

a noticeable elongation was observed. While these readings were

taken, it was decided to try a new method. An exact duplicate of item 43

Beam #5

Beam #5 was constructed using the alladin soldering method in Jig #2. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 2.0 inches
t = .091 inches
c = 1.28 inches
d = 2.75 inches
L = 33 inches

Moment of Inertia (I) = .7715

Deflection (D) = $.097 \times 10^{-3} P$

Stress (f) = 13.7 P

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.09037	.09056	.00019	.00016	15.8	21.9
5.0	.09041	.09110	.00069	.00048	30.4	68.5
13.0	.09041	.09193	.00143	.00126	11.9	178.0
20.5	.09041	.09337	.00296	.00199	32.8	280.0
27.7	.09062	.09395	.00333	.00269	19.2	379.0
34.65	.09041	.09505	.00464	.00336	27.6	473.0
42.50	.09060	.09619	.00559	.00412	26.3	583.0
50.25	.09060	.09752	.00692	.00487	29.6	689.0
58.05	.09081	.09870	.00789	.00563	33.2	795.0
65.20	.09090	.09959	.00869	.00632	27.3	895.0
73.60	.09102	.10071	.00969	.00713	26.7	1010.0
81.90	.09113	.10169	.01056	.00794	24.8	1120.0

Beam #5 was made longer than Beam #3, and of larger section. We made these changes to discover if perhaps length or size of section had a major effect on the results. The irregular results proved nothing other than it didn't appear to be acting as a beam. We next built beam #6.

These 10 are numbered and listed in the following table. It is noted that the vertical distance between the top of the beam and the center of the beam is 10.00 inches.

Number	Distance of beam from figure 10
1	10.00
2	10.00
3	10.00
4	10.00
5	10.00
6	10.00
7	10.00
8	10.00
9	10.00
10	10.00

Distance of beam from figure 10 = 10.00
 Distance of beam from figure 10 = 10.00
 Distance of beam from figure 10 = 10.00

Table 1

Beam No.	Distance of beam from figure 10					
1	10.00	10.00	10.00	10.00	10.00	10.00
2	10.00	10.00	10.00	10.00	10.00	10.00
3	10.00	10.00	10.00	10.00	10.00	10.00
4	10.00	10.00	10.00	10.00	10.00	10.00
5	10.00	10.00	10.00	10.00	10.00	10.00
6	10.00	10.00	10.00	10.00	10.00	10.00
7	10.00	10.00	10.00	10.00	10.00	10.00
8	10.00	10.00	10.00	10.00	10.00	10.00
9	10.00	10.00	10.00	10.00	10.00	10.00
10	10.00	10.00	10.00	10.00	10.00	10.00

These 10 are numbered and listed in the following table. It is noted that the vertical distance between the top of the beam and the center of the beam is 10.00 inches. The vertical distance between the top of the beam and the center of the beam is 10.00 inches. The vertical distance between the top of the beam and the center of the beam is 10.00 inches.

Beam #6

Beam #6 was constructed using the alladin soldering method in Jig #2. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 2.01 inches
t = .091 inches
c = .96 inches
d = 2.10 inches
L = 26 inches

Moment of Inertia (I) = .424

Deflection (D) = $.0864 \times 10^{-3} P$

Stress (f) = 15.7 P

Load	Dial Reading		Act. Def.	Comp. Def.	% Diff.	Stress
	Zero	Loaded				
1.6	.05533	.05543	.00010	.00014	40.0	25.1
10.0	.05545	.05626	.00081	.00085	4.9	157.0
18.4	.05546	.05645	.00199	.00157	21.1	289.0
25.9	.05550	.05834	.00284	.00221	22.2	407.0
33.65	.05580	.05968	.00388	.00287	26.0	528.0
41.65	.05605	.06040	.00435	.00355	18.4	653.0
48.80	.05608	.06110	.00502	.00417	16.9	765.0
64.55	.05610	.06384	.00774	.00557	28.0	1010.0
73.80	.05665	.06533	.00868	.00636	26.8	1158.0

Beam #6 didn't eliminate the errors although the percentage error was less than that occurring in beam #5.

Beam 44 was constructed using the ALLIANCE software
 method in 1978. It was tested on the vertical loading

Figure 44

Dimension of Beam (See Figure 44)	0 = 6.01 1 = 6.01 2 = 6.01 3 = 6.10 4 = 6.01	0 = 1 = 2 = 3 = 4 =
--------------------------------------	--	---------------------------------

Moment of inertia (I) = .444

Deflection (δ) = .0001 x 10⁻² p

Stress (σ) = 15.7 p

Load	Stress	Deflection	Load	Stress	Deflection
1.0	0.0002	0.0001	0.0002	0.0002	0.0001
10.0	0.0020	0.0010	0.0020	0.0020	0.0010
15.4	0.0030	0.0015	0.0030	0.0030	0.0015
25.9	0.0050	0.0025	0.0050	0.0050	0.0025
35.3	0.0070	0.0035	0.0070	0.0070	0.0035
41.6	0.0080	0.0040	0.0080	0.0080	0.0040
48.0	0.0090	0.0045	0.0090	0.0090	0.0045
54.5	0.0100	0.0050	0.0100	0.0100	0.0050
73.0	0.0130	0.0065	0.0130	0.0130	0.0065

Beam 44 didn't eliminate the error although the percentage
 error was less than that occurring in beam 43.

Beam #8

Beam #8 was constructed, using the alladin solder method in Jig #3. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.03 inches
c = .55 inches
d = 1.16 inches
t = .063 inches
L = 24 inches

Moment of inertia (I) = .0454

Deflection (D) = $.634 \times 10^{-3} P$

Stress (f) = 76.7 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.2825	.2835	.001	.00101	1.0	122.5
5.0	.2825	.2857	.0032	.00317	.94	383.0
12.2	.2825	.2912	.0087	.00773	11.5	931.0
19.85	.2825	.2964	.0139	.0126	9.35	1520.0
27.85	.2830	.3023	.0198	.0177	10.60	2130.0
35.70	.2850	.3077	.0247	.0227	8.10	2740.0
43.50	.2833	.3130	.0300	.0276	8.00	3330.0
51.25	.2835	.3183	.0350	.0325	7.13	3930.0
58.75	.2835	.3234	.0399	.0373	6.52	4500.0
65.90	.2835	.3286	.0451	.0408	9.53	5050.0
74.20	.2841	.3341	.0503	.0470	6.50	5680.0
82.35	.2840	.3399	.0558	.0521	6.71	6320.0
90.65	.2847	.3459	.0619	.0575	7.1	6950.0

The percentage error as indicated in beam #8 averages less than 10 percent. This indication that our methods and

TABLE 1

From 48 was constructed, using the standard 1000 ft. scale. In 1945 it was located on the vertical loading frame.

1 = 100 lbs	2 = 1.00 lbs	3 = 1.00 lbs	4 = 1.00 lbs	5 = 1.00 lbs	6 = 1.00 lbs	7 = 1.00 lbs	8 = 1.00 lbs	9 = 1.00 lbs	10 = 1.00 lbs
-------------	--------------	--------------	--------------	--------------	--------------	--------------	--------------	--------------	---------------

Height of load (1) = 1.00 ft
 Deflection (2) = .001 ft
 Stress (3) = 1000 psi

Load	Time	Deflection	Stress	Strain	Modulus	Creep
1.0	0.000	0.001	1000	0.0001	1000000	0.0000
2.0	0.000	0.002	2000	0.0002	1000000	0.0000
3.0	0.000	0.003	3000	0.0003	1000000	0.0000
4.0	0.000	0.004	4000	0.0004	1000000	0.0000
5.0	0.000	0.005	5000	0.0005	1000000	0.0000
6.0	0.000	0.006	6000	0.0006	1000000	0.0000
7.0	0.000	0.007	7000	0.0007	1000000	0.0000
8.0	0.000	0.008	8000	0.0008	1000000	0.0000
9.0	0.000	0.009	9000	0.0009	1000000	0.0000
10.0	0.000	0.010	10000	0.0010	1000000	0.0000
11.0	0.000	0.011	11000	0.0011	1000000	0.0000
12.0	0.000	0.012	12000	0.0012	1000000	0.0000
13.0	0.000	0.013	13000	0.0013	1000000	0.0000
14.0	0.000	0.014	14000	0.0014	1000000	0.0000
15.0	0.000	0.015	15000	0.0015	1000000	0.0000
16.0	0.000	0.016	16000	0.0016	1000000	0.0000
17.0	0.000	0.017	17000	0.0017	1000000	0.0000
18.0	0.000	0.018	18000	0.0018	1000000	0.0000
19.0	0.000	0.019	19000	0.0019	1000000	0.0000
20.0	0.000	0.020	20000	0.0020	1000000	0.0000

The percentage error as indicated in Table 1 is negligible. This indicates that the modulus and

techniques were improving convinced us that we should continue with our tests with only slight changes in our methods. It should be noticed that the beam is 24 inches long and of such a section that a large deflection is obtained. It is felt that a large deflection is necessary so that any errors that do occur are not a significant part of the deflection. It should also be noted that the horizontal shear on this beam reached 36.2 lbs./inches which is considerably above the absolutely safe value as determined by test. Therefore, in any future tests, a horizontal shear maximum of 10 lbs./inch can be assumed to be absolutely safe. With the above considerations in mind we constructed beam #9.

techniques were improved...
 with one case with slight changes in our system. It
 should be noted that the mean is 94 inches and at each
 a section that a large deflection is obtained. It is clear
 that a large deflection is necessary so that any amount that
 is made are not a sufficient part of the deflection. It
 should also be noted that the horizontal shear on this beam
 would be 25.9 lbs./inches which is considerably above the
 specified safe value as determined by test. Therefore, in
 any future tests, a horizontal shear maximum of 12 lbs./inches
 can be assumed to be specified safe. Also the above concrete
 regions in which we investigated were 50.

Span	Deflection	Shear	Moment	Stress
10	0.15	12.5	100	1500
20	0.30	25.0	400	3000
30	0.45	37.5	900	4500
40	0.60	50.0	1600	6000
50	0.75	62.5	2500	7500
60	0.90	75.0	3600	9000
70	1.05	87.5	4900	10500
80	1.20	100.0	6400	12000
90	1.35	112.5	8100	13500
100	1.50	125.0	10000	15000

The deflection curve for the beam is shown in the figure. The maximum deflection is 1.50 inches at the center of the span. The shear force is zero at the center of the span and maximum at the supports. The bending moment is zero at the supports and maximum at the center of the span.

Beam #9

Beam #9 was a "T" beam constructed using the alladin solder method in Jig #3 modified. It was tested on the vertical loading frame.

Dimensions of Beam
(See Figure 10)

b = 1.453 inches
c = .8244 inches
d = 1.0938 inches
t = .091 inches
L = 54 inches

Moment of inertia (I) = .02375

Deflection (D) = $1.38 \times 10^{-2} P$

Stress (f) = 468 P

Horizontal Shear (H) = $\frac{VQ}{I} = .623 P$

The neutral axis was computed to be .268 inches above the base.

Dial Reading

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.16340	.18820	.0248	.0221	10.9	747.0
2.0	.16340	.19210	.0287	.0276	3.8	935.0
3.0	.16340	.20710	.0437	.0414	5.24	1405.0
4.0	.16340	.22010	.0567	.0552	2.45	1870.0
5.0	.16340	.23420	.0708	.0690	2.54	2340.0

The error in beam #9 was not as great as that in beam #8. The horizontal shear at 5 lbs. was 3.115 lbs./inches. We stopped loading at 5 lbs. as we wanted to put another flange on the "T" beam to see the effect. Therefore, we soldered a flange on beam #9 to get beam #10.

When the 10% beam is used, the distance between the two points is 10 cm. The distance between the two points is 10 cm. The distance between the two points is 10 cm.

$I = 10$
 $I = 10$
 $I = 10$
 $I = 10$
 $I = 10$

$I = 10$
 $I = 10$
 $I = 10$

The vertical axis was measured to be 10 cm. The vertical axis was measured to be 10 cm.

Initial Position

Load	Time	Initial Position	Final Position	Displacement	Time	Initial Position
1.0	1.00	10.00	10.00	0.00	10.00	10.00
2.0	1.00	10.00	10.00	0.00	10.00	10.00
3.0	1.00	10.00	10.00	0.00	10.00	10.00
4.0	1.00	10.00	10.00	0.00	10.00	10.00
5.0	1.00	10.00	10.00	0.00	10.00	10.00

The error in time is 0.01 s. The error in time is 0.01 s.

Beam #10

Beam #10 is beam #9 with another flange soldered on.

Dimensions of Beam
(See Figure 10)

b = 1.453 inches
c = .548 inches
d = 1.188 inches
t = .091 inches
L = 54 inches

Moment of inertia (I) = .08873

Deflection (D) = $3.7 \times 10^{-3} P$

Stress (f) = 90.3 P

Horizontal Shear (H) = .408 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
1.6	.1320	.1382	.0062	.0059	4.8	144.5
2.0	.1319	.1397	.0078	.0074	5.1	180.5
3.0	.1320	.14285	.01085	.0111	2.3	271.0
4.0	.1320	.1469	.0149	.0148	0.6	361.0
5.0	.1320	.1500	.0180	.0185	2.8	451.0
6.0	.1320	.1541	.0221	.0222	0.4	542.0
7.0	.1320	.1580	.0260	.0259	0.4	631.0
8.0	.1320	.1620	.0300	.0296	1.3	722.0
9.0	.1320	.1658	.0338	.0333	1.5	811.0
10.0	.1320	.1697	.0377	.0370	1.9	903.0
18.0	.1321	.1998	.0678	.0666	1.8	1628.0

The small amount of difference between computed and actual deflections as evidenced by the percentage error was considered excellent. The horizontal shear obtained was 7.35 lbs./inches at 18 lbs. In view of the results, it was decided to construct a beam of larger cross section, to see if there would be any effect on the accuracy.

Table 100

From 1910 to 1920 the following amounts were received...

1910	1.00	1.00
1911	1.00	1.00
1912	1.00	1.00
1913	1.00	1.00
1914	1.00	1.00
1915	1.00	1.00
1916	1.00	1.00
1917	1.00	1.00
1918	1.00	1.00
1919	1.00	1.00
1920	1.00	1.00

Receipts of interest (1) = 10.00

Receipts of dividends (2) = 2.50

Receipts of other (3) = 0.00

Total receipts (4) = 12.50

Year	Dividends	Interest	Other	Total
1910	1.00	1.00	0.00	2.00
1911	1.00	1.00	0.00	2.00
1912	1.00	1.00	0.00	2.00
1913	1.00	1.00	0.00	2.00
1914	1.00	1.00	0.00	2.00
1915	1.00	1.00	0.00	2.00
1916	1.00	1.00	0.00	2.00
1917	1.00	1.00	0.00	2.00
1918	1.00	1.00	0.00	2.00
1919	1.00	1.00	0.00	2.00
1920	1.00	1.00	0.00	2.00

The total amount of interest received and dividends as indicated by the following table was considered excellent. The total amount of interest received was 10.00 and the total amount of dividends was 2.50. In view of the fact that the total amount of interest received was 10.00 and the total amount of dividends was 2.50, it is evident that the total amount of interest received was 10.00 and the total amount of dividends was 2.50.

Beam #11

Beam #11 was constructed using the alladin solder method in Jig #3 modified. It was tested on the vertical loading frame.

Dimensions of Beam (See Figure 10)	b = 1.234 inches
	c = 1.193 inches
	d = 2.477 inches
	t = .091 inches
	L = 54 inches

Moment of Inertia (I) = .4128

Deflection (D) = $.798 \times 10^{-3} P$

Stress (f) = 40.5 P

Horizontal Shear (H) = .1623 P

Load	Dial Reading		Act. Def.	Comp. Def.	% Diff.	Stress
	Zero	Loaded				
5	.0964	.1001	.0037	.0040	8.1	202.0
10	.0965	.1041	.0076	.0080	5.3	404.0
15	.0965	.1083	.0118	.0120	1.7	616.0
20	.0965	.1122	.0157	.0160	1.9	807.0
25	.0965	.1164	.0199	.0199	0.0	1015.0
30	.0967	.1208	.0243	.0239	1.6	1215.0
35	.0967	.1250	.0283	.0279	1.4	1417.0
40	.0967	.1290	.0323	.0319	1.2	1620.0
45	.0968	.1333	.0366	.0359	1.9	1823.0
50	.0969	.1380	.0412	.0399	3.2	2020.0
55	.0969	.1419	.0450	.0439	2.4	2230.0

The results of Beam #11 proved that our methods and techniques of constructing models were satisfactory. This beam was made with the idea in mind of using it for checking stresses and calibrating the horizontal loading frame. (See Figure 14.) These tests are explained in section IV.

Table 1

Table 1 shows the results of the tests conducted on the various specimens.

The specimens were tested on the vertical loading

Table.

Specimen	1	2	3	4	5	6	7	8	9	10
Load (lb)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
Deflection (in)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Results of tests (1) = 1000

Results of tests (2) = 2000

Results (3) = 3000

Results of tests (4) = 4000

Specimen	Load (lb)	Deflection (in)	Load (lb)	Deflection (in)	Load (lb)	Deflection (in)
1000	1000	0.1	2000	0.2	3000	0.3
2000	2000	0.2	3000	0.3	4000	0.4
3000	3000	0.3	4000	0.4	5000	0.5
4000	4000	0.4	5000	0.5	6000	0.6
5000	5000	0.5	6000	0.6	7000	0.7
6000	6000	0.6	7000	0.7	8000	0.8
7000	7000	0.7	8000	0.8	9000	0.9
8000	8000	0.8	9000	0.9	10000	1.0
9000	9000	0.9	10000	1.0		
10000	10000	1.0				

The results of these tests are shown in Table 1. The specimens were tested on the vertical loading machine. The results of the tests are shown in Table 1. The specimens were tested on the vertical loading machine. The results of the tests are shown in Table 1. The specimens were tested on the vertical loading machine. The results of the tests are shown in Table 1.

Beam #11 on Horizontal
Loading Frame

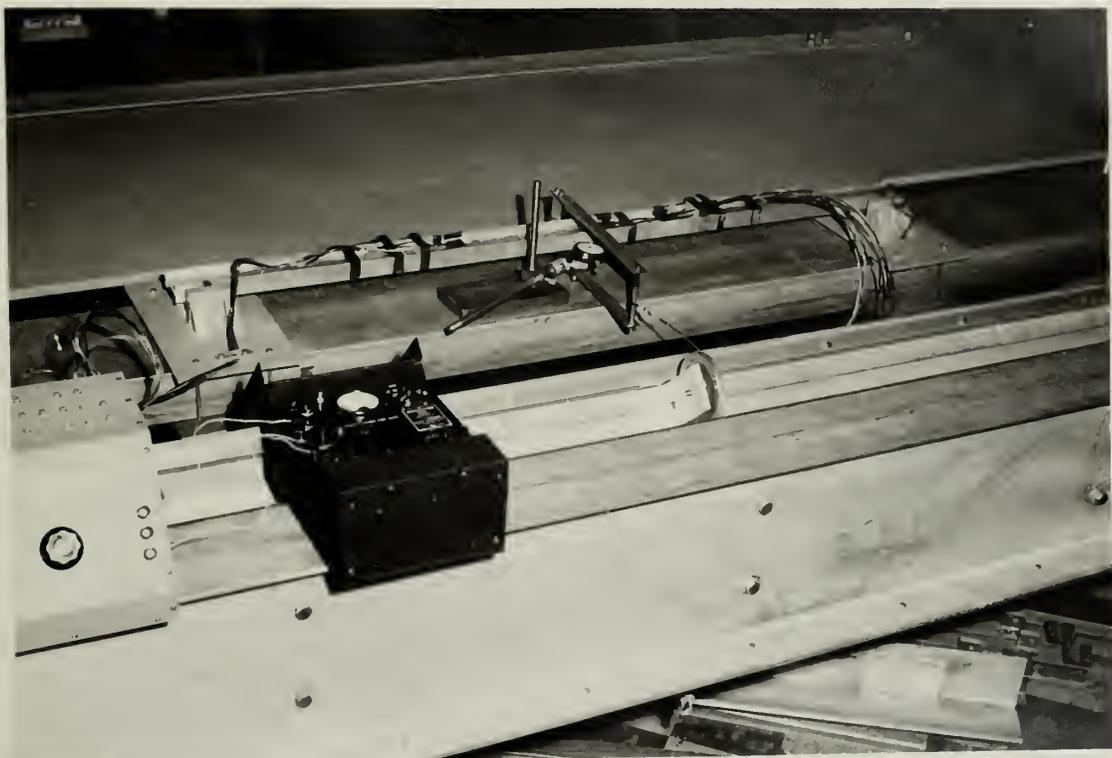
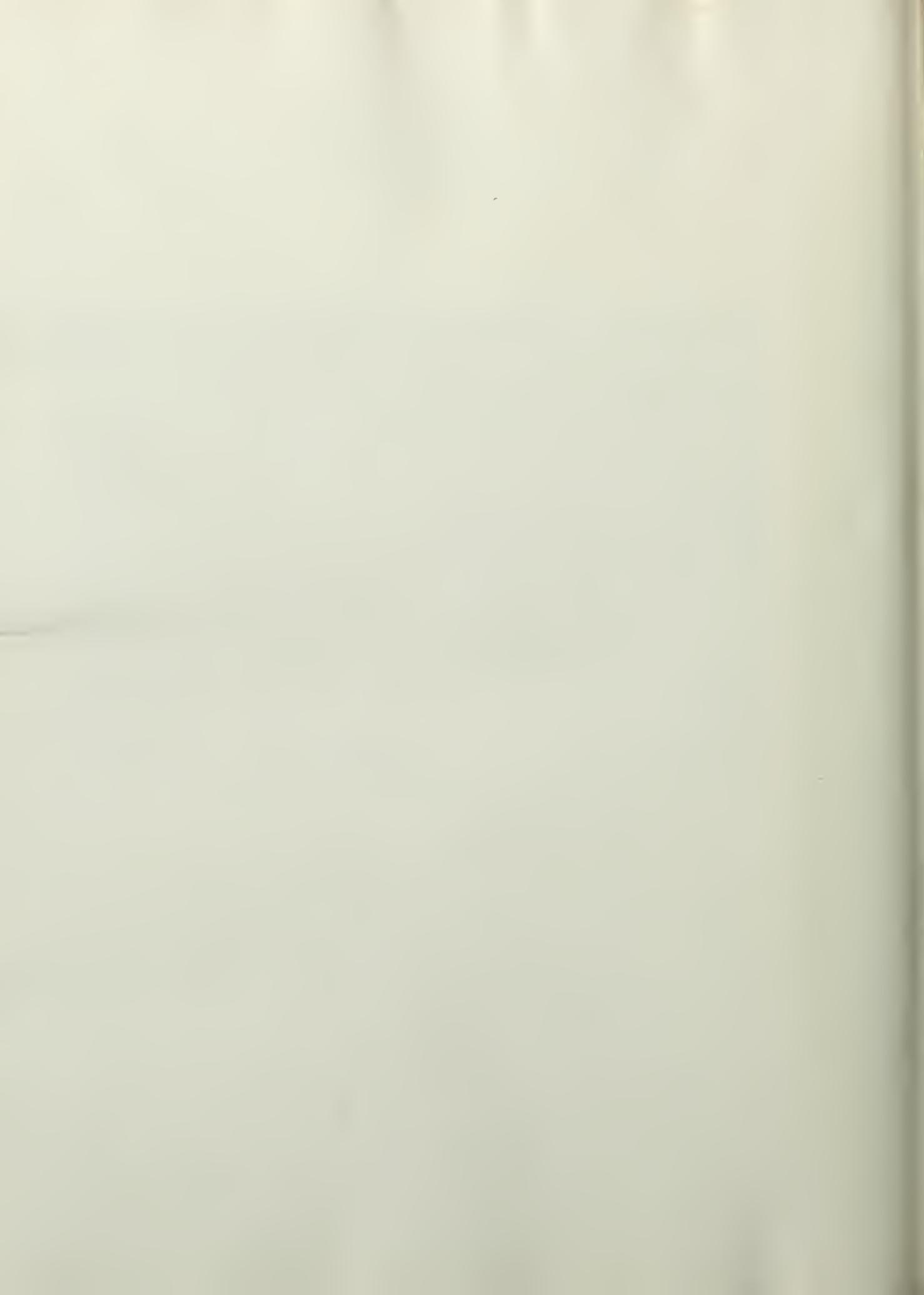


Figure 14



c. Furnace Brazing

The third method of constructing beams by furnace brazing was not successful. The furnace used was the same one that was mentioned in the "E" check discussion.

The beam constructed was 24 inches long, 1-1/2 inches deep, .091 inches thick and the flanges were 1-1/4 inches wide. The beam was held together in the manner discussed for Jig #3 modified, with clamps holding the flanges together. The joining material used was eutecrod. In order to get a thin foil, the eutecrod was rolled to a thickness of about .008 inches. It was inserted in the joint and held in place by the clamping action of the "C" clamps. Flux was placed along all the surfaces that were to be joined. The furnace temperature used was 1125° F. This was the temperature, found from tests, that was necessary for the materials to fuse. The jugged beam was placed in the furnace and allowed to remain for 15 minutes. At the end of the required time, the furnace was shut off and allowed to cool before inspecting the beam.

The whole beam was completely distorted and warped. (See Figure 15.) The flanges were welded to the web for only about 2 inches at one end. It was impossible to test the beam because of its condition.

3. Purge System

The third method of connecting beams by
purge system, was not successful. The furnace used
was the same one that was mentioned in the "P"
book discussion.

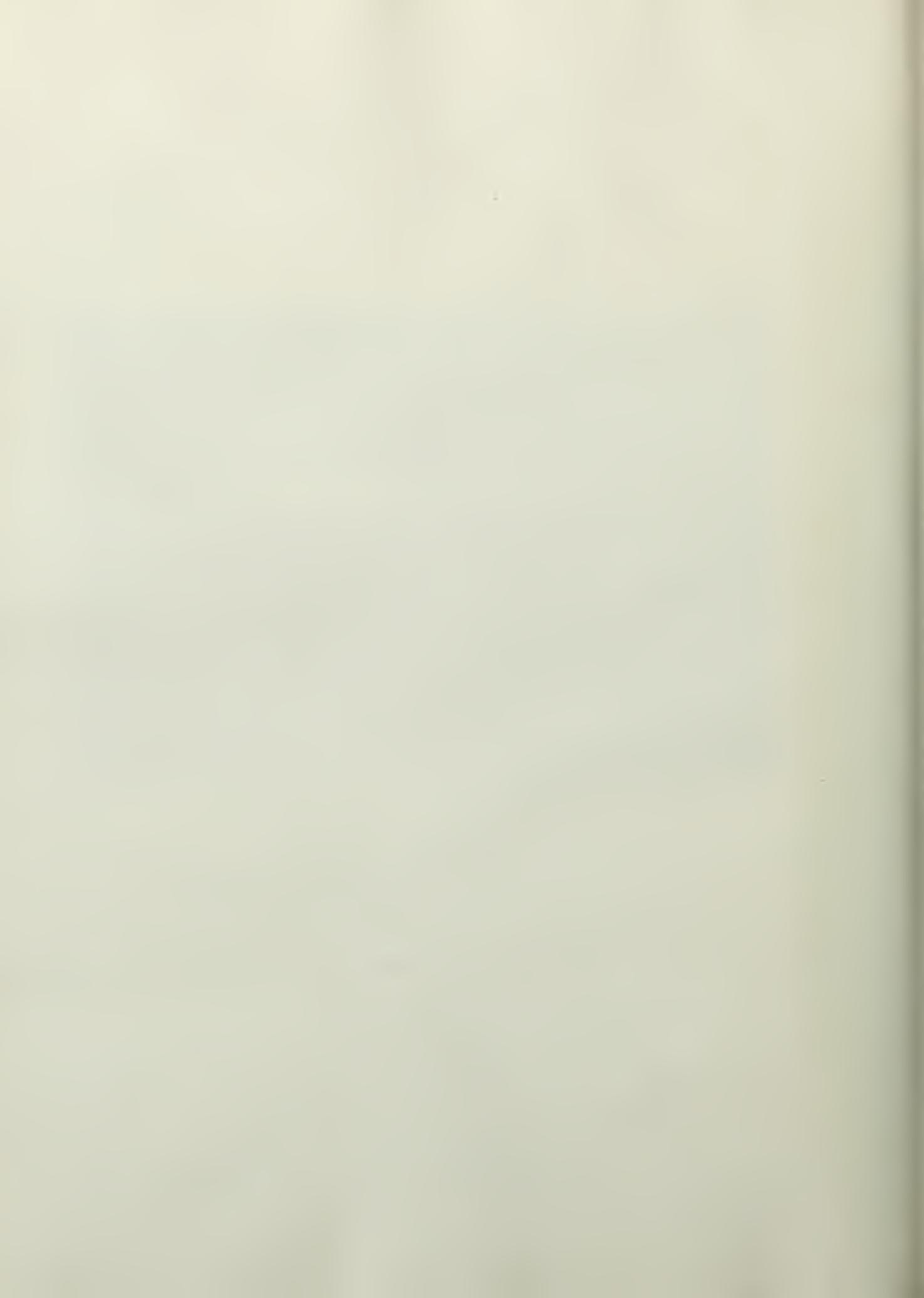
The beam described was 34 inches long, 1-1/8
inches deep, 3/4 inch thick and the flanges
were 1-1/4 inches wide. The beam was held in
place in the manner discussed for the "P" method.
After almost holding the flanges together. The
joining material used was subjected. In order to
get a thin foil, the electrode was rolled to a
thickness of about .002 inches. It was inserted
in the joint and held in place by the clamping
action of the "C" clamps. This was placed along
all the surfaces that were to be joined. The
furnace temperature used was 1500°. This was
the temperature, found from tests, that was
necessary for the material to fuse. The jigged
beam was placed in the furnace and allowed to
remain for 15 minutes. At the end of the required
time, the furnace was shut off and allowed to
cool before inspecting the beam.

The whole beam was completely inspected and
checked. (See Figure 12.) The furnace was held
at 1500° for only about 2 inches at one end.
It was impossible to heat the beam because of its
condition.

Furnace Brazed Aluminum Beam



Figure 15



This method is impractical for use with aluminum. The eutectoid will not flow by itself until a temperature of about 1125° F. is reached. This temperature is above the melting point of the alloy used, and the beam will not even support its own weight. Thus, with the jiggling system used, the weight of the clamps alone caused the whole beam to be pulled out of shape. Therefore, the authors felt it a waste of time to attempt any further tests.

B. Steel.

For the fabrication of steel models, we selected hot rolled strip steel, 1-1/2 inches wide and 0.056 inches thick. This particular size material was selected from the available stock at a local steel yard because it would require the least cutting in the fabrication of a model. Hot rolled strip was chosen in preference to cold rolled strip because of its being relatively free of residual stresses.

1. Preparation of Material

A hacksaw was used to cut the strip steel into the desired lengths. The rounded edges of the pieces were ground flat on a mechanical disc sander. Next, the scale on the edges and sides, where the pieces were to be joined, was removed by using emery cloth which gave a bright surface. Care should be exercised in grinding the edges to insure that a smooth, flat surface is obtained. Irregularities will cause a poor joint.

This method is experimental for use as a
 standard. The standard will not show the results
 until a temperature of about 1100° F. is reached.
 This temperature is about the melting point of
 the alloy used, and the heat will not even approach
 the true melting point. Thus, with the liquid system
 used, the weight of the sample about 100 mg. is
 used. The weight of the sample is about 100 mg. However,
 the volume of the sample is a factor of 10 in weight
 and liquid weight.

B. Steel.

For the fabrication of steel samples, as indicated by
 rolled strip steel, 1-1/2 inches wide and 0.005 inches thick.
 This particular size material was selected from the available
 stock of a local steel yard because it was available in
 least quantity in the fabrication of a model. The rolled
 strip was chosen in preference to cold rolled strip because
 of its better mechanical properties.

1. Preparation of Samples

A specimen was made by cutting the strip steel into
 the desired lengths. The rounded ends of the pieces were
 ground flat on a mechanical disc grinder. Next, the ends on
 the edges and along grain the pieces were to be polished, and
 removed by using emery cloth which gave a bright surface.
 Care should be exercised in grinding the edges so that they
 are smooth. The surface is finished. Investigation will
 cause a poor joint.

2. Jigs

Jigs used for making steel models were the same as those used for making aluminum models, as given in section III-A-2 above; consequently, they need not be discussed again in this section.

3. Techniques of Joining Flanges to Webs

a. Silver soldering with an oxyacetylene torch

In joining the pieces of steel together to form a model, we wanted a strong joint, which could be obtained without heating the steel into its critical range. Heating to a low temperature was desirable also to avoid large expansions and accompanying distortions. Silver soldering seemed to possess all of the above desirable characteristics. The "Easy Flow" solder we used flowed freely at 1175° F., which is well below steel's critical temperature, and it possessed a tensile strength of approximately 65,000 psi.

(1) Joint thickness

In the "Welding Handbook" of the American Welding Society, a graph is shown expressing the strength of a soldered butt joint, using silver solder to join stainless steel, as a function of the joint thickness. With a joint thickness of 0.003 inches, the joint strength was 117,000 psi, while with a

thickness of 0.024 inches, the strength was 47,000 psi. This shows the desirability of having a close fitting joint between the pieces being joined.

(2) Heating and fluxing

Before the joint was heated, a coating of flux* was painted on the surfaces to be joined, its purpose being to prevent oxidation of the solder and steel surfaces being joined, to dissolve any oxides that might form during heating, and to assist the flowing of the alloy. The flux also serves as a temperature indicator, in that the joint should be heated until the flux remains fluid if the torch flame is removed for an instant.

The models we made consisted of tee and wide-flange sections. In joining the web to the flange, the torch was held in a position so that the flame (a slightly reducing flame was used) was approximately parallel to the axis of the joint being soldered. (See Figure 12.) By directing the flame in this manner, the material in the vicinity of the torch tip was heated to the soldering temperature,

* A Borax and Boric Acid mixture.

while the material away from the torch tip in the direction of the flame became preheated to a relatively high temperature. When the correct temperature was reached, as indicated by the fluid flux, the silver solder rod was touched to the joint. The solder flowed freely along the joint until the joint became too cool. By moving the torch slowly and applying solder from the rod at about every inch, a strong joint was obtained throughout the length of the pieces.

If the joint is dirty, or if the flux is rubbed off at a point along the joint, no amount of heating will cause the solder to adhere to the pieces. In this event, wait until the pieces cool, clean and reflux the spot, then reheat and solder it.

(3) Test samples and results

In order to check the strength of the silver solder joint in shear and tension, test samples of joints were prepared and tested. (See Figure 13.)

Shear test

a = 1 inch
 L = 1 inch
 b = 3/4 inch
 h = .056 inch

Tension test

a = 1 inch
 b = 1 inch
 h = .056 inch

Two inches of joint tested in shear was

While the material was from the same lot
 in the direction of the three beams presented
 for a trial, the following observations were made
 for the first time, and after a few days
 was found to be true. The whole mass
 slowly along the joint with the joint
 some 500 feet. By moving the beam slowly
 and applying water from the top as shown
 very little, a strong joint was obtained
 throughout the length of the beam.

If the joint is strong, or if the flow is
 reduced off at a point along the joint, the
 amount of heating will cause the water to
 adhere to the glass. In this event, the
 water in the glass will flow and will be
 lost. This cannot be avoided.

(2) The results of the
 In order to avoid the possibility of the
 after a few days in the air and water,
 this method of jointing was suggested and
 tested. (See page 15.)

Chemical	1 = 1 inch
Water	1 = 1 inch
Oil	1 = 1 inch
Gasoline	1 = 1 inch
Alcohol	1 = 1 inch

The method of jointing was tested in three trials

stronger than the parent metal, while one inch tested in tension broke at 2830 pounds. The strength of the joint was seen to be more than sufficient for our purposes.

arranged for the...
 had been in...
 The...
 some...

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 ...
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(4) Beam tests and results

Beam #12

Beam #12 was a "T" beam constructed by using silver solder rod and an oxyactelylene torch, in Jig #2. It was tested on the vertical loading frame with the results as given below:

Dimensions of beam	b = 1.5 inches
(See Figure 10)	t = .056 inches
	d = 1.56 inches
	L = 22 inches

The neutral axis was computed to be .417 inches above the base.

Moment of Inertia (I) = .0905

Deflection (D) = .0817 P x 10⁻³

Stress (f) = 69.3 P

<u>Load</u>	<u>Dial Reading</u>		<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
	<u>Zero</u>	<u>Loaded</u>				
10	.4107	.4132	.0015	.00082	83.0	690.0
25	.4110	.4141	.0031	.00204	52.0	1735.0
50	.4110	.4170	.0060	.00408	47.0	3470.0
75	.4107	.4186	.0089	.00612	45.5	5200.0
100	.4108	.4220	.0112	.00817	37.1	6930.0
125	.4110	.4242	.0132	.01020	29.4	8670.0
150	.4111	.4259	.0148	.01223	21.0	10400.0

This beam was distorted from heating. The web was not exactly centered on the flange. The joint, however, appeared to be very good.

b. Furnace Brazing (See Figure 16)

In an effort to overcome the distortion of the material being joined resulting from localized heating with a torch, furnace brazing was tried. The bonding alloy was silver solder, in the form of a thin foil or sheet 0.005 inches thick. The pieces to be joined were prepared as stated in section III-A-1. Flux was applied to the surfaces for the purpose previously stated. Finally, strips of the foil were inserted in the joint between the pieces to be united, and the whole assembly clamped rigidly together. The pieces could be clamped rigidly together since there would be no differential expansion between the model components while in the furnace. The assembly was then inserted in the furnace.

(1) The furnace

The furnace used was a Lindberg type, belonging to the Metallurgy Department. It was an automatically controlled, electric furnace, equipped with a blower for circulating the air within it. Prior to inserting the model, the temperature was raised to 1175° F.

The model was left in the furnace for 15 minutes at the 1175° temperature, then

5. General Remarks (see figure 10)

In an effort to improve the efficiency of the electrical system, the following measures were taken. The power supply was replaced by a 1000 VA transformer. The power supply was replaced by a 1000 VA transformer. The power supply was replaced by a 1000 VA transformer.

The power supply was replaced by a 1000 VA transformer. The power supply was replaced by a 1000 VA transformer. The power supply was replaced by a 1000 VA transformer. The power supply was replaced by a 1000 VA transformer. The power supply was replaced by a 1000 VA transformer.

(1) The Power

The power was supplied by a 1000 VA transformer. The power was supplied by a 1000 VA transformer. The power was supplied by a 1000 VA transformer. The power was supplied by a 1000 VA transformer. The power was supplied by a 1000 VA transformer.

1100

The model was built in the laboratory for its studies at the 1100 temperature. The model was built in the laboratory for its studies at the 1100 temperature.

Furnace Brazed Steel Beam



Figure 16

taken out and allowed to cool in air.

(2) Patching the model

The model referred to in the above paragraph was a wide-flange section, about 22 inches long. Near one end, the flange was not joined to the web for a distance of about 2 inches. It is presumed that this bad joint was caused by an uneven web which allowed too large an opening to be filled by the solder. This spot was patched by placing another strip of foil in the opening, fluxing it, and reheating the area with a torch.

See following pages for the results of the testing of these models.

Model	Material	Length	Width	Flange	Web	Notes
10	Aluminum	22	2	Wide	Standard	Good
11	Aluminum	22	2	Wide	Standard	Good
12	Aluminum	22	2	Wide	Standard	Good
13	Aluminum	22	2	Wide	Standard	Good

The results of the tests conducted on these models are shown on the following pages. The tests showed very little distortion, and the joints appeared sound.

taken out and allowed to cool in air.

(2) Patching the model

The model referred to in the above paragraph was a wide-flange section, about 22 inches long. Near one end, the flange was not joined to the web for a distance of about 2 inches. It is presumed that this bad joint was caused by an uneven web which allowed too large an opening to be filled by the solder. This spot was patched by placing another strip of foil in the opening, fluxing it, and reheating the area with a torch.

See following pages for the results of the testing of these models.

It was not allowed to come in.

(The witness was asked)

The witness referred to in the above

was a white female, about 25

years old, the witness was

not joined to the car for a distance of about

100 feet. It is assumed that this witness

was caused by an injury was seen

two days or more to be killed by the

bullet. This was not a

bullet shot at all in the opening. Finding

it, and following the view with a

gun following her for the results of

the firing of this bullet.

(3) Beam test and results

Beam #13

Beam #13 was a "T" beam fabricated by furnace brazing with silver solder using Jig #3 modified, and clamping the pieces rigidly together with "C" clamps. It was tested on the vertical loading frame with the following results.

Dimensions of Beam	b = 1.5	inches
(See Figure 10)	t = .056	inches
	d = 1.56	inches
	L = 16	inches

The neutral axis was computed to be .417 inches above the base.

Moment of Inertia (I) = .0905

Deflection (D) = .0315 P x 10⁻³

Stress (f) = 50.4 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
10	.1520	.1476	.0044	.00315	28.5	504.0
35	.1581	.1478	.0103	.0110	6.8	1765.0
60	.1600	.1478	.0122	.0890	55.0	3030.0

The erratic results were thought to have been caused by buckling of the web as the load was applied. The beam showed very little distortion, and the joint appeared sound.

(33-2000-100) and section 100

Form 100

Some of the "..." have been ...
with other ... and ...
... together ... it was ...
the vertical ... the following ...

...
...
...
...
...

The vertical axis was ...

the page.

$W = 1000 \text{ lb}$
 $D = 1000 \text{ lb}$
 $S = 1000 \text{ lb}$

Load	...	...	...	...	...	...
10	...	...	...	...	...	...
25	...	...	...	...	...	...
50	...	...	...	...	...	...

The vertical results were ...
... of the ... the load was applied. The ...
very little distortion and the joints appeared sound.

Beam #14

Beam #14 was a wide flange section which was furnace brazed using silver solder. Jigging method #3 modified, with the assembly clamped rigidly together, was used.

Dimensions of Beam	b = 1.5	inches
(See Figure 10)	t = .056	inches
	d = 1.61	inches
	L = 22	inches

Moment of Inertia (I) = .1172

Deflection (D) = .0631 P x 10⁻³

Stress (f) = 37.8 P

<u>Load</u>	<u>Zero</u>	<u>Loaded</u>	<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
110	.18440	.19490	.0150	.00695	33.8	4160.0
185	.18450	.20180	.01730	.01169	32.0	6990.0
60	.18530	.19130	.00600	.00380	36.5	2270.0

This beam appeared to be distortion free and unwarped throughout its length. The joint, after it was patched, appeared to be satisfactory. The cause of the bad test results could be attributed only to the imperfect joint, which, even after being patched, probably was not strong enough.

Types of Beams Constructed



Figure 17

IV. Check of Beam #11 by Electric Strain Gages

Beam #11 was found to be very satisfactory when loaded on the vertical loading frame. The average variation between the computed and actual deflections of this model under load was less than two percent. It could be presumed, then, that as a whole the model was acting as a wide-flange beam should. However, in order to check this beam further and in particular to find out something about the stress distribution at various sections along its length, several SR-4 electric strain gages were mounted on it.

A. Location of Gages

A total of 11 gages were mounted on the web and flange of the beam as shown in Figure 18. Gages #1 and #4 were located at a distance of one beam depth away from the centerline of the beam, where the load was applied. According to the St. Venant principle, the stress at this section should be as given by the elastic theory. Gages #2, #3, #5, #6, and #7 were placed at a distance of three beam depths away from the load on one side of the mid-point while gages #8, #9, #10, and #11 were placed at a like distance on the other side of the mid-point. By locating the gages at these sections and placing some on the flange and others at different distances from the neutral axis on the web, we attempted to obtain a representative set of stress values.

B. Loading and Results

As stated previously, this beam had already been checked on the vertical loading frame. Since it was antici-

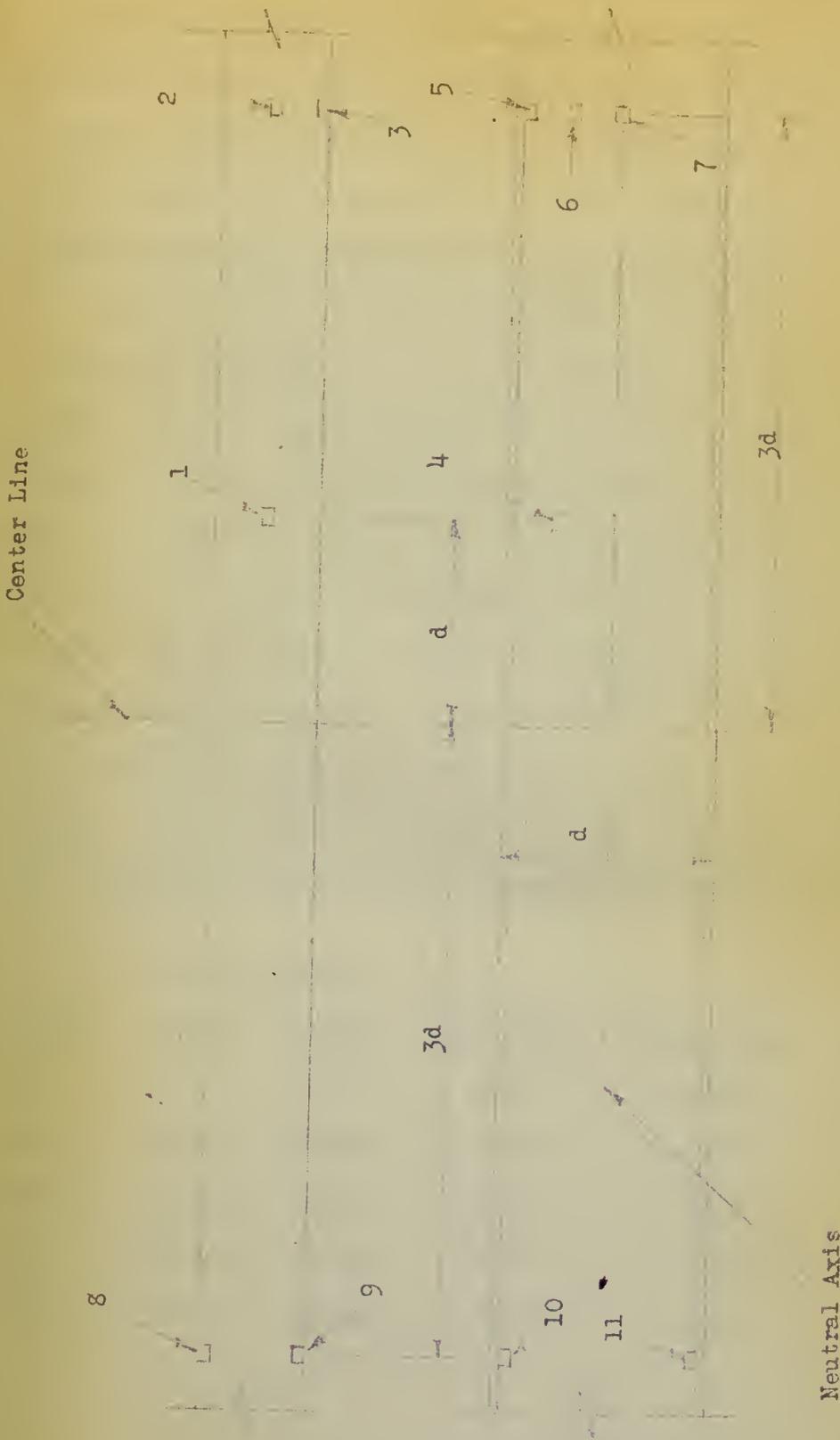
Beam III was found to be very satisfactory when loaded on the vertical loading frame. The average velocity of the beam was found to be about 1000 ft. per sec. The beam was found to be very satisfactory when loaded on the vertical loading frame. The average velocity of the beam was found to be about 1000 ft. per sec. The beam was found to be very satisfactory when loaded on the vertical loading frame. The average velocity of the beam was found to be about 1000 ft. per sec.

A. Location of Beams

A total of 12 beams were mounted on the top and bottom of the beam as shown in figure 10. Beams 11 and 12 were located at a distance of one beam width away from the centerline of the beam, where the load was applied. Beams 13 to the 20. Vertical distance, the average of all beams should be as given by the electric energy. Beams 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 were placed at a distance of three beam widths away from the load on one side of the mid-point while beams 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 were placed at a like distance on the other side of the mid-point. By locating the beams at these positions and placing some on the top and others at different distances from the central axis on the top, we attempted to obtain a representative set of stress values.

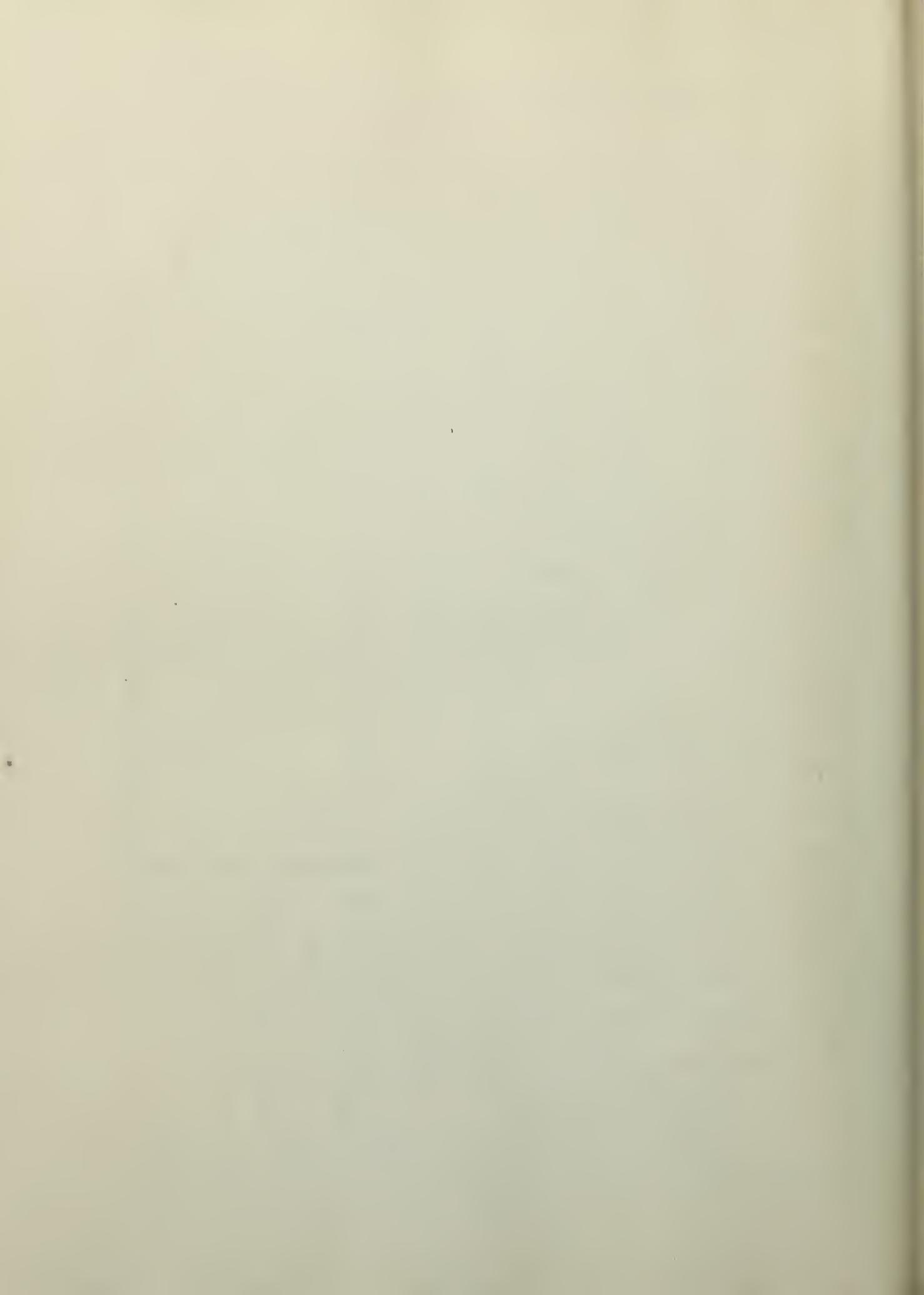
B. Loading and Results

As stated previously, this beam had already been checked on the vertical loading frame. Figure 11 was used



Alladin Soldered Beam # 11, Showing Strain Gage Location

Figure 18



pated that models made by our technique would be tested eventually on the horizontal loading frame, it was necessary first of all to check the action of the horizontal loading frame. (See Figure 19.) It was feared that there would be some friction losses caused by the change in direction of application of the load over a pulley.

Beam #11 was placed upon the loading frame in a horizontal position with steel ball bearings, sandwiched between glass plates, supporting it. (See Figure 14.) The same loading yoke that was used for vertical loading was supported at the center of the beam on ball bearings. The flanges at the end of the beam were pushed snugly against the vertical knife edge supports, making sure that the flanges were bearing along their whole length against the knife edges. A load of known value was applied, then, at the end of a steel cable, which passed over the pulley and was attached to the yoke.

The results of this loading are shown below:

<u>Load</u>	<u>Dial Reading</u>		<u>Act. Def.</u>	<u>Comp. Def.</u>	<u>% Diff.</u>	<u>Stress</u>
	<u>Zero</u>	<u>Loaded</u>				
10	.0745	.0826	.0081	.0080	1.25	405.0
20	.0745	.0900	.0155	.0160	3.1	810.0
30	.0745	.0979	.0234	.0240	2.5	1215.0
40	.0745	.1058	.0313	.0320	2.2	1620.0
50	.0745	.1138	.0393	.0400	1.75	2025.0

tested these models made up of the following would be tested eventually on the horizontal loading frame, if necessary. It is necessary to test the entire of the horizontal loading frame. (See Figure 10.) It was tested that there would be some friction losses caused by the change in direction of application of the load over a pulley.

Beam #11 was placed upon the loading frame in a horizontal position with steel ball bearings, interposed between glass plates, supporting it. (See Figure 14.) The same loading yoke that was used for vertical loading was supported at the center of the beam on ball bearings. The hinges at the end of the beam were loaded roughly against the vertical knife edge supports, which were that the hinges were being about their own weight against the knife edges. A load of known value was applied, then, at the end of a steel cable which passed over the pulley and was attached to the yoke. The results of this loading are shown below:

Load	Dial Reading		Temp. Sol.	# Ditt.	Stress
	Low	Loaded			
10	.0788	.0888	.0000	1.04	400.0
20	.0788	.0900	.0100	2.1	800.0
30	.0788	.0978	.0200	3.2	1200.0
40	.0788	.1038	.0300	4.3	1600.0
50	.0788	.1118	.0400	1.75	2000.0

Horizontal Loading Frame



Figure 19

A comparison of the actual and computed deflections shows that the friction losses are negligible since the actual differences are no greater than those occurring with vertical loading. These encouraging results showed that the horizontal loading frame, with all of its advantages in accommodating large models and in the case of applying diversified loads, could be used for future tests.

Leads from the SR-4 gages were connected with the indicating device, and values of strains read for different loads. The results of these loadings are shown on the next few pages.

A comparison of the actual and expected latencies shows that the typical latencies are negligible since the actual differences are so small. The time taken during the various loading. These unexpected results show that the program is loading faster, with all of the advantages in accommodating large models and in the case of multiple distributed loads, could be used for future tests.

Tests from the 10-4 series were compared with the data being given, and values of stress were for different loads. The results of these tests are shown on the next few pages.

Form of Computations for Stresses at Various Sections Along
Beam #11

Computations:

Section at "d" distance from the center (See Figure 18)

$$M = \left(\frac{P}{2}\right) (24.5) = 12.25 P \quad I = .4128$$

$$\text{Computed } f = \frac{Mc}{I} = \frac{(12.25 P)(c)}{.4128} = 29.6 Pc$$

$$\text{Actual } f = eE = e \times 10^{-7}$$

Section at 3 "d" distance from the center

$$M = \left(\frac{P}{2}\right) (19.56) = 9.78 P$$

$$\text{Computed } f = \frac{Mc}{I} = \frac{(9.78 P)(c)}{.4128} = 23.7 Pc$$

$$\text{Actual } f = eE = e \times 10^{-7}$$

Terms Defined:

I, moment of inertia, inches⁴

M, bending moment, inch lbs.

P, load, lbs.

f, stress, lbs./inch²

c, distance from neutral axis of beam to center of gage

e, strain indicated by SR-4 gage, micro-inches/inch

E, modulus of elasticity of aluminum, lbs./inch²

Values of c:

gage 1, 1.238	gage 5, .88	gage 9, 1.238
gage 2, 1.238	gage 6, .45	gage 10, .88
gage 3, 1.238	gage 7, 0	gage 11, .93
gage 4, .47	gage 8, 1.238	

P = 10 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0622	0113	0732	1900	0370	1361	1453	1052	1884	0798	0260
Loaded	0598	0091	0709	1887	0350	1351	1452	1022	1860	0779	0273
e	24	22	23	13	20	10	1	30	24	19	13
Act. f	240	220	230	130	200	100	10	300	240	190	130
Comp. f	367	293	293	138	207	106	0	293	293	209	220
% Diff.	34.5	24.9	21.5	5.8	3.4	5.7		2.4	18.1	9.0	41.0

P = 20 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0622	0113	0732	1900	0370	1361	1453	1052	1884	0798	0260
Loaded	0561	0064	0686	1871	0332	1340	1454	0998	1835	0761	0288
e	61	49	46	29	38	21	1	54	49	37	28
Act. f	610	490	460	290	380	210	10	540	490	370	280
Comp. f	735	587	587	277	415	213	0	588	588	417	441
% Diff.	17.0	16.5	21.7	4.7	8.5	1.4		8.2	16.7	11.2	36.4

P = 30 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0622	0113	0732	1900	0370	1361	1455	1052	1884	0798	0260
Loaded	0529	0035	0662	1858	0312	1328	1453	0968	1808	0743	0300
e	93	78	70	42	58	33	2	84	76	55	40
Act. f	930	780	700	420	580	330	20	840	760	550	400
Comp. f	1100	880	880	417	625	320	0	881	881	626	662
% Diff.	15.5	11.3	13.6	0.7	7.2	3.1		4.6	13.7	12.1	39.7

P = 40 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0622	0113	0732	1900	0370	1361	1453	1052	1884	0798	0260
Loaded	0498	0009	0640	1840	0292	1317	1452	1022	1860	0779	0273
e	124	104	92	60	78	44	1	30	24	19	13
Act. f	1240	1040	920	600	780	440	10	300	240	190	130
Comp. f	1470	1175	1175	555	831	426	0	293	293	209	220
% Diff.	15.6	11.5	21.7	8.1	6.1	3.3		2.4	18.1	9.0	41.0

P = 50 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>
Zero	0624	2115	0731	1900	0564	1355	1451	1052	1884	0798	0260
Loaded	0461	1984	0620	1829	0273	1301	1449	0906	1763	0709	0329
e	163	131	111	71	91	54	2	146	121	89	69
Act. f	1630	1310	1110	710	910	540	20	1460	1210	890	690
Comp. f	1838	1470	1470	695	1040	533	0	1470	1470	1442	1102
% Diff.	11.3	10.9	24.5	2.2	12.5	1.3		0.7	17.6	14.6	37.5

C. Conclusions

In general, the difference between the computed and actual values of stress becomes less as the load is increased. This indicates that for higher stresses, errors introduced by slight inaccuracies in construction have reduced effect. The difference between values of stress indicated by gages 2 and 3 shows that the edge of the flange participates less in resisting the load than the center of the flange. This was probably due to a slight buckling of the flange at its outer edge. Gages 4 and 6, which were located on the web midway between the neutral axis and the flange, gave consistently good results. This was due, it was thought, to their location away from the point where the web and flange were joined. Gages 5 and 10, located on the web near the flange, gave good results, but a little less accurately than gages 4 and 6. The difference between stresses at gages 8 and 9 was caused by the knife edge of the loading yoke not bearing evenly across the top flange. This caused one side of the flange to assume more load than the other. No reason can be given for the large discrepancy between the computed and actual stresses given by gage 11, unless it was due to a defective gage.

An overall comparison of computed and actual stresses indicated that the model was acting satisfactorily. The stress distribution closely approximated that given by the flexural theory.

5. Conclusions

In general, the difference between the computed and actual values of stress increases as the load is increased. This indicates that the stress distribution is not uniform by the time the load is increased. The difference between values of stress indicated by pages 2 and 3 shows that the edge of the beam is subjected to a stress also. The fact that the center of the beam is also subjected to a stress is a slight deviation of the theory. At the center edge, pages 4 and 5, which were located on the top edge between the neutral axis and the flange, have consistently good results. This was due to the fact that the stress distribution was from the center where the two ends were joined. Pages 6 and 7, however, do not give the same results, but a little less consistently than pages 4 and 5. The difference between stresses at pages 6 and 7 was caused by the hole edge of the beam, from the neutral axis to the edge of the flange. This caused one side of the flange to assume more load than the other. No reason can be given for the large discrepancy between the computed and actual stresses given by page 11, unless it was due to a defective

Case:

an overall comparison of computed and actual stresses indicated that the work was being satisfactorily. The stress distribution closely approximated that given by the theory.

Theory:

V. Constructing and Testing a Rigid Frame

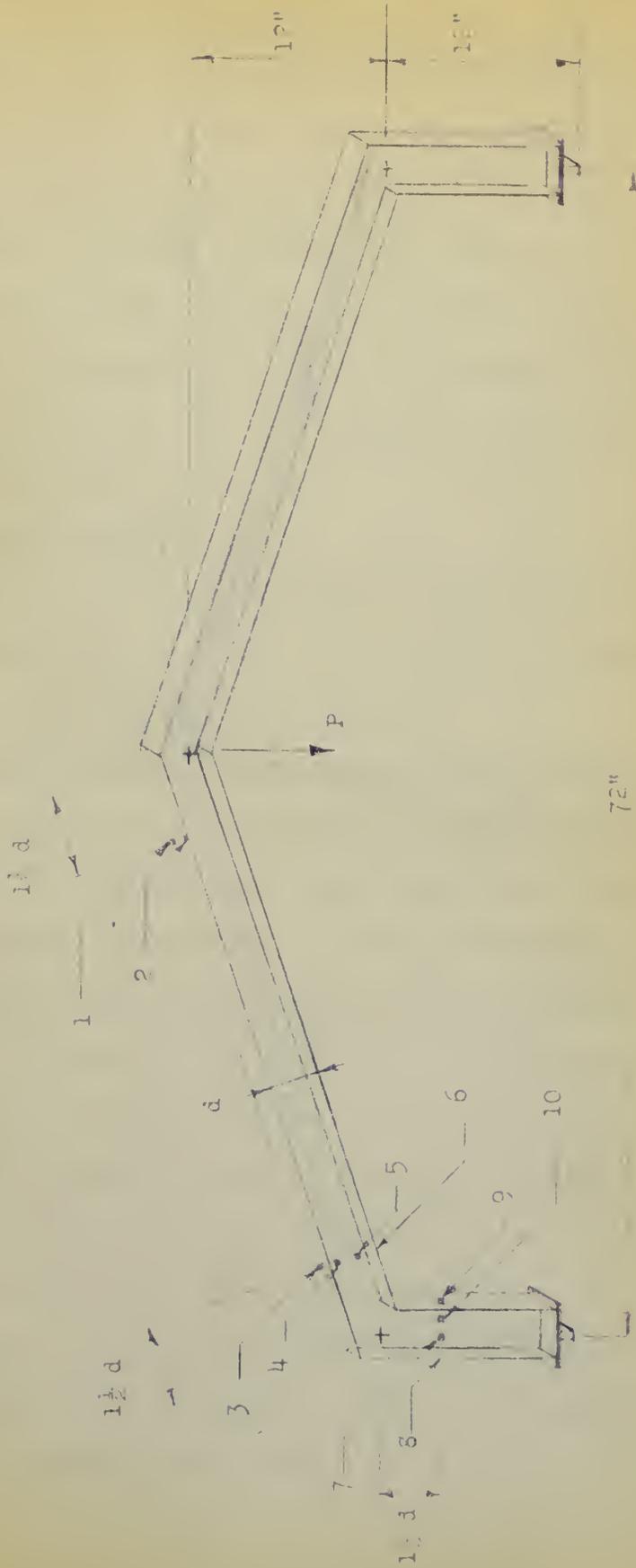
The construction and testing of a rigid frame was considered as the culmination of all the work done on this thesis. A rigid frame is one that is constructed to resist moment at the joints. The method of building a joint to resist moment may be either by riveting or welding. It is in this section that we discuss how we constructed and tested a welded rigid frame.

A. Purpose

The task of constructing a rigid frame was undertaken for two main reasons. The first, and most important to us, was to investigate the soundness of our techniques and methods in building models other than plain straight beams. Our last tests of beams were very successful, however, the beams were all of the same design. Thus, in order to be certain that the techniques and methods were sound, we built the rigid frame as shown in Figure 20. It would have been possible to construct a differently shaped model to test, but it was for the reason mentioned below that made us decide in favor of a rigid frame. As evidenced by the tests run on rigid frames, as mentioned in the introduction, there was still much to be learned, particularly about the stresses at the knees. Therefore, by building a rigid frame, we hoped not only to prove that our techniques were sound, but also to advance, perhaps, the understanding of stresses at knees in rigid frames.

B. Design

The design of the frame was not completely an



Rigid Frame Showing Location of Strain Gages

Figure 20



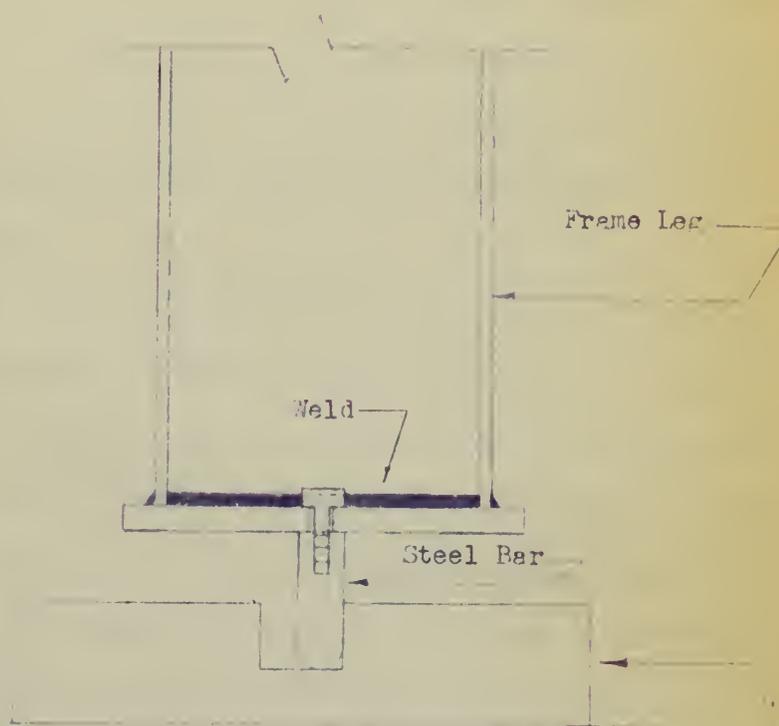
arbitrary one. We attempted to build a frame that, although not an exact copy of a large structure, was similar in most ways to one that might possibly be built. The important feature that influenced our design was the limit we placed on the amount of horizontal shear that we would allow. Although our sample tests indicated that we could go to about 12 lbs./inch, we tried to stay down lower than 8 lbs./inch to be sure that no harm would be done to the welds. Therefore, we designed the frame to give us a maximum deflection with the span being used, along with the lowest possible horizontal shear for any given load.

C. Construction

The rigid frame was constructed using the alladin solder method. It was held and supported as indicated in the discussion under jiggling #3 modified.

The base detail of the legs is indicated in Figure 21. Since there are several ways of testing the frame, it was necessary to develop a base detail that would accommodate any desired method. Therefore, a piece of aluminum plate about 1/4 inch thick was welded to the base of each leg. Two holes were drilled through each plate so that different types of base attachments could be used. The particular attachment we used was a simulated pin on each leg. This was accomplished by bolting a piece of steel bar, rounded on the bottom, to the plate. When the rigid frame was mounted on the horizontal loading frame, the steel bar was inserted into a slotted plate mounted on the loading frame. This slot supported the bar at the bottom and along the sides.

Rigid Frame Base Details



Support attached to horizontal loading frame

Figure 21



Since the length of the frame was 6 ft., it was impractical to cut the flanges and web in one piece. Therefore, it was necessary to devise a method for splicing. It was felt that the best way to insure the maximum strength was to stagger the splices. The location of these splices are shown in Figure 22. In making a splice, the ends of the material should be prepared as shown in Figure 22. This is a recognized method for butt joints as recommended by the Aluminum Company of America. The splices were made using alladin solder, care being used not to apply too much heat, such that the pieces being joined would warp at the splice.

D. Mounting

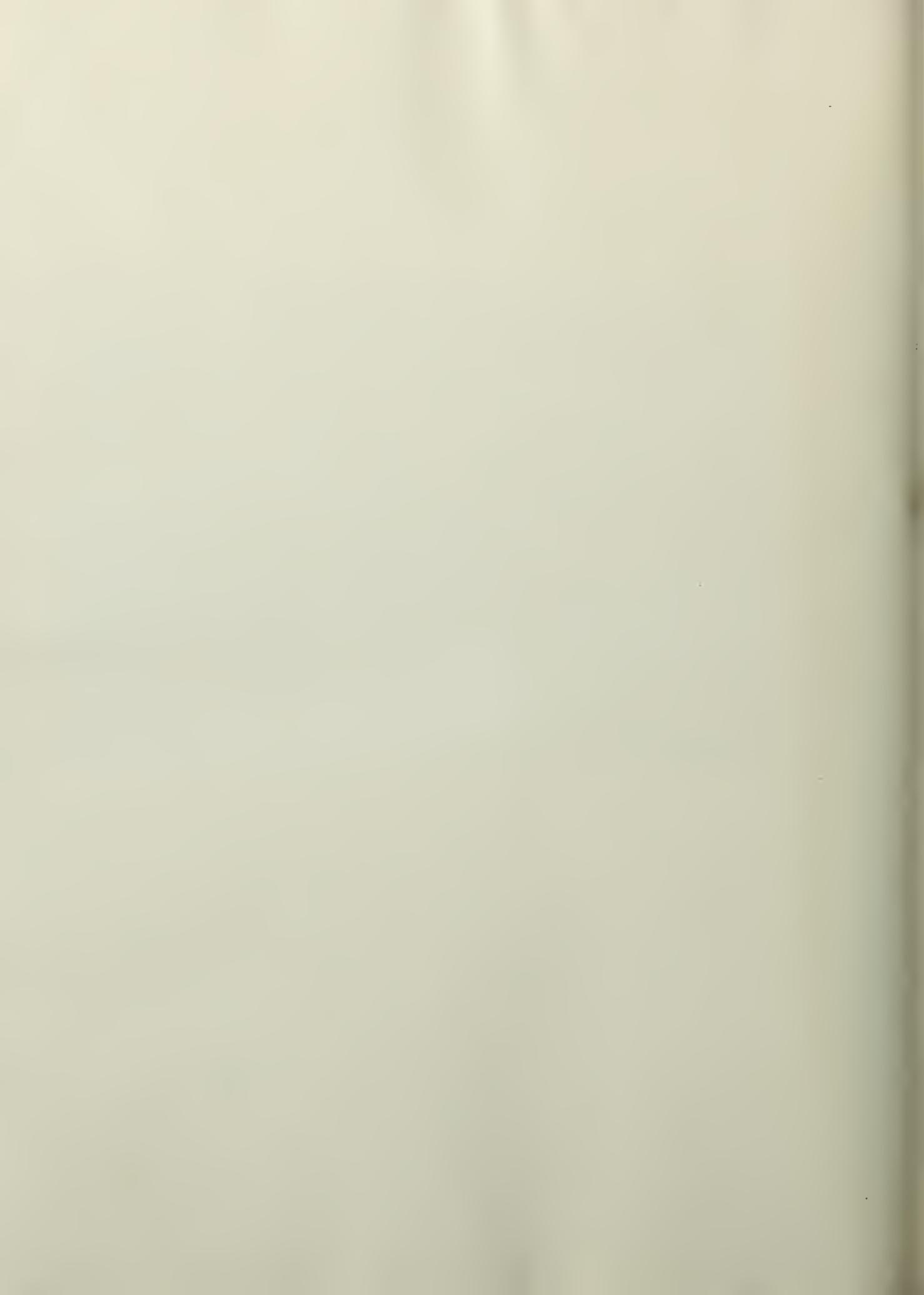
The frame was mounted on the horizontal loading frame in the same way that beam #11 was mounted. (See Figures 23, 24 and 25.) The four support points used were under the two knees, and one on each side of the load point. Lateral support was provided by two pound weights placed on the frame above the support points. It should be noted here that great care must be taken to insure that the beam is supported correctly at the bases. It is important to have both the bottom of the steel bar and the side of the steel bar bearing along the whole length of the support, or the readings taken will be inaccurate.



Rigid Frame on Horizontal
Loading Device



Figure 23



Rigid Frame Peak Detail

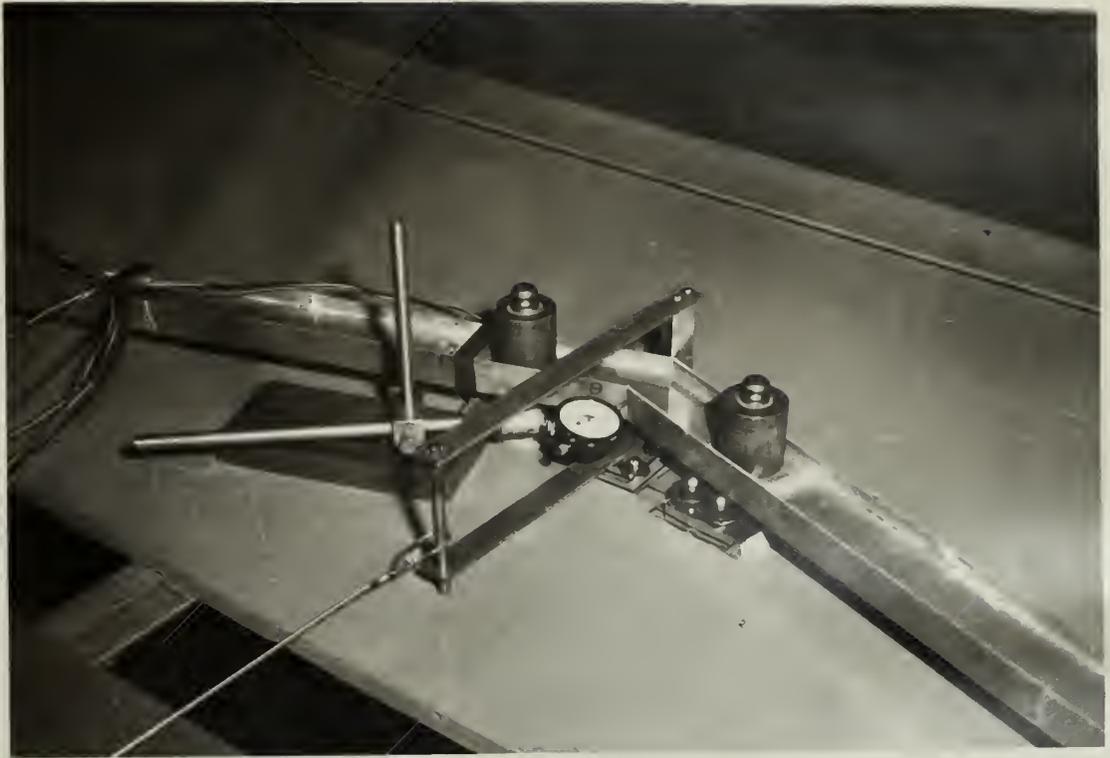


Figure 24

E. Computations

1. Solution for Deflection of Rigid Frame by the
Conjugate Structure Method for a Pinned Base.

See Figure 26

$$(a) \quad D_A = M_{xx} = (20)(341 P)(2) = 13640 P$$

$$(b) \quad d_H = M_{xx} = (72)(8)(2) + (2)(455)(18) + (2)(228)(20) = 26632$$

$$H_A = \frac{13640 P}{26632} = .513 P$$

$$(c) \quad (60.9 P)(6.25) + (65.75)(60.9 P) + (37 P)(72) - (51.7 P) \\ (30.25) - (51.7 P)(41.75) - 72 \theta_E = 0$$

$$\frac{3333 P}{72} = \theta_E = 46.25 P$$

$$\frac{EID_B}{2} = (46.25 P)(12) - (37.0 P)(4) + (60.9 P)(2.08) - \\ (51.7 P)(8.16) = 111.8 P$$

$$D_D = D_B = \frac{(2)(111.8)}{(10^7)(.4)} = .0000559 P$$

$$EID_C = (46.25 P)(36) + (51.7 P)(5.75) - (60.9 P)(29.75) - \\ (37 P)(36) = 1182 P$$

$$D_C = \frac{1182 P}{(10^7)(.4)} = .000296 P$$

Computer

1. Solution for selection of 8148 from 8148
Computer selection method for a fixed base.

See Figure 28

$$D_A = \frac{13840}{20000} = 0.692$$

$$D_B = \frac{13840}{20000} = 0.692$$

$$D_C = \frac{13840}{20000} = 0.692$$

$$D_D = \frac{13840}{20000} = 0.692$$

$$D_E = \frac{13840}{20000} = 0.692$$

$$D_F = \frac{13840}{20000} = 0.692$$

$$D_G = \frac{13840}{20000} = 0.692$$

Diagram for solution of Conjugate Structure

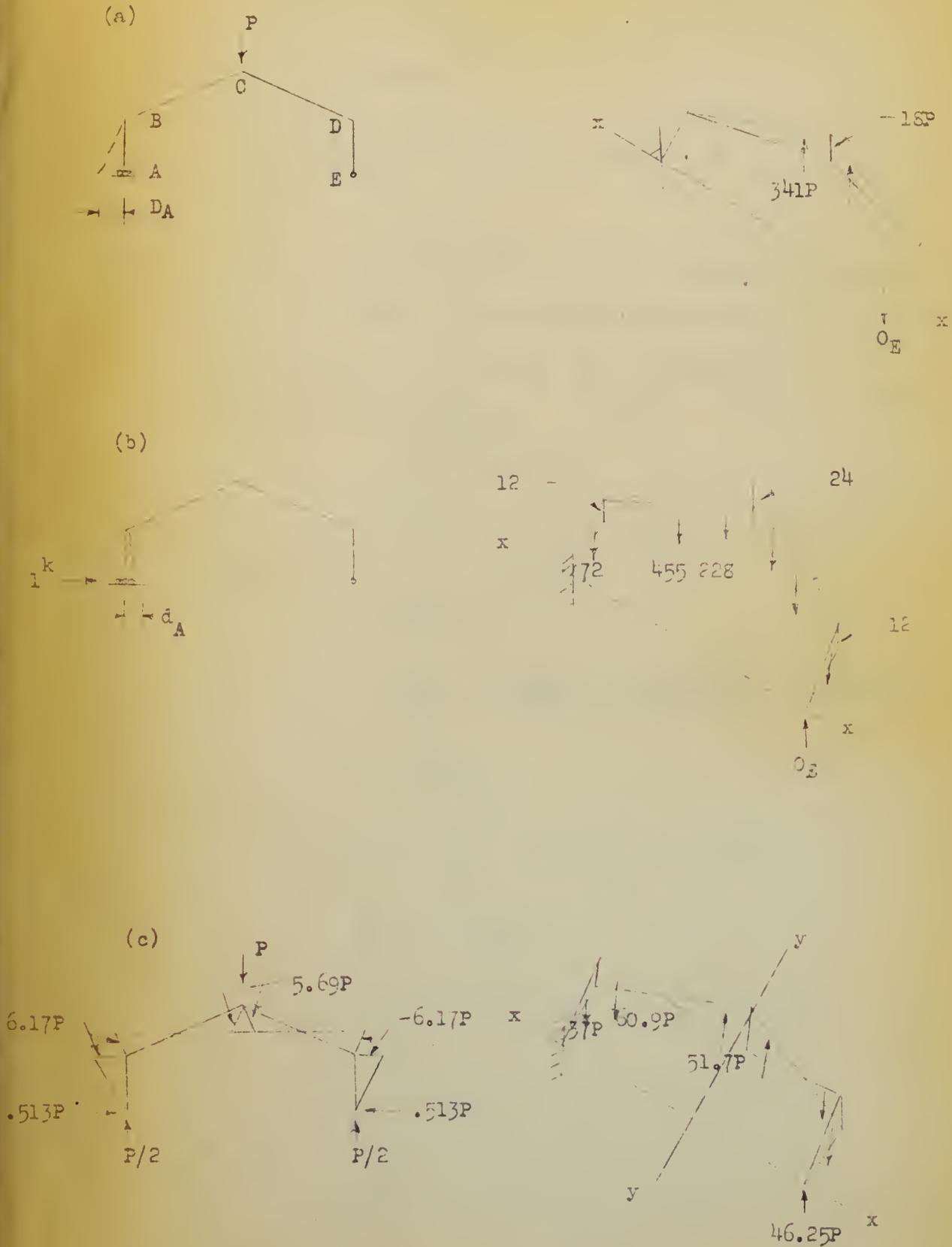


Figure 26

2. Check Solution for Deflections of Rigid Frame
by Integration Using the Method of Virtual Work

$$EID_c = \int M m dx$$

$$EID_c = \int_0^{12} (.513 Px)(.513 x) dx$$

$$+ \int_0^{37.93} \left[(.513 P)(12 + x \sin a) - \frac{P}{2} (x \cos a) \right] \\ \left[(.513)(12 + x \sin a) - .5 (x \cos a) \right]$$

$$= .264 P \int_0^{12} x^2 dx + \int_0^{37.93} (38.1 P - 3.85 P x + \\ .0974 Px^2) dx$$

$$= 152 P + 1441 P - 2760 P + 1765 P$$

$$= 598 P$$

$$D_c = 2 \left(\frac{598 P}{EI} \right) = 2 \frac{(598 P)}{(10^7)(.4)} = .000299 P$$

These solutions for the values of the variables
are given in the table below.

$$x = 100$$

$$y = 200$$

$$\left[\begin{matrix} 100 & 200 \\ 200 & 100 \end{matrix} \right]$$

$$x + y = 300$$

$$x - y = -100$$

$$x = 100$$

$$y = 200$$

3. Corrections to Deflections Resulting from Movement of Base.

It was noted that the base deflected a slight amount when the structure was loaded; therefore, it was necessary to correct previously computed deflections for this movement. This was accomplished by interpolating between the deflections resulting from a pinned base and a base on rollers to obtain the correct deflections.

a. Solution for horizontal deflection at E, with E on rollers. (See Figure 27.)

$$D_E = \int \frac{Mm \, dx}{EI}$$

$$\frac{EI \, D_E}{2} = \int_0^{37.93} (P/2)(.949)(x)(12 + .316x) \, dx = 6820 \, P$$

$$D_E = \frac{(2)(6820)(P)}{(.4)(10^7)} = .00341 \, P$$

b. Solution for vertical deflection at C with E on rollers. (See Figure 27.)

$$D_C = \int \frac{Mm \, dx}{EI}$$

$$\frac{EI \, D_C}{2} = \int_0^{36} .25 \, P \, x^2 \, dx = 3888 \, P$$

$$D_C = \frac{(2)(3888 \, P)}{(.4)(10^7)} = .001944 \, P$$

c. Sample correction for any load P.

	D_C	D_E
Base pinned	.000296 P	0
Actual Conditions	Z	R
Base on rollers	.001944 P	.00341 P

4. Consideration in Definition 2.1 is not
 necessary to correct previously computed deflections for
 this movement. This was accomplished by superposing be-
 tween the deflection resulting from a given load and a
 base on rollers to obtain the correct deflection.

a. Solution for vertical deflection at B
 with B on rollers. (See Figure 27.)

$$D_B = \frac{1811000(12)}{1.4(10^6)} = 15681 \text{ in.}$$

$$\frac{1}{2} D_B = \frac{1}{2} (15681) = 7840.5 \text{ in.}$$

$$D_B = \frac{1811000(12)}{1.4(10^6)} = 15681 \text{ in.}$$

b. Solution for vertical deflection at C with B
 on rollers. (See Figure 27.)

$$D_C = \frac{1811000(12)}{1.4(10^6)} = 15681 \text{ in.}$$

$$\frac{1}{2} D_C = \frac{1}{2} (15681) = 7840.5 \text{ in.}$$

$$D_C = \frac{1811000(12)}{1.4(10^6)} = 15681 \text{ in.}$$

c. Similar correction for any load P.

Base on rollers	15681 in.	15681 in.
Actual conditions	7840.5 in.	7840.5 in.
Base pinned	7840.5 in.	7840.5 in.

Diagram for Solution of Deflections by virtual work

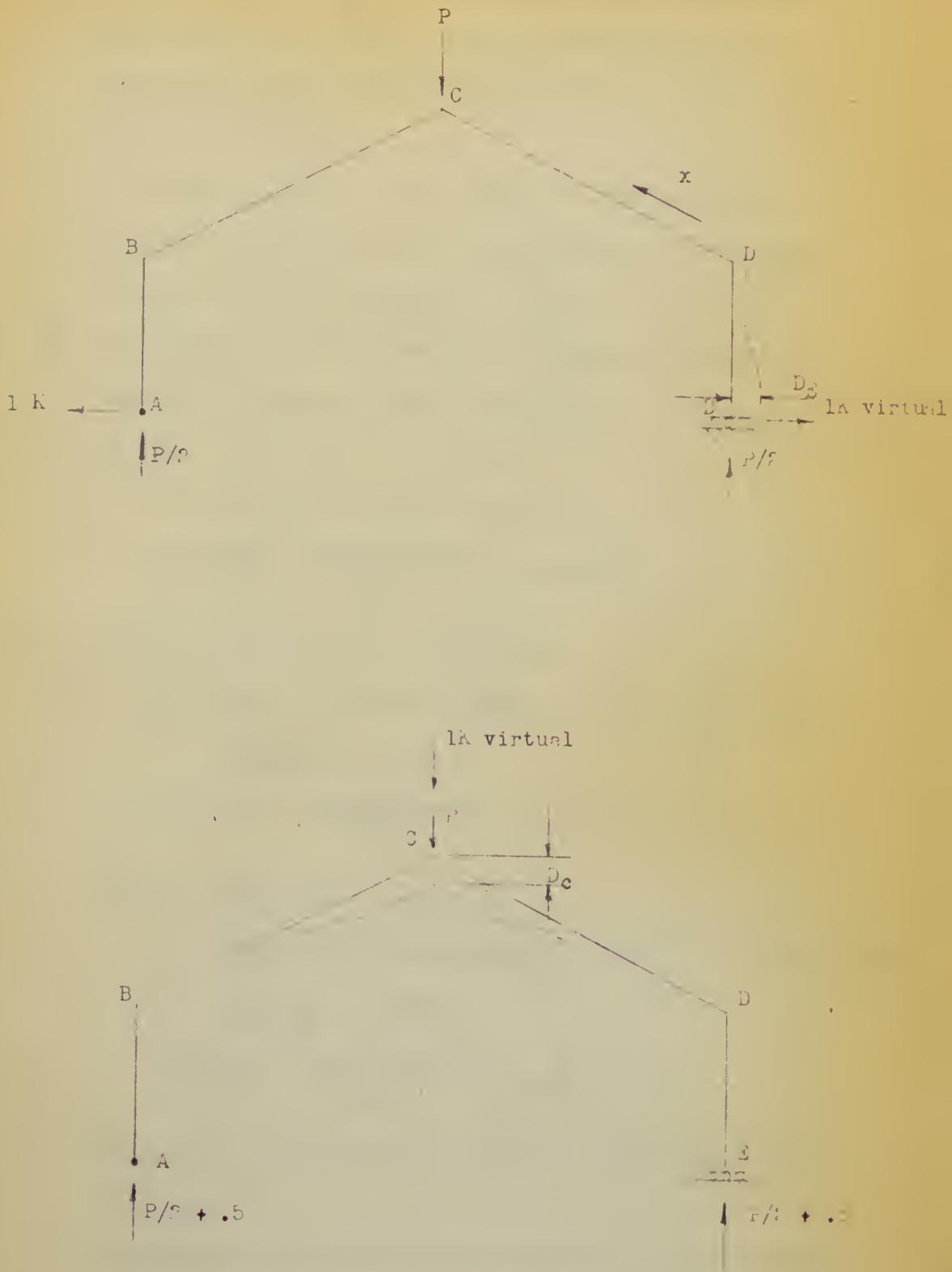


Figure 27

R is the sum of the outward deflections at the bases, as determined by mechanical dials.
Z is the corrected deflection at C, arrived at by interpolation.

The corrected deflection at the knee is arrived at by applying the movement of the base directly to the computed value at the knee.

4. Computations for stresses at various sections along the frame. (See Figure 20.)

On the leg, 1.5 d from knee:

$$M = (.513 P)(8.30) = 4.27 P$$

$$f = \frac{Mc}{I} = \frac{(4.27 P)(c)}{.40} = 10.66 Pc$$

On the girder, 1.5 d from knee

$$M = .513 P \left[(3.75) \left(\frac{12}{37.93} \right) + 12 \right] - \left(\frac{P}{2} \right) (3.75) \left(\frac{36}{37.93} \right) = 4.99 P$$

$$f = \frac{Mc}{I} = \frac{(4.99 P)(c)}{.40} = 12.5 Pc$$

On the girder 1.5 d from C:

$$M = (.513 P) \left[(34.55) \left(\frac{12}{37.93} \right) + 12 \right] - (P/2)(34.55) \left(\frac{36}{37.93} \right) = 4.60 P$$

$$f = \frac{Mc}{I} = \frac{(4.60 P)(c)}{.40} = 11.5 Pc$$

5. Correction to stresses resulting from movement of base.

Due to the movement of the base it was necessary to apply a correction to the stresses computed in section 4

The first, as defined by geometrical data, is the horizontal distance of the arrival of the wave at the surface of the sea is

The vertical distance of the wave is arrived at by applying the movement of the base directly to the horizontal axis of the wave.

4. Computations for distance in various sections

Along the track (see Figure 20.)

On the line, I. A. & from base

$$x = \frac{100}{1} = 100 \text{ ft}$$

$$y = 100 \sin(15^\circ) = 25.98 \text{ ft}$$

On the line, I. B. & from base

$$x = \frac{100}{1} = 100 \text{ ft}$$

$$y = 100 \sin(15^\circ) = 25.98 \text{ ft}$$

On the line, I. C. & from base

$$x = \frac{100}{1} = 100 \text{ ft}$$

$$y = 100 \sin(15^\circ) = 25.98 \text{ ft}$$

5. Computations for distance from various

of base.

Due to the movement of the base it was necessary

to apply a correction to the straight line distance in section 4

above. The manner in which the stresses were corrected is shown below.

	H_E	D_E
Base Pinned	.513 P	0
Actual Conditions	Y	Q
Base on Rollers	0	.00341 P

Q is the average of the outward deflection at the two bases.

Y is the corrected value of horizontal reaction (H_E) due to movement of the bases. The corrected stresses are obtained

by multiplying the computed values, as obtained in section 4

above, by $\frac{Y}{.513 P}$.

F. Load Tests and Results

1. Deflections

a. Deflections at C

<u>Load</u>	<u>Dial Reading</u>		<u>Act. Def.</u>	<u>Corr. Def. (Z)</u>	<u>% Diff.</u>
	<u>Zero</u>	<u>Loaded</u>			
10	.1085	.11225	.00375	.00339	10.6
20	.1095	.1166	.0071	.00683	3.2
30	.1095	.1212	.0117	.01036	12.9
40	.1090	.1250	.0160	.01443	9.8
50	.1090	.1290	.0200	.01796	11.3

b. Deflection at B or D

<u>Load</u>	<u>Dial Reading</u>		<u>Act. Def.</u>	<u>Corr. Def.</u>	<u>% Diff.</u>
	<u>Zero</u>	<u>Loaded</u>			
10	.04085	.04185	.0010	.000609	64.0
20	.0415	.0434	.0019	.00192	1.0
30	.0549	.0579	.0030	.00288	4.2
40	.0483	.0528	.0045	.00464	3.0
50	.0537	.0478	.0059	.0060	1.7

c. Sum of the Deflections of the two bases

<u>Load</u>	<u>Deflection</u>
10	.0009
20	.0020
30	.0031
40	.0054
50	.0066

Table 1. Daily Production

1. Production

2. Production

<u>Date</u>	<u>Time</u>	<u>Production</u>	<u>Production</u>	<u>Production</u>	<u>Production</u>
1.1	0.00	0.00	0.00	0.00	0.00
1.2	0.00	0.00	0.00	0.00	0.00
1.3	0.00	0.00	0.00	0.00	0.00
1.4	0.00	0.00	0.00	0.00	0.00
1.5	0.00	0.00	0.00	0.00	0.00

3. Production

<u>Date</u>	<u>Time</u>	<u>Production</u>	<u>Production</u>	<u>Production</u>	<u>Production</u>
1.6	0.00	0.00	0.00	0.00	0.00
1.7	0.00	0.00	0.00	0.00	0.00
1.8	0.00	0.00	0.00	0.00	0.00
1.9	0.00	0.00	0.00	0.00	0.00
1.10	0.00	0.00	0.00	0.00	0.00

4. Sum of the Production of the two lines

<u>Production</u>	<u>Production</u>
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00

2. Stresses

P = 10 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0220	1878	1202	0770	0220	1699	2000	1340	1069	1981
Loaded	0206	1865	1217	0778	0216	1686	2003	1352	1060	1977
e	14	13	15	8	4	13	3	12	9	4
Act. f	140	130	150	80	40	130	30	120	90	40
Corr. f	140	140	151.5	67.7	67.7	151.5	51.2	130	130	59
% Diff.	0	7.1	1.0	18.1	40.7	14.1	41.6	7.7	32.5	32.2

P = 20 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0220	1878	1202	0770	0220	1699	2000	1340	1069	1981
Loaded	0193	1850	1230	0783	0209	1673	2008	1362	1051	1971
e	27	28	28	13	11	26	8	22	18	10
Act. f	270	280	280	130	110	260	80	220	180	100
Corr. f	280	280	304	136	136	304	102	260	260	118
% Diff.	3.5	0	7.8	4.4	19.1	14.5	21.6	18.2	30.8	15.2

P = 30 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0220	1878	1198	0770	0220	1698	1998	1330	1072	1981
Loaded	0178	1836	1241	0788	0200	1660	2011	1373	1041	1965
e	42	42	43	18	20	38	13	43	31	16
Act. f	420	420	430	180	200	380	130	430	310	160
Corr. f	419	419	457	204	204	457	155	389	389	178
% Diff.	.2	.2	5.9	11.7	1.9	16.9	16.1	10.5	20.3	10.1

P = 40 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0219	1874	1198	0768	0220	1698	1998	1330	1072	1981
Loaded	0161	1821	1251	0791	0193	1649	2015	1381	1033	1960
e	58	53	53	23	27	49	17	51	39	21
Act. f	580	530	530	230	270	490	170	510	390	210
Corr. f	557	557	604	270	270	604	205	517	517	236
% Diff.	4.1	4.1	12.2	14.8	0	18.8	17.0	1.3	24.6	11.0

P = 50 lbs.

<u>Gage</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
Zero	0219	1874	1198	0768	0220	1698	1998	1330	1072	1981
Loaded	0149	1806	1263	0796	0186	1634	2018	1393	1023	1953
e	70	68	65	28	34	64	20	63	49	28
Act. f	700	680	650	280	340	640	200	630	490	280
Corr. f	696	696	756	337	337	756	256	645	645	295
% Diff.	.6	2.3	14.0	16.9	.9	15.3	21.3	2.3	24.9	18.6

3. Conclusions

In the process of testing our beams and the rigid frame on the horizontal loading device, we came across a method of loading that eliminates the possibility of the beam twisting due to the eccentricity of the load.

It was necessary to have some method for centering the load since any twisting causes errors in the values of the stresses. The way this was done for the rigid frame is indicated below.

Gages #1 and #2 were mounted, one on each side of the loaded flange near the load point. The loading yoke was then adjusted so that the stresses indicated by these gages were as near equal as possible. When these stresses are equal, the yoke is applying the load correctly to the frame. By using this method, the percentage error for all strain gages was less.

Although the differences between the observed and calculated stresses and deflections for the rigid frame were greater than for beam number 11, they were still considered satisfactory. There were many more sources of error in the construction of a rigid frame. Possibilities for inaccuracies were introduced in the fabrication of other than a straight model, in splicing, and in the construction of the base detail. The base detail, in particular, introduced complications. It should be noted that corrections to both the deflections and stresses had to be made to compensate for horizontal movement of the base, which was originally designed for no movement.

2. Discussion

In the process of having our feet and the right hand to the horizontal loading device, we must know a method of loading that eliminates the possibility of the feet twisting due to the eccentricity of the load.

It was necessary to have some method for centering the load since any lateral loading errors in the center of the structure. The way this was done was the rigid frame is indicated below.

When it was first mounted, one on each side of the loaded frame was the load point. The loading force was then adjusted so that the reaction indicated at these points was the same as indicated. When these reaction were equal, the frame is considered the load correctly to the frame. By using this method, the reactions were equal to their proper size.

Although the observations between the structure and uniaxial stresses and deflections for the rigid frame

were greater than the load number 11, they were still considered satisfactory. There were only very small errors in the comparison of a rigid frame. Uniaxial stresses for concentrated were introduced in the distribution of stress from a vertical load, in addition, and in the comparison of the data detail. The data detail, in particular, indicated comparisons. It should be noted that experiments to show the deflection and stresses and to show to compare the theoretical results of the data, also are slightly different for the comparison.

In general, the authors felt that the results indicate the overall soundness of the techniques and methods used.

VI. Discussion

In writing this thesis, we have attempted to break it down into sections so that each division was a subject in itself. This method allowed us to gather the results from each test and to present them along with the material from which they were deduced. Therefore, it will not be necessary for us to mention the results we have already listed. There are, however, several items of a general nature that are of interest as an overall result of each method attempted.

The welding of aluminum using eutecrod was very difficult. It took weeks of practice for us to become proficient enough to weld the aluminum without fear of completely melting the parent material. Also, the heating of the aluminum to a high temperature annealed it so that a large furnace for heat treatment would be required to temper it. We, therefore, conclude that eutecrod welding is impractical for building models in the laboratory.

From the tests we have run, we feel that the construction of accurate models by soldering is practical. It is definitely possible to construct models and to obtain reasonable results with close accuracy. The major fault with soldering is that low loads must be applied in order to stay within the required limits of horizontal shear. Although the models constructed were near perfect, the allowable stress was never developed, and it was, therefore, impossible to ascertain the effects of high stresses.

In writing this paper, we have attempted to show that the method of least squares is not the best method for fitting a curve to a set of data. We have shown that the method of least squares is based on the assumption that the errors are normally distributed. This method allows us to estimate the parameters of the curve from the data and to test the hypothesis that the errors are normally distributed. However, when the errors are not normally distributed, the method of least squares is not the best method. In such cases, the method of maximum likelihood is a better method. The method of maximum likelihood is based on the assumption that the errors are normally distributed. It allows us to estimate the parameters of the curve from the data and to test the hypothesis that the errors are normally distributed. The method of maximum likelihood is a better method than the method of least squares when the errors are not normally distributed.

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The results from the tests run on the beams constructed with steel and silver solder were not satisfactory. The beams obtained from the furnace method seemed absolutely perfect. We have no explanation for the poor results obtained, other than perhaps that the joint was not perfectly soldered although it appeared to be so. In view of the high loads the horizontal loading frame is capable of handling, we feel that the investigation of steel should be continued. It is definitely the feeling of the authors that a small amount of work with the steel method would produce very satisfying results.

VII. Conclusions

A. Aluminum soldering, using alladin rod to form the joint between model components, which are assembled in accordance with jiggling method number 3 modified, is suitable for model construction.

B. Aluminum welding as a method of joining model components is not feasible because of the amount of time required to become proficient in welding, and because of the uncontrollable warping and distortion attendant with it.

C. Furnace brazing aluminum, using eutecrod as the filler material, is not possible.

D. With further work and development, a method of silver soldering steel to fabricate models suitable for high stresses could be evolved.



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