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BURBANK, CALIFORNIA

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FINAL REPORT

VOLUME NO. I *

FORMING MACHINED INTEGRALLY STIFFENED WING SKIN PANELS

SUBMITTED UNDER

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ABSTRACT

The following report describes an investigation conducted by Lockheed Aircraft Corporation for the purpose of developing production techniques for forming the contours of machined Integrally Stiffened Wing Skin Panels. It was found that Upper and Lower Integrally Stiffened Panels could be formed to precision contours by means of stretch forming. Leading Edge Integrally Stiffened Panels were contoured by combination stretch and compression forming. The success of both methods was dependent upon the development of specialized tooling and techniques.

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FOREWORD

The structural requirements of modern aircraft have for some time pointed to the need for a fundamental change in the conventional theory of sheet metal wing design. We have witnessed tremendous increases in dynamic loading of wings while at the same time the dictates of aerodynamics have forced reductions in wing thickness. The result of progress, in this case, has been to greatly increase the complexity, cost and weight of the sheet metal parts and supporting structure.

In view of the requirements of modern aircraft, this trend, then, appears to be operating in reverse; whereby, as the need for space and load carrying capacity increases, the possibilities of obtaining it diminish. Furthermore, from a practical viewpoint, it has been found difficult to achieve the required aerodynamic smoothness in the process of assembling the typical high-performance sheet metal wing. Lockheed recognized this problem and has been engaged in certain development work for some time. This work has culminated in the development of a wing structure incorporating "Integrally Stiffened Wing Skin Panels". (Figure 1)

The new panel consists of one piece only, with the ribs, stiffeners, reinforcements, etc., machined, forged or extruded integrally with the skin. By way of contrast, the comparable sheet metal panel is comprised of a myriad of stringers, clips and doublers riveted to a sheet metal skin.

The merits of integrally stiffened skins, or wing panels, have been established to the extent that consideration is being given to their use in current and future fighter and bomber designs. However, since it was doubtful whether recognized fabrication techniques would be adequate when it came to shaping the integrally stiffened panels to the contours of wing surfaces, the research program described in this report was proposed to determine suitable methods of forming this new structural member.

The material reported herein pertains to the research carried out as of December 30, 1949. Volume II, to be submitted June 30, 1950, will contain the results of further investigations on the same subject as well as final conclusions covering the whole program.

INTEGRALLY STIFFENED
LEADING EDGE AND
UPPER SURFACE WING
PANELS K-8382-P

FIG. 1

FINAL REPORT

VOLUME NO. I OF II

CONTRACT #33(038)-1178

RESEARCH PROGRAM

ON

FORMING MACHINED INTEGRALLY STIFFENED WING SKIN PANELS

1.0 OBJECT

1.1 To develop tooling and production methods for forming the contours of Machined Integrally Stiffened Wing Skin Panels applicable to the F-90 fighter.

TYPES

a. Wing Leading Edge Panels

b. Wing Upper Surface Panels

MATERIALS

a. 75S-T6

1.2 To evaluate the following forming techniques:

a. Stretch Forming

b. Compression Forming

c. Rubber Forming

d. Die Forming

e. Roll Forming

f. Bumping

2.0 SUMMARY OF RESULTS

2.1 UPPER WING SURFACE INTEGRALLY STIFFENED PANELS

2.11 STRETCHING: Full size upper surface integrally stiffened panels were successfully stretch formed in S-W temper in a 1500-ton Clearing double action press. (Figure 1) The panels produced conformed to contour and surface smoothness requirements. The unique processes and tooling developed for this purpose can be produced for a cost equivalent to conventional stretch form tooling of similar size. With the techniques at the present stage of development, the production rate through the forming operation is estimated to be approximately 5 per hour per press. Development of auxiliary tooling and improved technique will result in an output approaching 15 per hour per press.

2.12 RUBBER FORMING: (a) Preliminary tests, wherein integrally stiffened specimens in S-W temper were bent to the contoured surface of a female die by means of a rubber platen press, gave negative results. It was found that the springback was variable, depending on the various longitudinal cross-section configurations, and could not be compensated for by means of any known die making technique. (b) However, when the part ends were restrained from moving inward, as in the case of pure stretching (2.11), some elongation of the specimen was achieved which resulted in more accurately contoured specimens. However, the rubber pressures involved would require a press of 8,000 to 10,000 tons capacity to produce elonga-

2.12 RUBBER FORMING (Cont'd.)

tions necessary to set part contour. For this reason, rubber-"stretch" forming cannot be considered feasible at this time for these panels.

2.13 DIE FORMING: As in rolling and rubber forming, die forming is essentially a bending process. Therefore, the variables in section modulus which require variable compensation for springback affect die forming in like degree. Preliminary tests demonstrated that mating dies could not be adjusted to compensate for variable springback by any known technique. Further, were it possible to produce dies so adjusted in curvature, the variations parallel to the element lines of the curve would result in discontinuities or steps, an impossible situation. The die forming process, then, cannot be considered as a feasible method for producing the integrally stiffened panels of this study.

2.14 ROLL FORMING: Preliminary tests, wherein integrally stiffened specimens were rolled in S-O and S-W tempers on several types of three-roll machines, gave negative results. As in rubber forming, or for that matter any bending operation, the varying section modulus of the parts under consideration resulted in variations in the final contour of the rolled specimen. Sharp breaks in contour occurred at stiffener ends and other discontinuities in the stiffener pattern. There is no rolling equipment in existence which will automatically and continuously compensate in roll setting for variables in the

2.14 ROLL FORMING (Cont'd.)

part, and further, which will compensate in different amounts along the bend line. Thus, rolling as a process for forming integrally stiffened skins is not considered to be feasible for the panels in question.

2.15 BUMPING: Bumping has been employed as a laboratory process to produce random specimens of integrally stiffened skins. However, in view of the excessive time and effort required to produce a single specimen and the mediocre results achieved, the process cannot remotely be considered a production method.

2.2 LEADING EDGE INTEGRALLY STIFFENED PANELS

2.21 STRETCH FORMING: (a) Single operation stretching of a full size leading edge skin to final contour was not attempted due to early difficulties in development of tooling. However, in view of the results achieved on upper panels (2.11), coupled with later developments in means for clamping the part ends, it is felt that the process could now be developed to give good results.

(b) Stretching was employed as a first operation in the combination method reported in 2.22 (b). Full size leading edge skins were successfully stretched to an open contour wherein the full length of the upper and lower surfaces were brought to correct contour and a small segment (6 inches) at the entering edge was left flat. (Figure 37) Methods and tooling

2.21 STRETCH FORMING (Cont'd.)

employed and production characteristics in this case are virtually identical to those reported in upper panel stretching (2.11).

2.22 COMPRESSION FORMING: (a) Full size leading edge panels were compression formed to excellent contours in the 1500-ton Clearing press, but this method was not able to remove all buckling resulting from heat treatment prior to forming. Consequently, the resultant panels were not satisfactory from a smoothness standpoint. It is felt that the process would operate adequately on leading edge panels comprised of plate or the non-heat-treatable alloys. It is further believed that considerable improvement could be achieved by additional development of the tooling employed.

(b) Full size leading edge panels were successfully formed by a combination method wherein the part was (1) initially stretched to impart correct contour to the upper and lower surfaces (2.21 (b)) and then (2), compression formed to produce and blend the contour around the entering edge. (Fig. 61) Stretching, in this case, performs the function of removing heat treat distortion and, by means of an intermediate milling operation, makes feasible the production of heavy gage leading edge panels with a thin or reduced section at the entering edge. The panels produced by this method showed excellent contour, but surface smoothness did not meet the anticipated standard. The trouble in this case was traced to imperfections in

2.22 COMPRESSION FORMING (Cont'd.)

the first operation stretch tooling which have been eliminated in further developments. There is no reason to doubt leading edge panels can be formed by this combination method with smoothness characteristics at least as good as those of the upper surface panels.

2.23 RUBBER FORMING: Negative results were achieved in tests on rubber forming upper surface panels. In view of the greater difficulties involved in forming leading edge panels, it was considered unnecessary, therefore, to continue rubber forming tests.

2.24 DIE FORMING: (a) Negative results were achieved in test on die forming upper surface panels. In view of the greater difficulties involved in forming leading edge panels, it was considered unnecessary, therefore, to continue die forming tests.

(b) Early experiments on die forming the entering edge of leading edge panels, which were pre-formed as in 2.21 (b), showed poor results. Therefore, no attempt was made to produce full size panels by this method. However, recent developments show that it may be entirely possible to produce acceptable leading edge panels by such means.

2.25 ROLL FORMING: Negative results were achieved in tests on roll forming upper surface panels. In view of the greater difficulties involved in forming leading edge panels, it was considered unnecessary, therefore, to continue roll forming tests.

2.2 LEADING EDGE INTEGRALLY STIFFENED PANELS (Cont'd.)

2.26 BUMPING: Negative results were achieved in tests on bumping upper surface panels. In view of the greater difficulties involved in forming leading edge panels, it was considered unnecessary, therefore, to continue bumping tests.

8.0 APPENDIX

Before work on this project could start it was necessary to determine (a) the method of producing the unformed integrally stiffened panels, and (b) the design limitations of the various elements such as stiffener and web tapers, thicknesses, reinforced areas and cutouts.

The following sections contain a description of methods employed and studies undertaken in the solution of the above problems. In addition, this appendix contains a detailed, illustrated discussion of the testing procedures employed in the investigation of each forming method, as well as drawings of the full size panels and the dies used in forming them.

The tests reported are those which were pertinent to the objects of this program. Numerous auxiliary tests were made, however, for the purpose of establishing design and construction data for tooling and equipment. Those tests are not included herein.

3.0 APPENDIX (Cont'd.)

3.1 PRODUCTION OF FLAT INTEGRALLY STIFFENED PANELS

At the outset, it was evident that the art of forging, extruding or rolling integrally stiffened panel materials was not sufficiently advanced to be of any help to the program. Accordingly, it was determined that the test panels would have to be machined from plate materials. This at once imposed a problem in that the largest milling equipment at Lockheed was far from adequate considering the overall dimensions of the panels in question.

To activate the program, Lockheed commissioned The Cincinnati Milling Machine Company to build a large horizontal milling machine capable of handling plate materials 72 inches by 168 inches. The machine was provided with hydraulic duplicating means of the type employed in the well known Cincinnati Hydrotel. In addition, feeds and speeds were provided in conformance with the best practice for milling aluminum alloys. The above described equipment was delivered and installed in June, 1949 and was used to machine many of the test specimens and all of the full size panels. (Figures 2 and 3)

The fact that the question of milling equipment had been disposed of, however, did not completely eliminate the machining problem. From experiments conducted by Lockheed, dating back to 1946, it was learned that distortion attendant to the machining of large heat treated aluminum plates was severe. So severe, in fact, as to make it virtually impossible to achieve the necessary part tolerances by ordinary machining methods.

3.1 PRODUCTION OF FLAT INTEGRALLY STIFFENED PANELS (Cont'd.)

However, in view of the restrictive forming limits of 75S alloy in the heat treated (T6) temper, it was decided that all forming operations would be conducted in the freshly quenched "W" condition. This necessitated purchase of plate stock in the annealed or "O" temper. Consequently, machining of all specimens as well as the full size parts was handled in this latter condition. This resolved, to a great extent, the problem of distortion during machining.

3.2 STIFFENER AND WEB DESIGN TESTS

Early integrally stiffened panel designs consisted for the most part of a series of uniformly spaced stiffeners integral with a skin or web of nominal thickness. The stiffeners terminated abruptly at thickened attaching edges and at thickened central areas intended for tank and inspection openings. (Fig. 4) It was quite obvious that, regardless of the forming method employed, this arrangement of elements would impose difficulties due to the abrupt change in section modulus. Further, the non-uniform cross-sectional areas in planes normal to the stiffeners precluded use of methods where considerable permanent elongation was introduced, as in stretching, since failure would probably occur in the weaker areas.

Therefore, prior to the start of the production forming tests, a series of studies were made to determine whether the design of the various elements of the panel could be altered to improve the forming characteristics and at the same time satisfy the requirements of

3.2 STIFFENER AND WEB DESIGN TESTS (Cont'd.)

stress and weight.

A number of specimens were made comprised of only two stiffeners, in which the cross section was typical of the panel in question, but embodying variations in thickness and the taper of stiffener and web (skin). These specimens were made to determine:

(a) Uniformity of elongation,

(b) Amount of distortion in regions of varying sectional shape, and

(c) Fracture characteristics.

As a result of these tests, it was found that:

(a) Tapers of the stiffeners and web (skin) must be adjusted to maintain nearly constant cross-sectional areas.

(b) Thick, non-stiffened areas, such as attaching edges and reinforcements for openings must be of a cross-sectional area approximately equivalent to the average through the stiffened portion of the panel.

(c) Taper ratio of stiffeners (length to height) should be approximately 5:1, or greater.

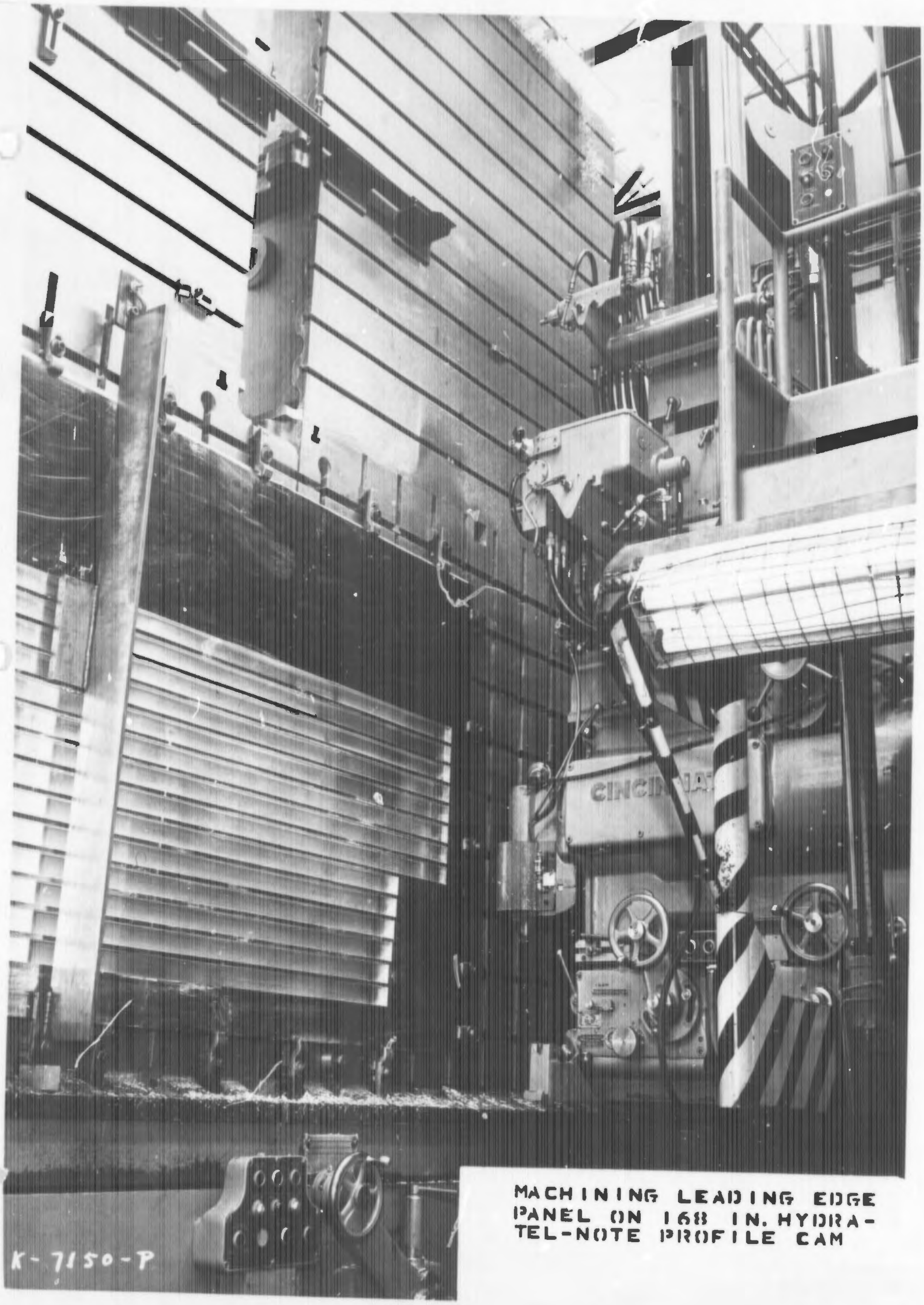
(d) Taper ratio of web should be approximately 20:1, or greater. (Figures 5 and 6)

Specimens embodying the design elements listed above were stretched as much as 6%, or far beyond actual forming requirements, with no sign of failure. Distortion did occur in the areas where stiffener and web tapered, but in moderate amount. Considering the fact that the sec-

3.2 STIFFENER AND WEB DESIGN TESTS (Cont'd.)

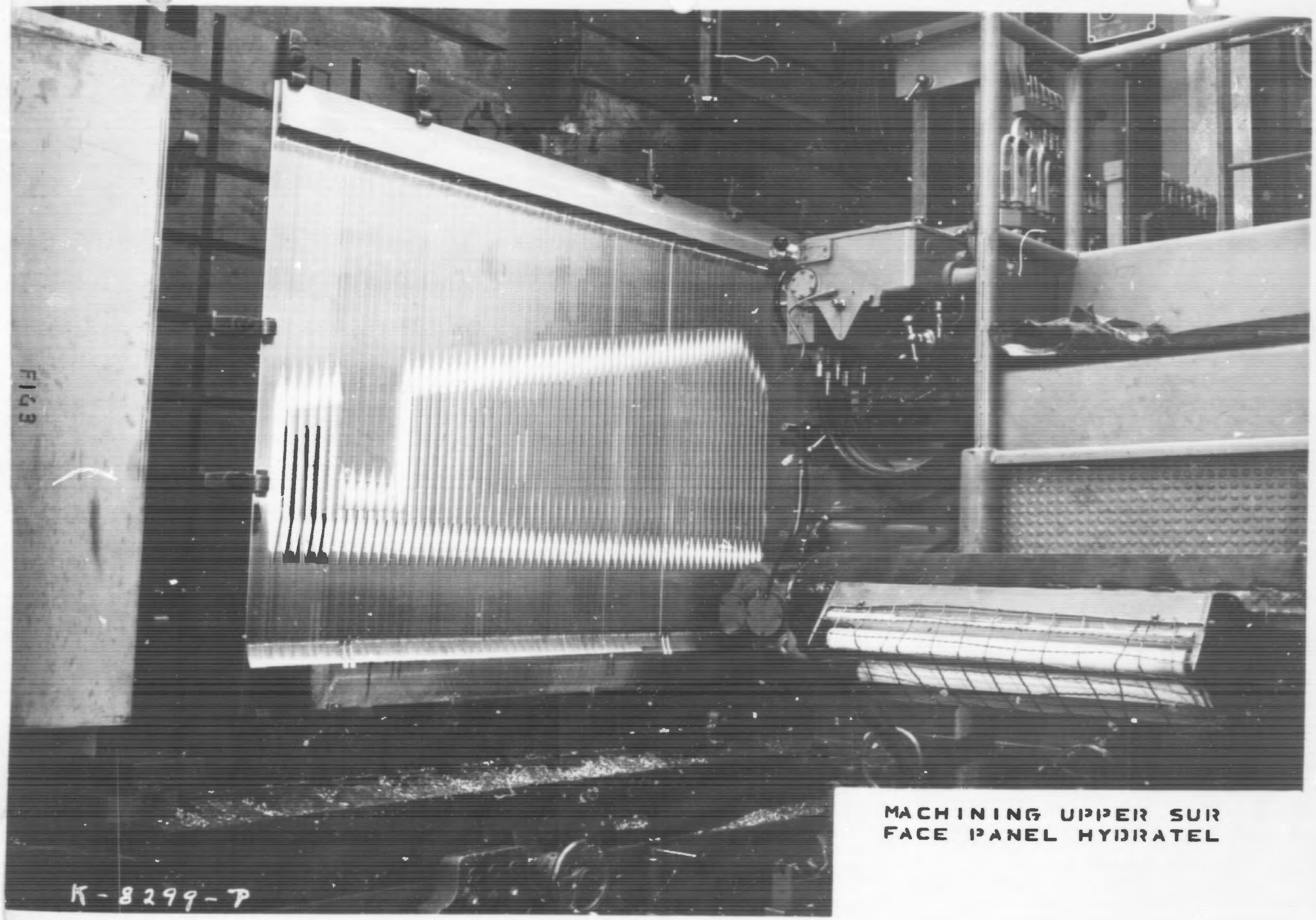
tion centroid varies in relation to the centerline of stretching force in this area, it is obviously impossible to entirely eliminate this effect by means of changes to the element design. However, it was felt that the slight tendency to waviness occurring at the ends of the stiffeners could be adequately reduced or eliminated by provisions in the tooling which would ultimately be developed to form the integrally stiffened panels.

As a result of the above design study, two drawings were produced incorporating the recommended changes. These were: (1) P.D.115 - Panel Assembly, Integrally Stiffened, Upper, and (2) P.D.9?3-23 - Panel Assembly, Integrally Stiffened, Leading Edge Inboard. All further work throughout the program employed these designs both in the reduced area specimens and the full size panels. (Figures 86 and 87)

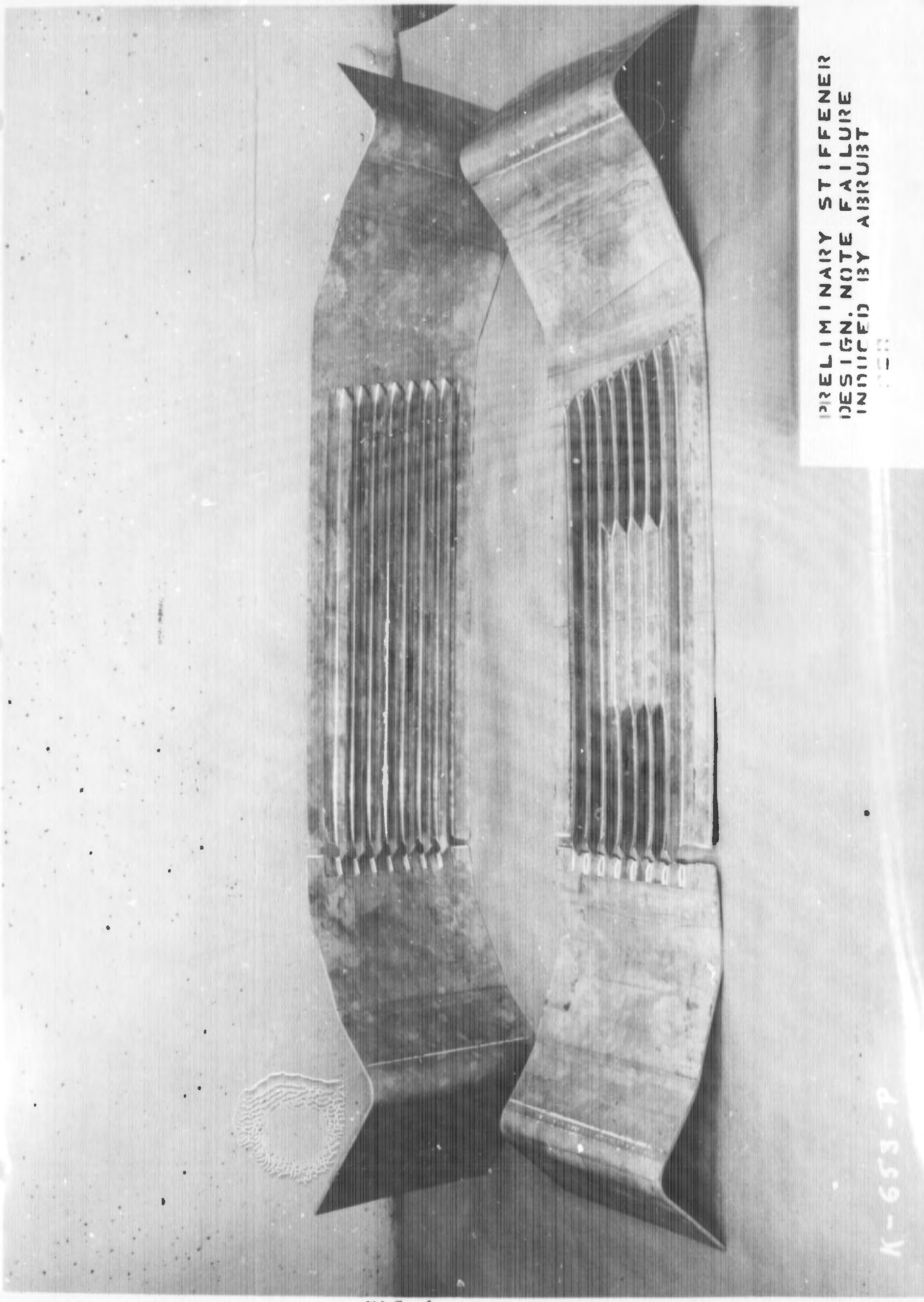


MACHINING LEADING EDGE PANEL ON 168 IN. HYDRA-TEL-NOTE PROFILE CAM

FIG 2



MACHINING UPPER SUR
FACE PANEL HYDRATEL



PRELIMINARY STIFFENER DESIGN, NOTE FAILURE INDUCED BY ABRUPT

FIG 4


STRETCHED SPECIMEN IN-
CORPORATING IMPROVED
STIFFENER-BOTTOM-
K-1209-P

FIG 5

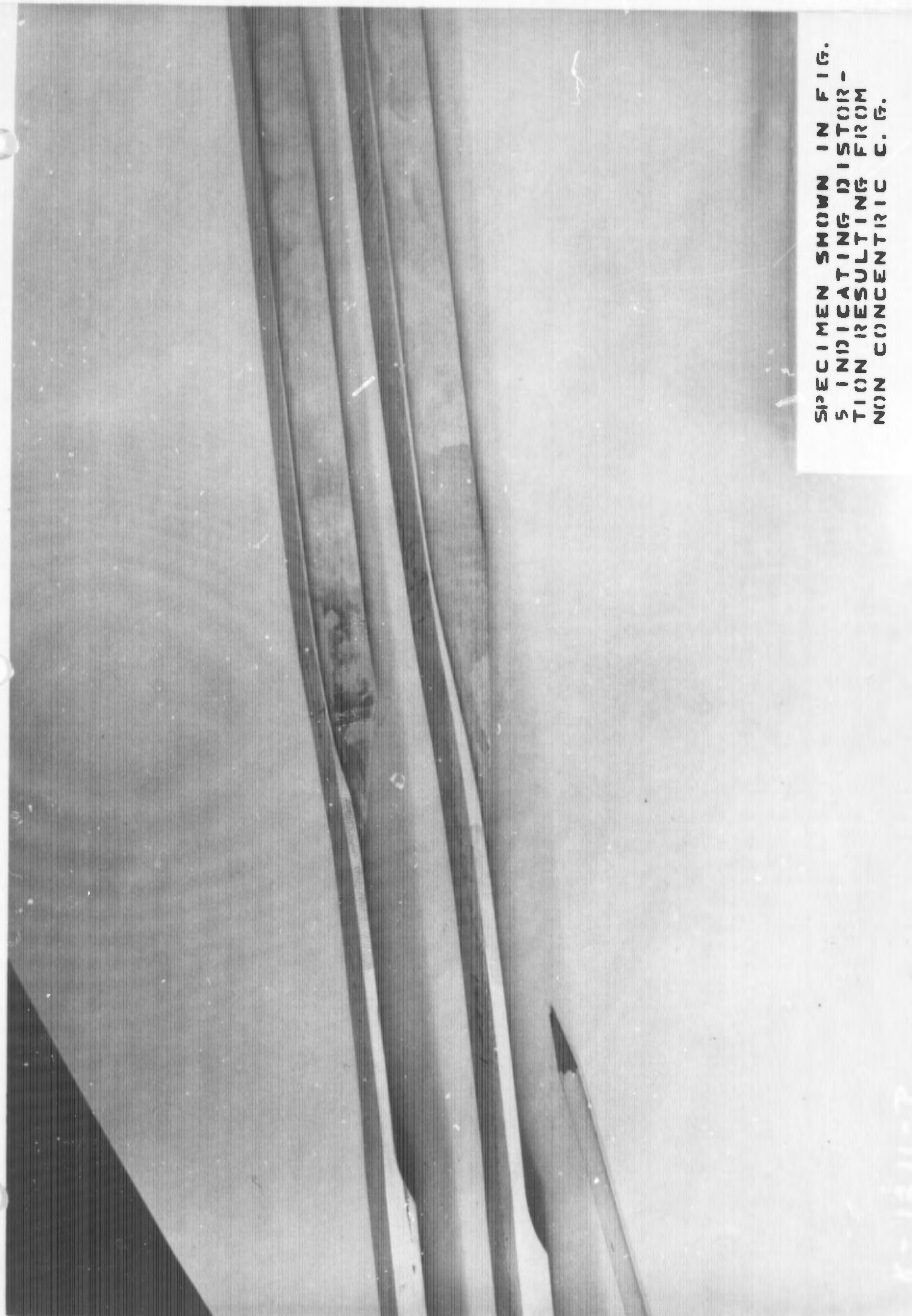

SPECIMEN SHOWN IN FIG.
5 INDICATING DISTOR-
TION RESULTING FROM
NON CONCENTRIC C. G.

FIG.6

3.0 APPENDIX (Cont'd.)

3.3 TEST PROCEDURE

3.31 STRETCH FORMING

EQUIPMENT

The cross-sectional area of P. D. 115, Upper Surface Integrally Stiffened Panel, is approximately 26 sq. in. in a spanwise direction. In 75S-W material at 50,000 lbs. per sq. in. ultimate tensile strength, therefore, a force of approximately 650 tons would be required to stretch this part to failure. The 1500-ton Clearing double action press, located in the Lockheed fabrication shop, was the only equipment available of adequate bed size which would at the same time generate forces of this magnitude. This press, then, was selected as the instrument upon which all stretch forming tests and production of full size panels by stretching would be accomplished. (Figure 7)

It should be noted, however, that when a part is stretched by means of forcing a moving die into a part locked in stationary grips, the total force required is double the calculated yield force. In this case, then, the Clearing press would be required to exert up to 1300 tons force on the main ram, or almost the full rated capacity of the press.

The cross-sectional area of P. D. 903-23, Leading Edge Integrally Stiffened Panel, is approximately 14 sq. in. in a spanwise direction. As in the case of the upper surface panel, the only

3.31 STRETCH FORMING - Equipment (Cont'd.)

equipment available at Lockheed of adequate power and bed size to handle this part was the 1500-ton double action Clearing press. For pre-bending operations of the entering edge a large 20-ton Ceco stamp was used in lieu of a power brake, mainly because this machine afforded greater accessibility and freedom from obstructions.

TESTS: UPPER SURFACE PANELS

A number of specimens were prepared which duplicated the cross-sectional characteristics of P. D. 115. These specimens were approximately 12-inches wide and represented a section parallel with the stiffeners and through the central portion of the full size panel. Machining of the specimens was terminated at a point eight inches beyond the part trim line, leaving a thick pad across the width of the specimen approximately four inches wide and equal in thickness to the stiffener height. (Fig. 8)

TEST NO. 1

A male stretch die to inside part contour was assembled using a laminated construction of masonite. In the process of laminating, slots for the stiffeners and depressions for variations in web thickness were provided by variations in the individual laminate sections. This die was mounted on the main ram of the Clearing press. Several standard specimens were selected and the thick pads at either end milled down to correct edge thickness. The specimen was heat

3.31 STRETCH FORMING - Test No. 1 (Cont'd.)

treated to S-W temper, placed in the press and clamped at both ends in standard Lockheed "V" type friction gripper rails. The die was brought into contact with the part and advanced until the specimen stretched to the required elongation.

At elongations of 2% to 4%, the specimen showed severe malformation. Each stiffener produced a wave on the opposite surface of the panel throughout its full length. At the terminal point of the stiffeners, eccentric loading of these members due to displacement of the section c. g. resulted in a pronounced hump extending from stiffener to stiffener across the direction of stretch. (Figure 9 depicts this condition, however, specimen shown was of early design, employing short taper at stiffener ends.)

It was concluded from this test that:

(a) The force couple induced by eccentric loading at the stiffener terminations which caused the panel to pull away from the die would have to be offset by means of improved tooling.

It was also found that:

(a) Friction clamping means did not have the necessary capacity for this application, were unreliable and had a tendency to slip and to induce fracture.

3.31 STRETCH FORMING - Test No. 1 (Cont'd.)

(b) Production of stretch dies to inside contour and configurations of integrally stiffened panels was impractical. The tooling techniques involved in producing an accurately contoured surface in which is impressed a pattern of stiffeners and varying web thicknesses are beyond the average aircraft foundry and die shop.

TEST NO. 2

In line with the findings of Test #1, it was concluded that if the part were stretched between mating dies the force couple could be resisted and the part held in the line of the stretching force. It was reasoned that if the part was not allowed to deviate from the true contour line during elongation, then it could be set to that contour and would not spring away upon release of the restraining forces.

Accordingly, a cast Kirksite male stretch die was cast and ground to exact part contour. This tool did not incorporate slots to accommodate stiffeners or other configurations of the specimen. To this was ground and blued a Kirksite female die. Special gripper jaws or rails were designed which employed a 1-inch square C.R.S. key as the sole means of restraining part movement. The standard specimens were prepared by milling a 1-inch key slot along the length of the

3.31 STRETCH FORMING - Test No. 2 (Cont'd.)

thick pads at the part ends. One of the specimens was used as the mould into which was poured a 1½" thick layer of a phenolic casting plastic. (Resolin, Inc., L. A.) The necessary clearances for part elongation were provided by affixing sheet wax of predetermined thickness to the areas affected. Upon curing, the plastic plate was removed from the part, ground to uniform thickness, and the ends trimmed and radiused. This block was used as a filler making it unnecessary to provide slots in the face of the die. (Figures 10 and 10a)

The male die or punch was mounted on the main ram of the Clearing press and the female was set on the pins of the 200-ton hydro-pneumatic cushion. With the rails in place, the specimen in fresh S-W temper was placed over the keys and clamped at 30 tons per foot of rail clamp by means of flat pads operated from the blank holder ram. Then the filler blocks were placed over the stiffened area of the specimen. The upper die was caused to exert enough force on the part to bend it, as well as the filler block, to contour only. At this point the air cushion was raised, resulting in the specimen being clamped firmly between the two dies. Pressure exerted was approximately 20 tons per square foot of surface area. Both dies were then lowered until the desired elongation had been reached (2½%). (Figures 11, 12, 13 and 14)

3.31 STRETCH FORMING - Test No. 2 (Cont'd.)

The specimens resulting from this forming operation proved to be acceptable in every respect, both in regard to contour and surface smoothness. A summary of the dimensional check follows:

Springback from lofted contour - .017" in the center of 28" span.

Joggle at stiffener ends due to eccentric loading - .008"

Corrugation height at stiffener ending - .006" max., .004" min.

Corrugation length at stiffener ending - 3/4"

General corrugation over-all surfaces - .002"

Transverse bow - .002" in 11"

Elongation in center - 3%

Elongation at ends - 3%

Elongation beyond die (free stretch)- 3½%

Necking in center (transversely)- 1%

Heat treatment warpage - Entirely eliminated.

It should be noted that the above distortions compare favorably with F-80 contour requirements. Springback of .017", for instance, was obtained on dies that had not been developed for this factor. The corrugation and joggle effects of .004" to .008" resulted from the necessary clearances at the stiffener ends of the plastic filler block.

3.31 STRETCH FORMING - Test No. 2 (Cont'd.)

It should also be noted that elongation was virtually the same throughout the part which is unusual performance when compared to typical stretching operations. This was achieved despite the clamping action of the bottoming pad and serves to prove that a light clamping pressure will eliminate distortions without hindering the stretching action. (Figure 15)

From this test was concluded that:

(a) It is entirely feasible to accurately stretch-form integrally stiffened panels in the "W" temper provided that adequate tooling is employed.

(b) That the novel tooling developments of plastic filler blocks, mating stretch dies and keyed clamping rails showed sufficient merit to warrant further development.

TEST NO. 3

A final test was conducted to determine the performance of the tools developed for Test No. 2 when stretch forming variations of the standard specimens. For this test the specimens, though of the same over-all dimension, varied in thickness and stiffener configuration. One specimen was machined with a step in web thickness at the half breadth, one side being .050" thick, and the other .180". The other specimen was machined with a discontinuity in a

3.31 STRETCH FORMING - Test No. 3 (Cont'd.)

portion of the stiffeners representing a thickened non-stiffened area as for an inspection hole.

From this test it was concluded that:

(a) The small scale stretch form tooling developed and employed in these tests would adequately form sections containing all the variables of the full size integrally stiffened upper surface panel, P. D. 115.

(b) Evidence of the efficiency of this tooling development was sufficient to warrant the construction of a full size stretch form die set and clamp rails.

TEST NO. 4

Test series Nos. 1, 2 and 3 having been completed with satisfactory results, plans were made to form full size integrally stiffened upper panels. This involved machining three blanks, 60 in. x 105 in., from 1½ inch thick 75S-0 plate. Machining was performed on the 168-inch Hydrotel. Manual control of the machine was reduced to a minimum by the employment of adjustable tracer cams controlling both stiffener and web profiles. (See Upper Part of Fig. 2)

While work on the parts was proceeding, construction on a mating stretch die set, 60 in. x 105 in., was started.

3.31 STRETCH FORMING - Test No. 4 (Cont'd.)

It immediately became apparent that the large size of the dies would impose difficult problems in the die shops. Aside from problems of casting, handling and machining, the most serious involved the method to be employed in grinding and bluing the dies to a true mating fit and correct contour.

The solution to this latter difficulty lay in the development of a means of casting a plastic working face onto a rough contoured Kirksite base. The principle feature of the plastic material employed (Rezolin) is great dimensional stability through the curing cycle. As a result, it was found practical to cast this material in a 3-inch layer between the rough face of the Kirksite base casting and an accurately contoured plaster splash. Bonding of the plastic layer to the Kirksite was accomplished by means of roughening the surface of the Kirksite base. The resulting composite die had a smooth, accurately contoured face of low frictional characteristics which required no grinding or bluing in. (Figures 16 through 20)

Construction of the mating element of the die set was accomplished in the same fashion with the exception that the operation of casting the plastic working face was simplified. In this case, the completed die element described above was employed in the place of a plaster splash. The resulting die set checked for fit to approximately .010"

3.31 STRETCH FORMING - Test No. 4 (Cont'd.)

or less.

Key type clamp rails 9-feet long and plastic filler blocks were also constructed following the practice used successfully in specimen Test #2.

Actual operation of stretching the full size integrally stiffened upper panels followed the same pattern employed in specimen Tests # 2 and # 3. The panels were prepared by milling 1-inch key slots in the thick pads outside of the trim lines. (Figure 21) The panels were then heat treated and "dunk" quenched in accordance with AN specifications for 75S materials. Considerable distortion resulted from the quench operation, but not sufficient to prevent the part from entering the dies. (Figure 22) Some hand straightening of tilted stiffeners was required and several large buckles were flattened by auxiliary means. Total straightening time amounted to about fifteen minutes.

The straightened parts in the "fresh" S-W condition (two hours out of quench) were then stretched on the above described die set in the 1500-ton Clearing press. Pressures employed were 1490 tons on main ram, 200 tons on cushion, and 500 tons on the blank holder ram. A uniform elongation of 3½% was achieved. (Figures 23 through 26)

The resulting formed panels (Fig. 1) had approximately the

3.31 STRETCH FORMING - Test No. 4 Cont'd.

dimensional characteristics of the smaller specimens previously tested. Contours and surface smoothness were within engineering tolerance for the wing area involved and, in general, were far superior to conventional assembled type sheet metal panels. However, several small areas of these panels are slightly corrugated on the outer surface. These small deviations from an otherwise perfectly smooth and fair surface are the result of slight imperfections in the filler blocks. Methods to improve the block construction technique have since been developed and in this light the imperfections in the sample panels are not considered to be important.

TESTS: LEADING EDGE PANELS

Consideration was given, during the early phases of the program, to the development of a technique for stretch forming leading edge panels to final contour in one operation. The development of clamping means, however, posed difficulties which were not immediately solved. In addition, manufacture of a stretch punch appeared to be impracticable, and the maximum opening of the 1500-ton Clearing was insufficient to accommodate the necessary die set and still allow sufficient stroke to permit loading of the parts. In view of the promising results being obtained in Compression Forming leading edge specimens (3.32), it was decided to defer experiments on the single operation stretching technique.

As the program advanced, however, it became evident the warpage resulting from heat treatment seriously reduced the effectiveness of the compression forming technique. (Fig.27) In addition, it was indicated that from a weight standpoint it would be desirable to produce leading edge panels with a relatively thin web or skin section at the entering edge. It was obvious that reducing the web cross-sectional area prior to forming would result in all yield occurring in the weakened area while it was equally impractical, because of limited access, to reduce this section after the panel had been formed to final contour.

For these reasons, it appeared best to attempt forming the leading edge in two stages, employing stretching as the first, and compression forming as the second. This was accomplished by stretching the leading edge to an open contour wherein the full length of the upper and lower surfaces were brought to contour and a small segment (six inches) at the entering edge was left flat. Subsequently, the entire panel was brought to correct contour by compression forming in a second operation as described in 3.32.

3.31 STRETCH FORMING - Tests: Leading Edge Panels (Cont'd.)

This two-stage forming technique effectively eliminated heat treatment distortion prior to compression forming, or the second stage, and at the same time, made it possible to produce a thin web at the entering edge if desirable. This latter operation is accomplished by milling the web to the required reduced thickness between the first and second forming operations, at which stage the contour is sufficiently open to permit access. It should be noted that in such panels forming in the second operation will be accomplished in the reduced section only. However, the contour produced in this area will blend with that of the upper and lower surfaces produced in the stretching or first operation.

The testing procedure followed the pattern described above under "Upper Surface Panels". The data accumulated in the development of stretch forming dies for the upper surface panels made it possible to predict the results which could be obtained in stretching the leading edge panels. Accordingly, only sufficient test specimens were prepared to provide data pertinent to the slight variations in stiffener pattern as compared to those of the upper surface panels. These specimens were approximately the same over-all dimensions and embodied the same thick, keyed gripping pads as those used in upper panel tests.

3.31 STRETCH FORMING - Tests: Leading Edge Panels (Cont'd.)

TEST NO. 5

Mating Kirksite stretch dies were prepared, following the same principles as the test die used in Test #2, Upper Surface specimens. The keyed gripper rails used in Test #2 were employed. However, in place of the cast plastic filler blocks previously employed, an attempt was made to incorporated the stiffener pattern into the male die face. This was accomplished by the following means.

A plaster replica of the stiffener and web pattern was built up on the face of the female die. The male die was positioned 2 inches from the face of the female die and the opening around the edges dammed with plywood and plaster. Into the space thus created was poured liquid casting plastic of the same type used in casting the filler blocks. Bonding of the plastic to the face of the male die was accomplished by roughening the metal plus drilling and counterboring several 2-inch holes.

The male die was mounted on the main ram of the 1500-ton press and the female die set on the pins of the hydro-pneumatic cushion. The specimen, in fresh S-W temper, was placed between the dies, engaging the keys in the gripper rails with the clamp pads closed at 30 tons per foot of rail. When the die was advanced into the part it was found

3.31 STRETCH FORMING - Test No. 8 (Cont'd.)

that heat treatment warpage made it difficult to guide the stiffeners into the accommodating slots in the die. This fact raised speculation as to the difficulties which might be encountered in the case of the full size leading edge parts which were five feet wide.

Stretching was accomplished in exactly the same manner as Test No. 2 until an elongation of 2½% had been achieved. The specimens resulting from this test proved to be acceptable in every respect, both in contour and surface smoothness. A check of these factors gave approximately the same readings as in the case of upper surface specimens in Test No. 2. (Figures 28, 28a, 29 and 29a.)

From this test, it was concluded that:

(a) The small scale stretch form tooling developed and employed in these tests would adequately form sections containing the stiffener and web pattern of leading edge integrally stiffened panel, P. D. 903-23.

(b) Evidence of the efficiency of this tooling development was sufficient to warrant the construction of a full size stretch form die set and clamp rails for first operation forming of leading edge panels.

3.31 STRETCH FORMING - Tests (Cont'd.)

TEST NO. 6

Satisfactory results having been obtained from specimen tests, plans were made to form full size leading edge panels through the first forming stage as described above. Three blanks 58 inches x 106 inches were machined from 1½" 75S-O plate on the 168-inch Hydrotel. (Figure 30) Adjustable tracer cams were employed to automatically profile the stiffener and web pattern.

Construction was started on the stretch die set which, except for contour, employed the same design as used in Test #4, full size Upper Surface panels. Attempts at casting the stiffener pattern into the plastic male die face were abandoned and plastic filler blocks of the same type used in forming upper surface panels were specified. (Fig. 31) However, due to the limited flexibility of the plastic material, the back surface of these blocks were scored at 2-inch intervals with saw cuts 1-inch deep, or 60% of the block thickness. This measure was required because of the more severe contours of the upper and lower surfaces of the leading edge panels. Key-type clamp rails of greater height were also constructed.

The machined panels were prepared by milling 1-inch key slots in the thick pads outside of the trim lines. Heat treatment to AN specifications followed. Since the stif-

3.31 STRETCH FORMING - Test No. 6 (Cont'd.)

feners on these panels were somewhat heavier in section than those on the upper surface panels, it was deemed advisable to quench the parts in a jig, designed to prevent excessive twisting of the stiffeners. The jig consisted simply of an 8-inch channel notched to accommodate the stiffeners at the mid-point of their length. However, upon quenching, the distorting forces were so great that the stiffeners were forced against the jig hard enough to severely mark the part at the contact points. (Figure 32)

Since all full size leading edge panels were quenched in these jigs, no information is available as to the probable distortion of the panels had such jigs not been used. However, it would be well to point out that quench jigs were not employed in heat treating the upper surface panels. Such distortion as did occur did not hinder entrance of the stiffeners into the filler block slots and disappeared entirely in stretching.

The panels, while still in the fresh S-W condition (two hours out of quench) were stretched 2½%. Pressures required were 900 tons on main ram, 200 tons on cushion, and 500 tons on blank holder ram. (Figs. 33 through 37) The resulting formed panels exhibited excellent conformance to contour, but considerable corrugation effects on the outside surface. (Fig. 1) An examination of the dies and filler blocks disclosed that considerable deviation

3.31 STRETCH FORMING - Test No. 6 (Cont'd.)

from contour existed in the female stretch die. In some areas the gap between male and female dies amounted to as much as 3/16" where the maximum mismatch specified was .015". Thus, the action of the female die, in resisting the force couples induced by non-uniform stress loading, was negligible over large areas of the panel.

It was felt that this surface roughness was due to a tooling discrepancy and could be avoided in the future. Evidence that this assumption is correct is seen in the satisfactory surface smoothness of the formed upper surface panels.

(See 3.32 "Stretch-Compression Forming of Leading Edge Panels" for description of compression forming operations to complete forming of leading edge panels stretched as above.)

VIEW OF 1500 TON CLEARING PRESS

FIG.7

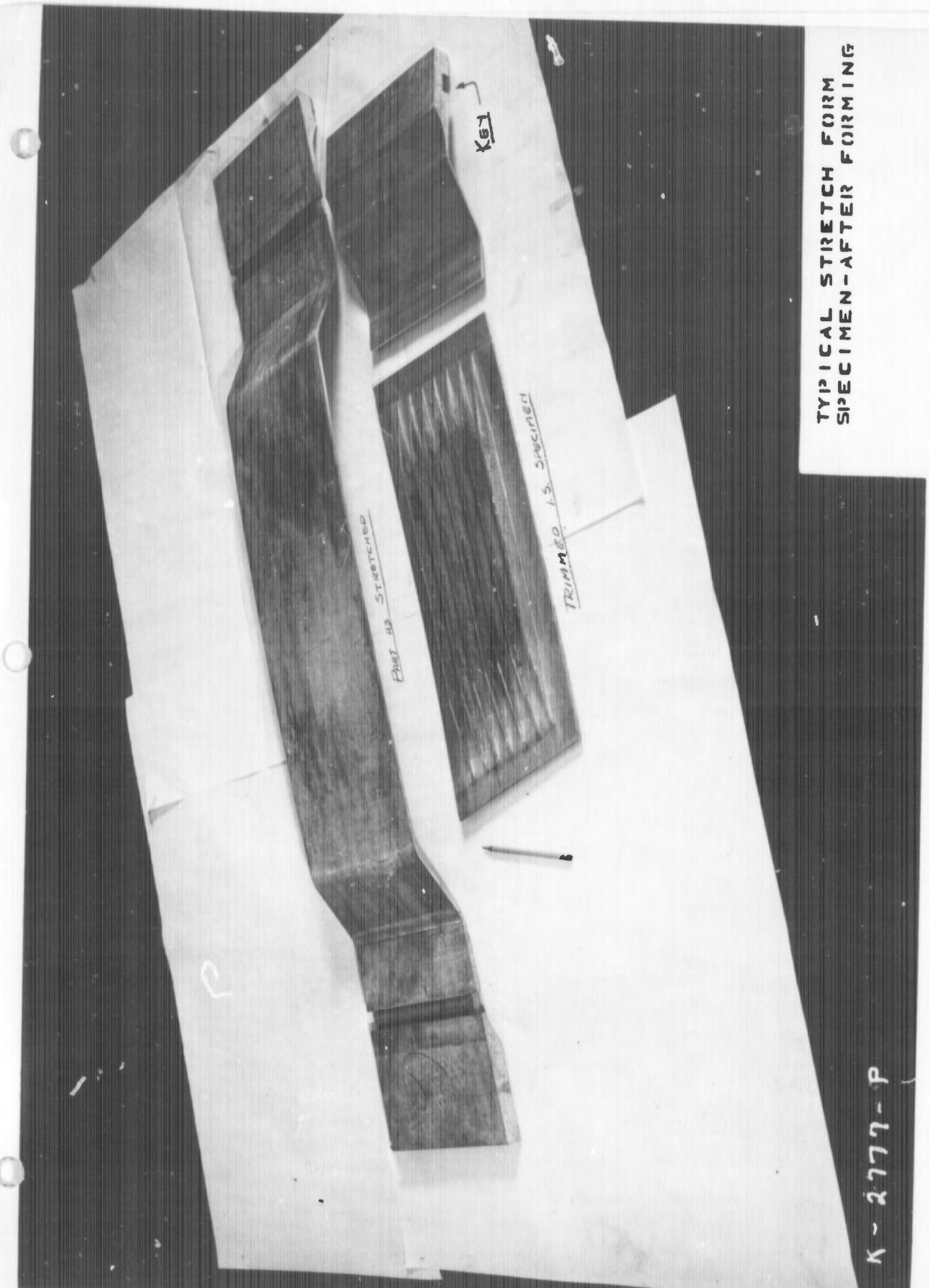


FIG.8

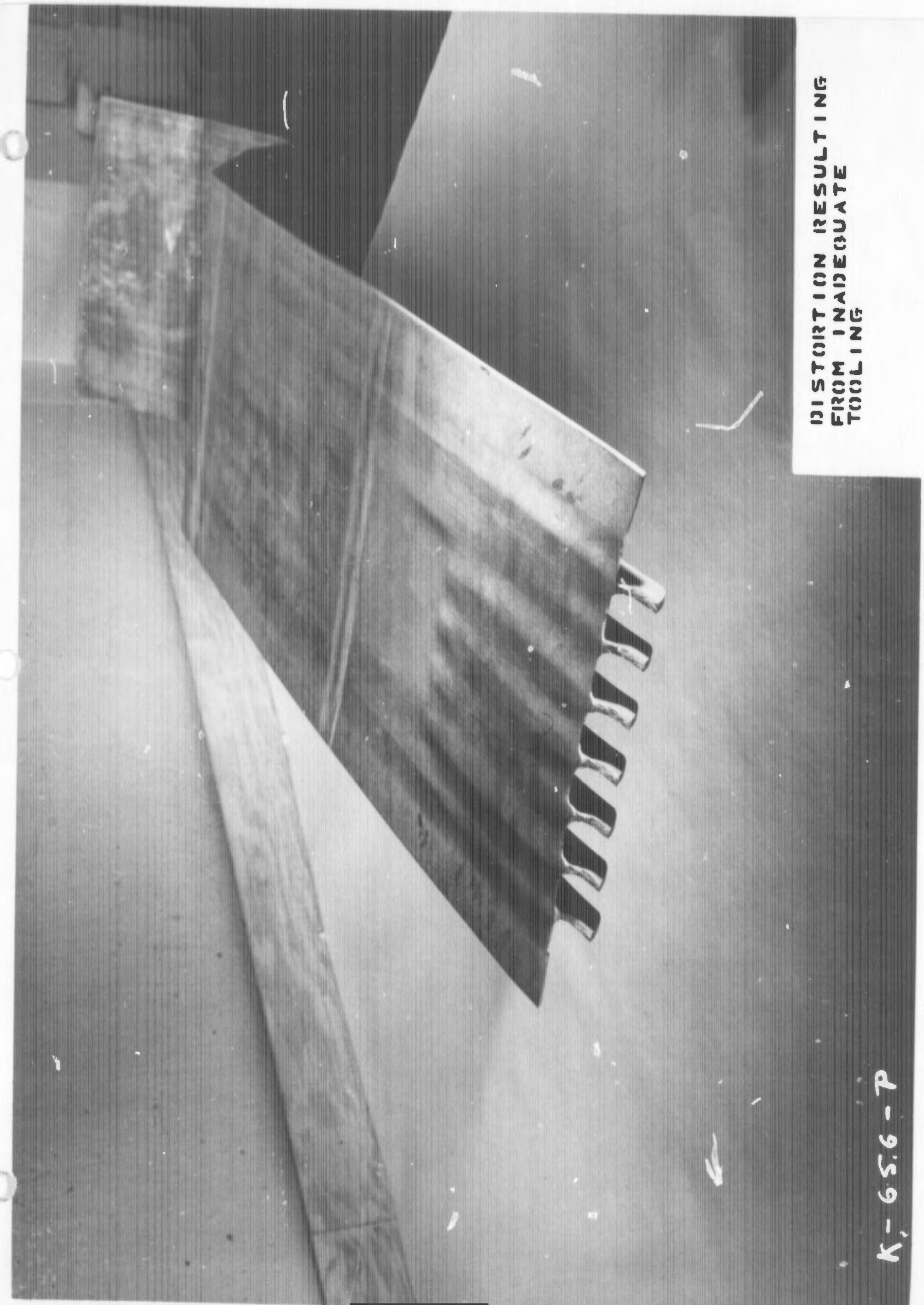


FIG. 9

TYPICAL CAST PLASTIC FILLER BLOCK USED IN SPECIMEN FORMING

FIG.10

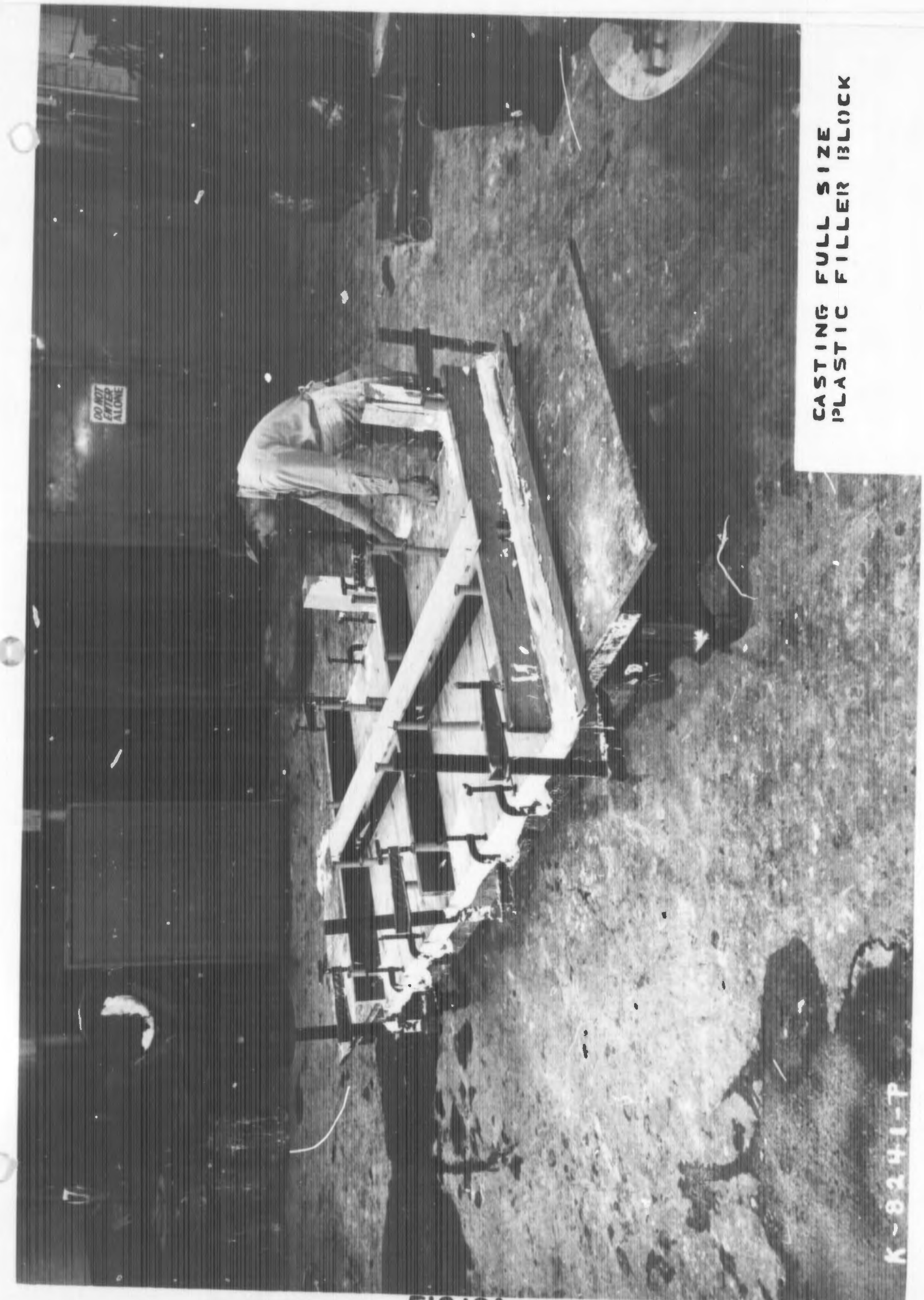

CASTING FULL SIZE
PLASTIC FILLER BLOCK
K-8241-P
DO NOT ENTER ALONE

FIG.10A

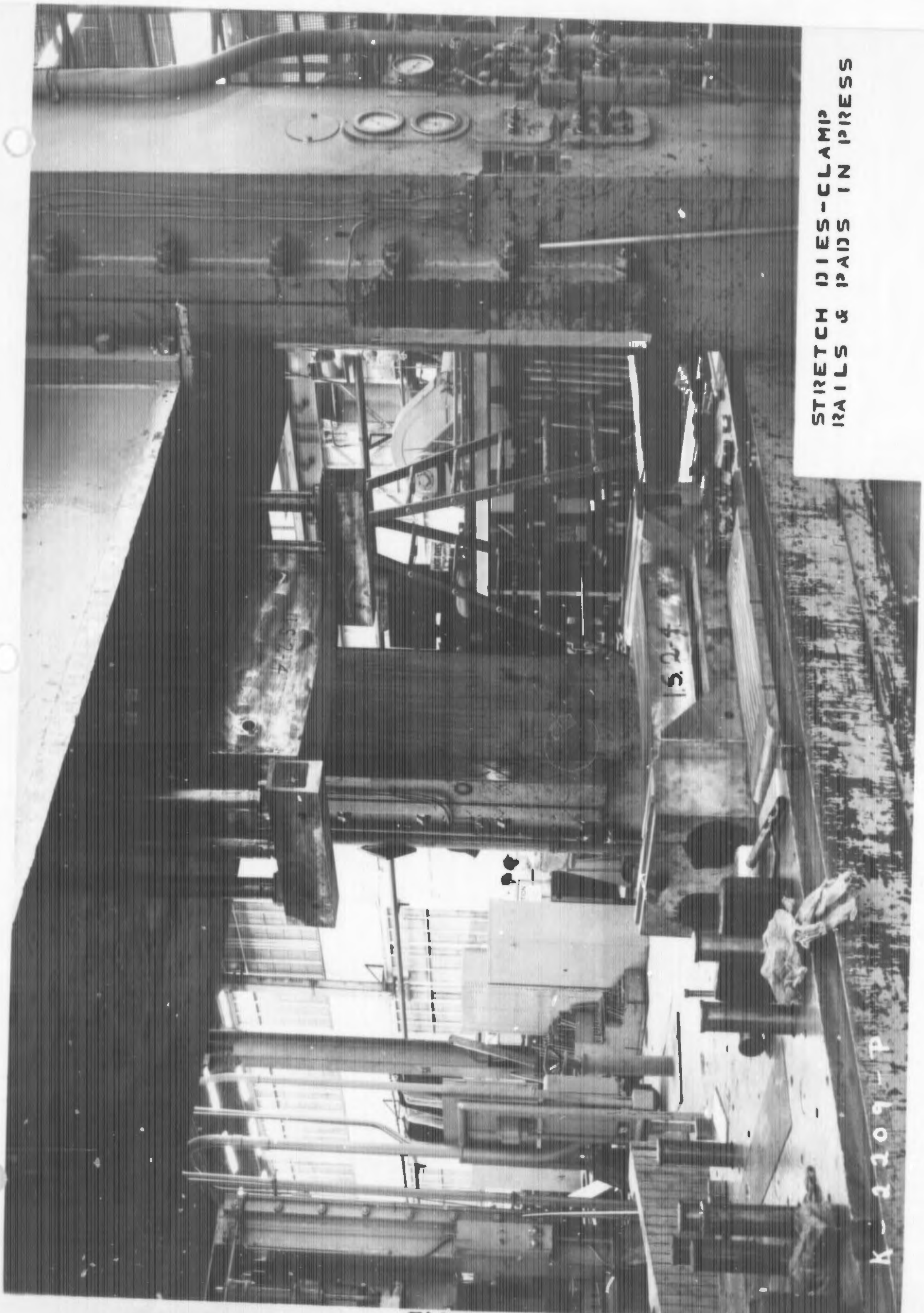


FIG.11

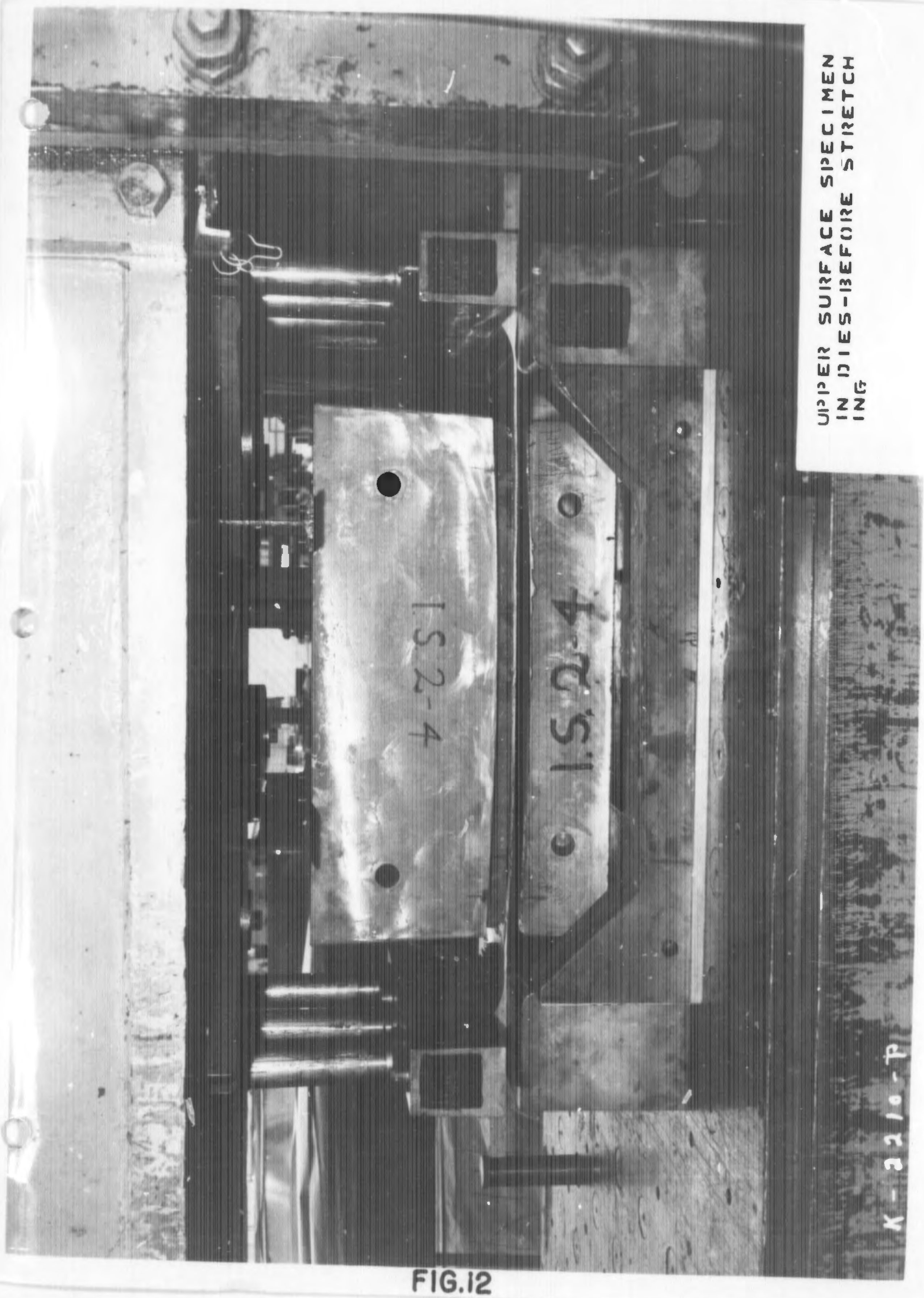


FIG.12

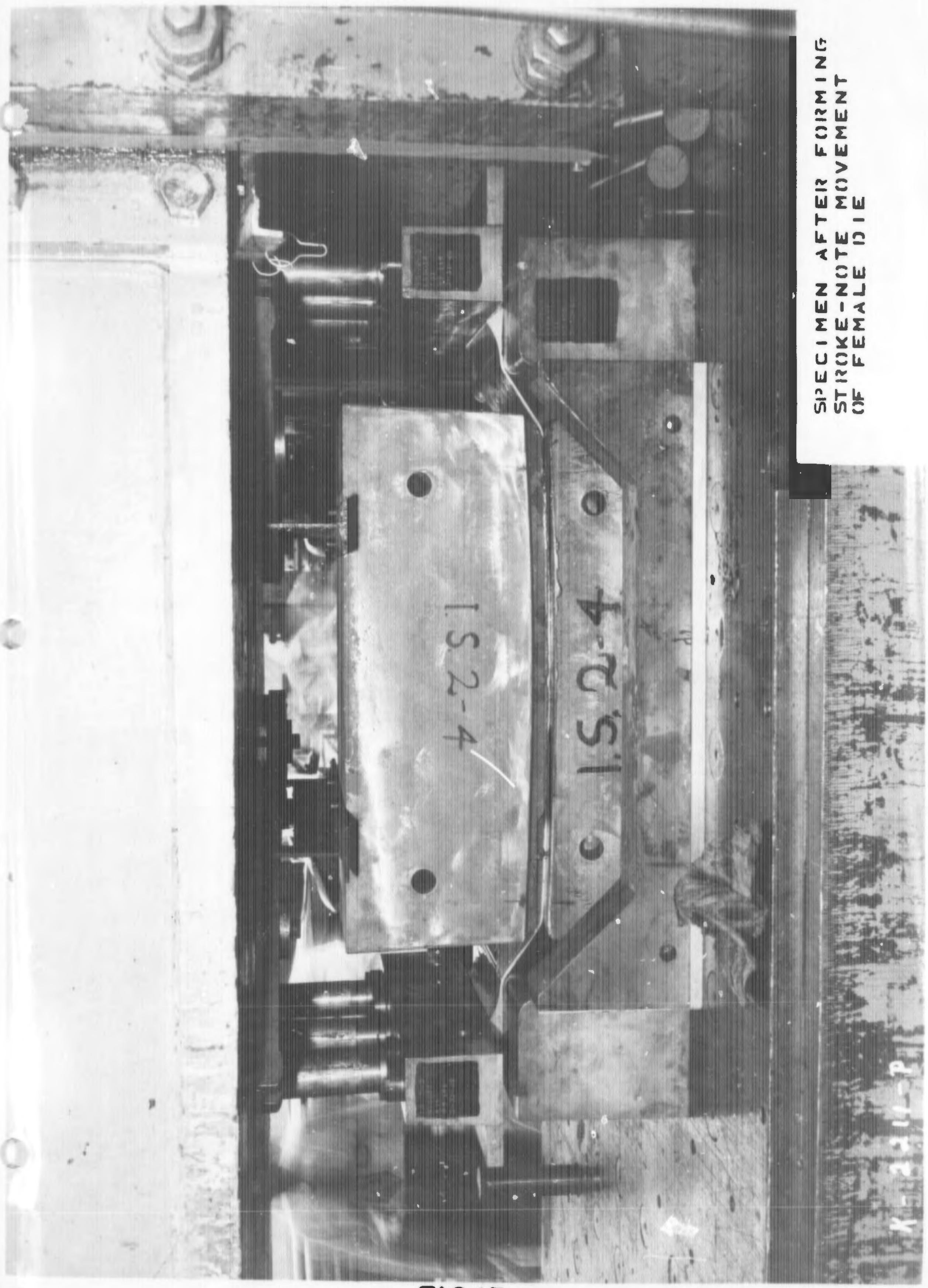

SPECIMEN AFTER FORMING
STROKE-NOTE MOVEMENT
OF FEMALE DIE
1S2-4
1S2-4

FIG.13

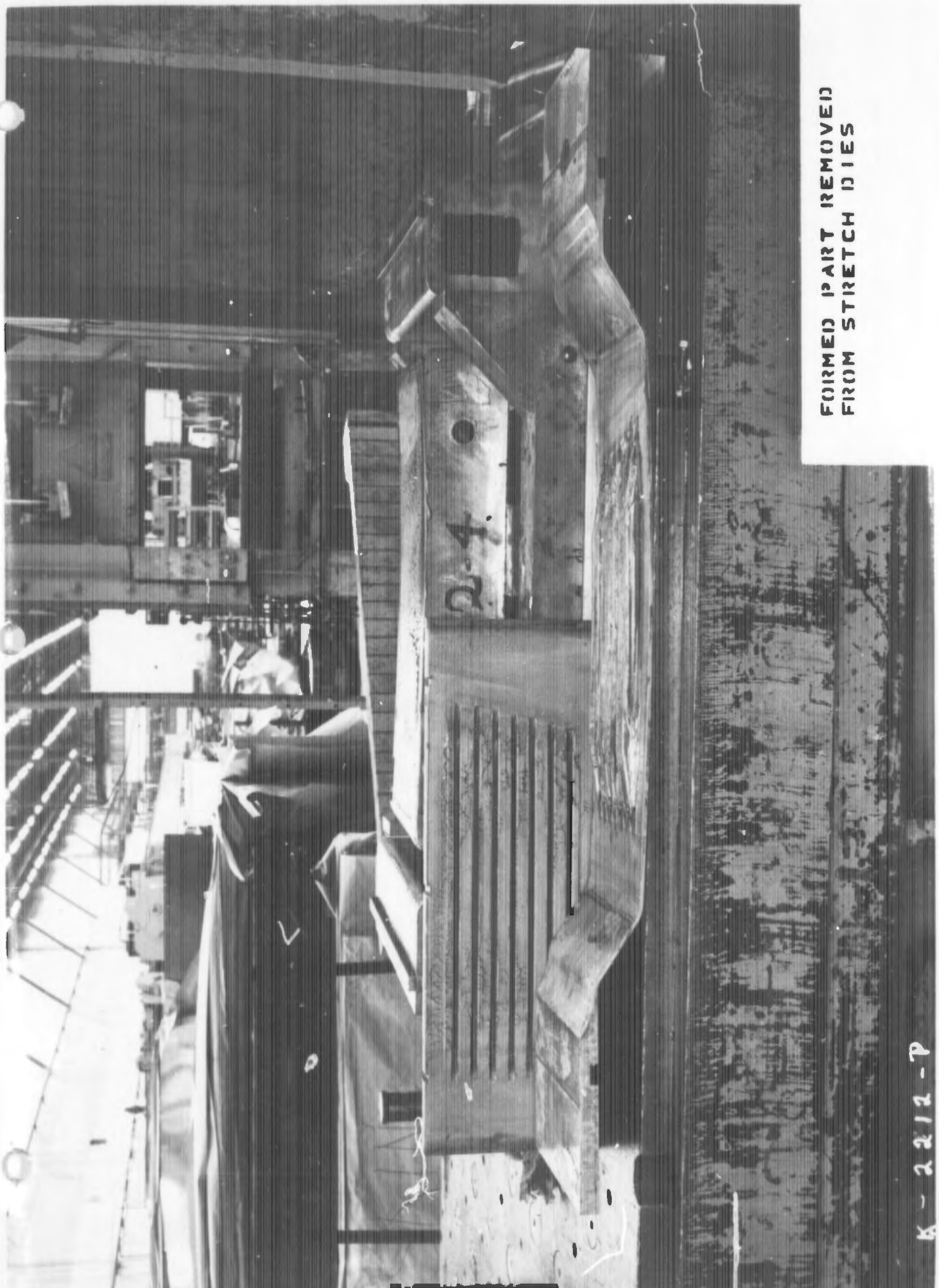


FIG.14

OUTSIDE SURFACE OF FORMED SPECIMEN SHOWING MINOR IRREGULARITIES

FIG.15

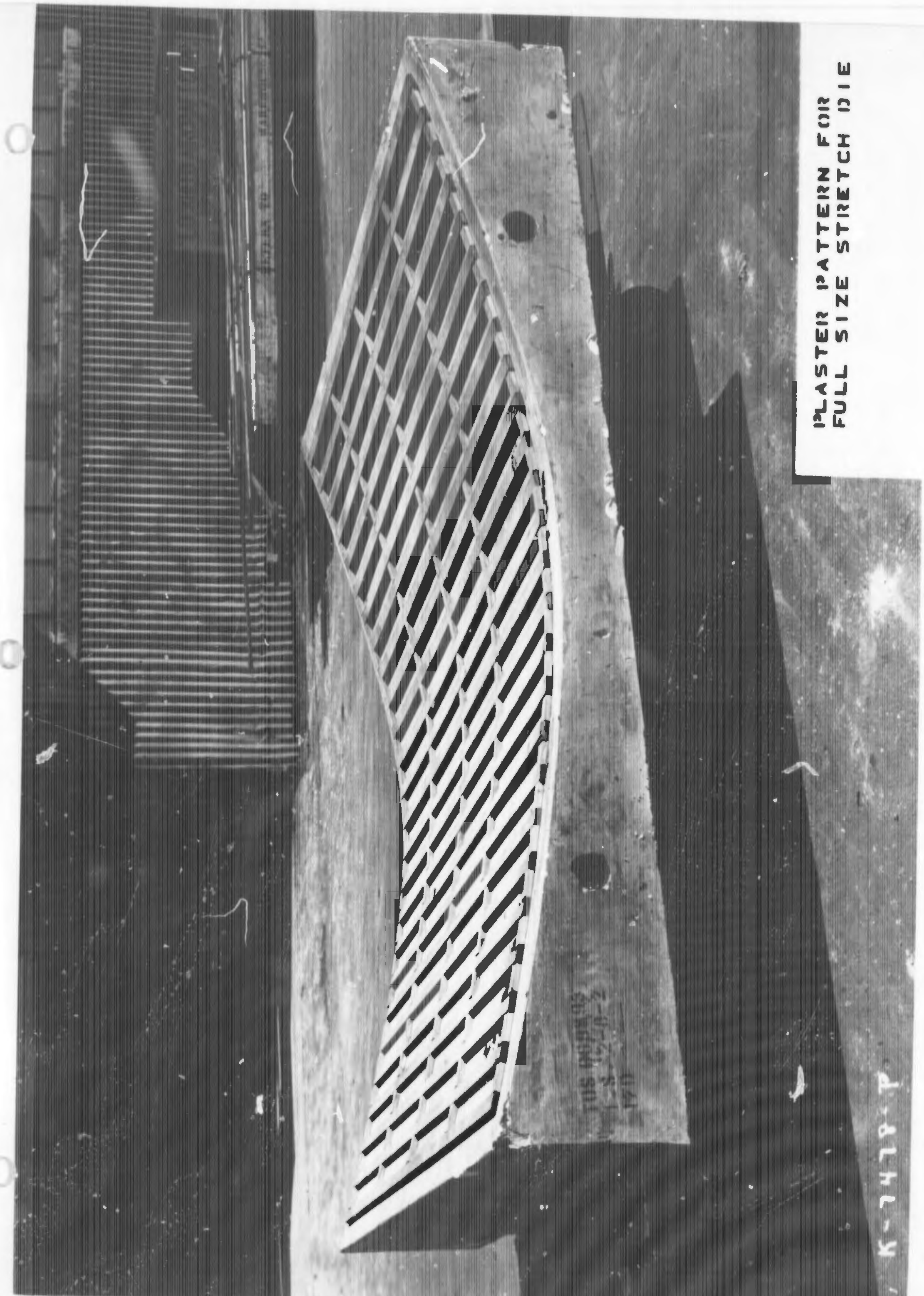


FIG.16

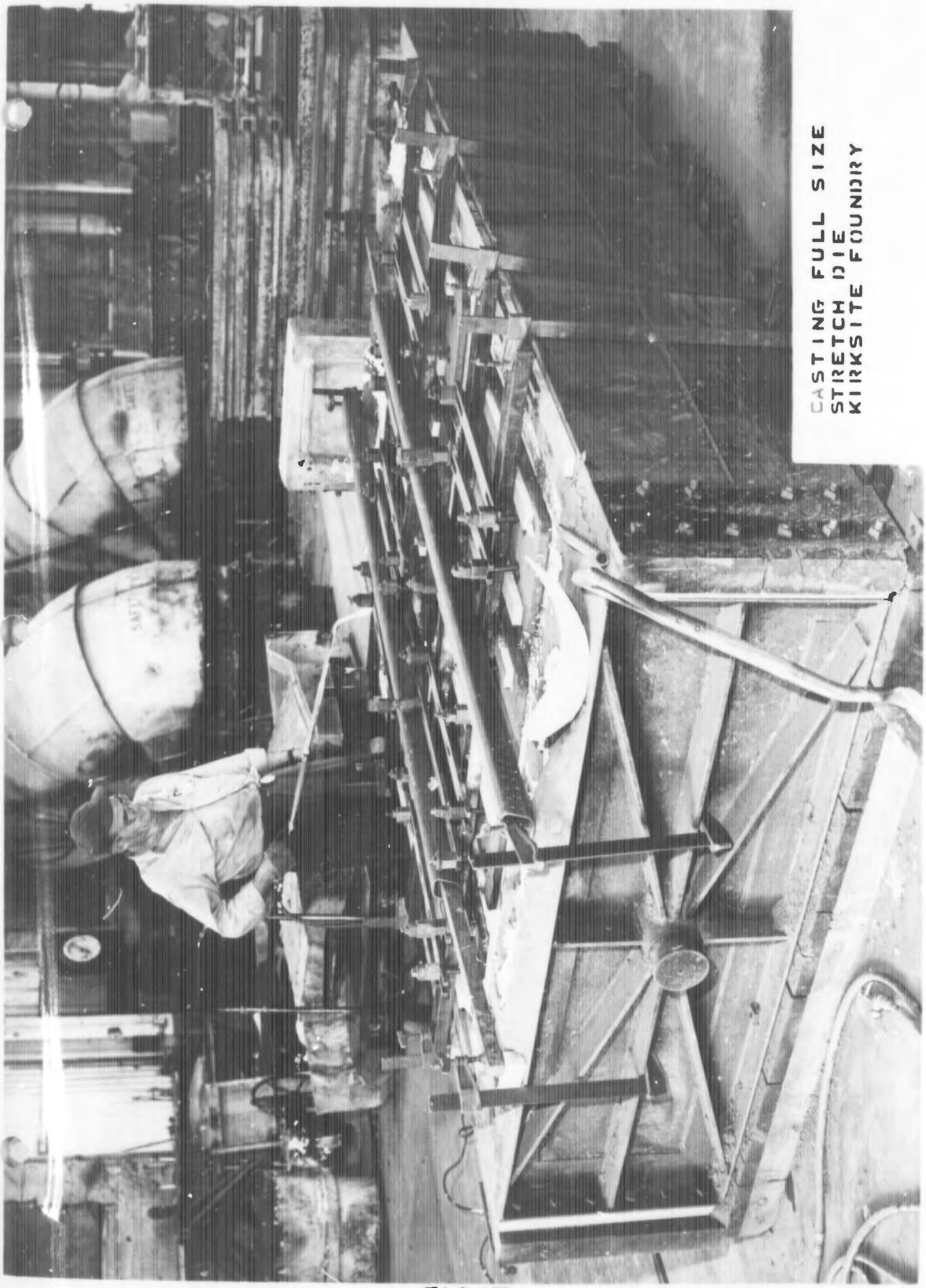


FIG.17

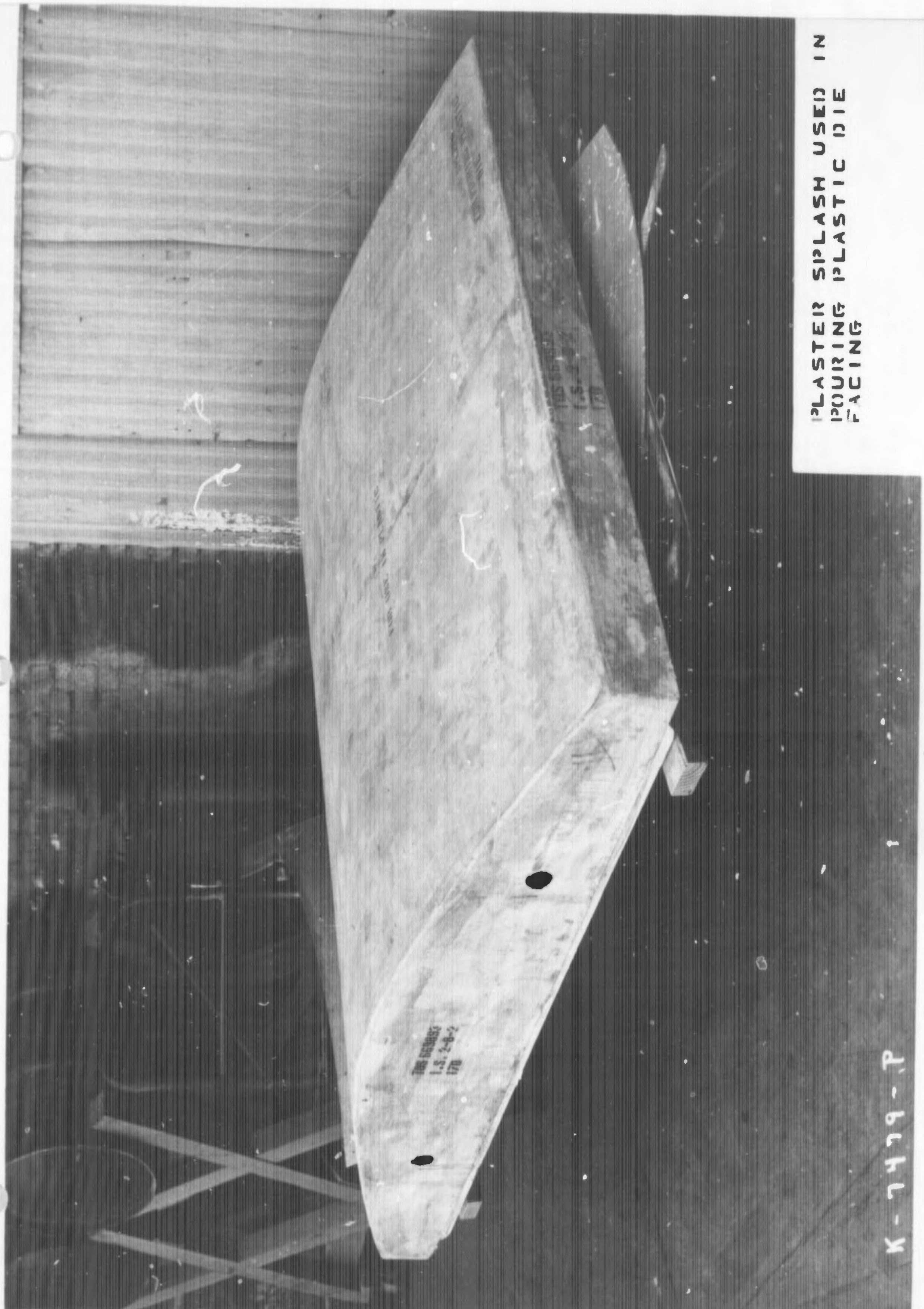


FIG 18

CASTING PLASTIC DIE FACING

FIG 19

FIG 19

FIG.20

FIG.21

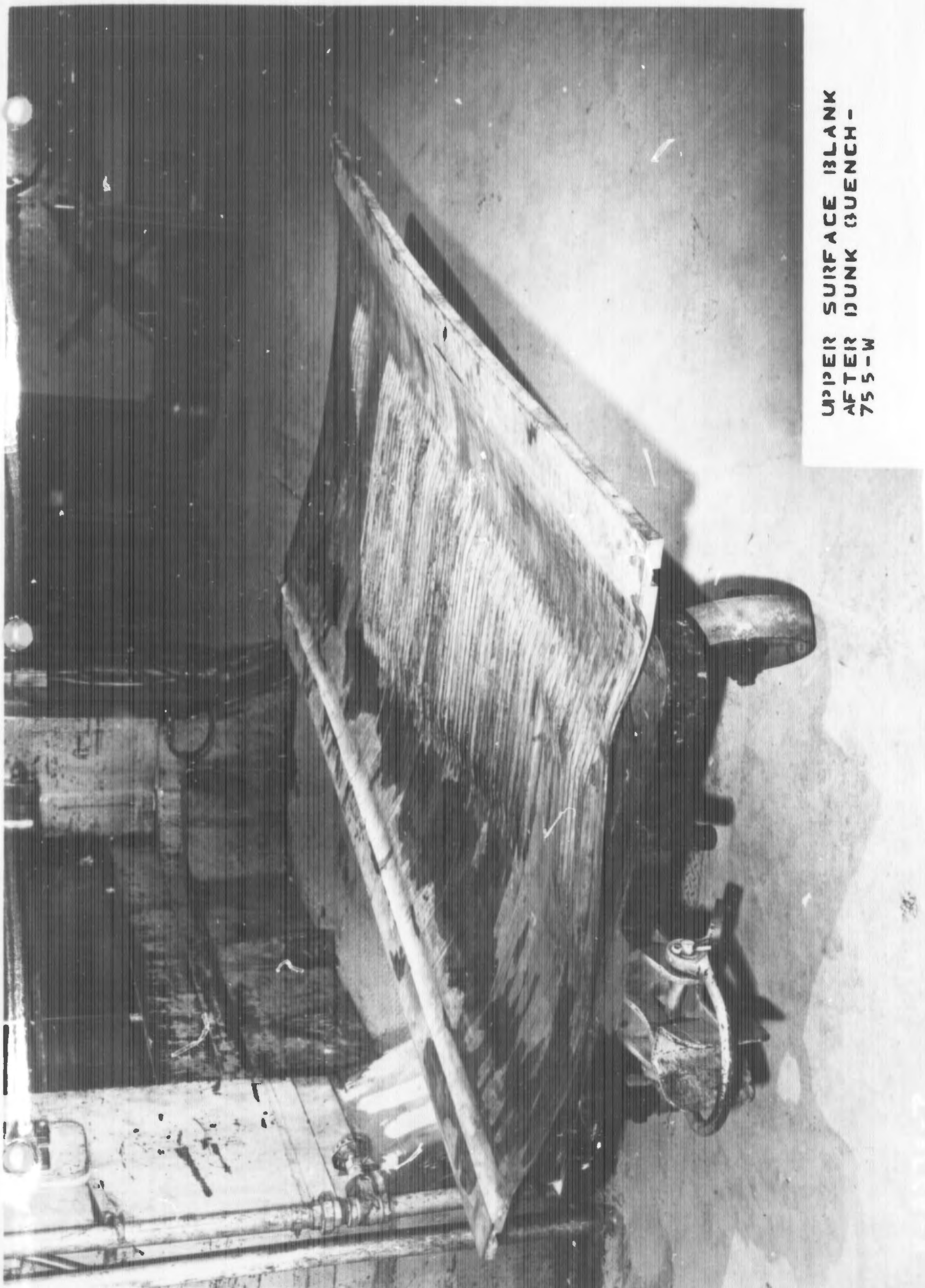
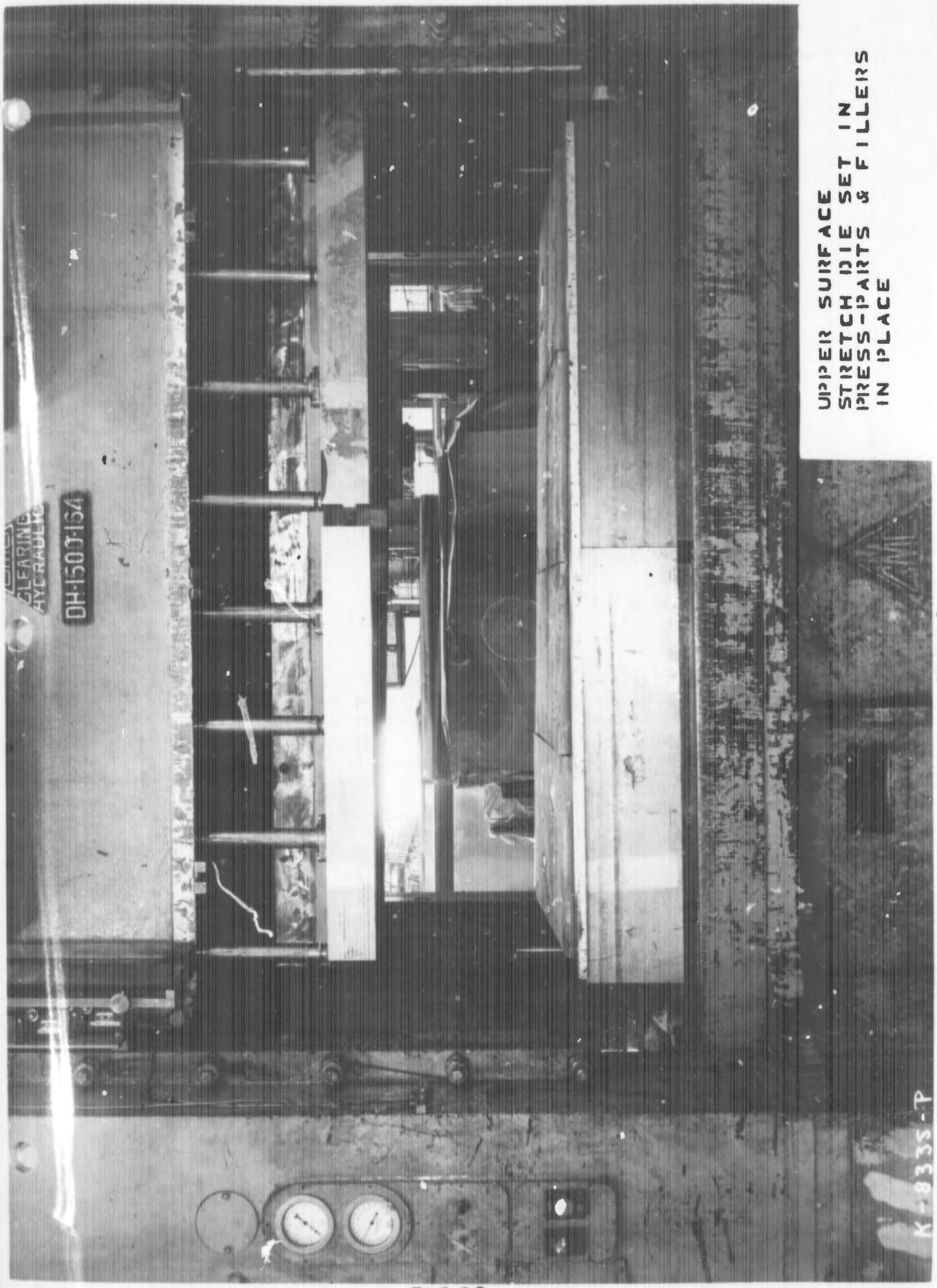


FIG.22



UPPER SURFACE
STRETCH DIE SET IN
PRESS-PARTS & FILLERS
IN PLACE

FIG 23

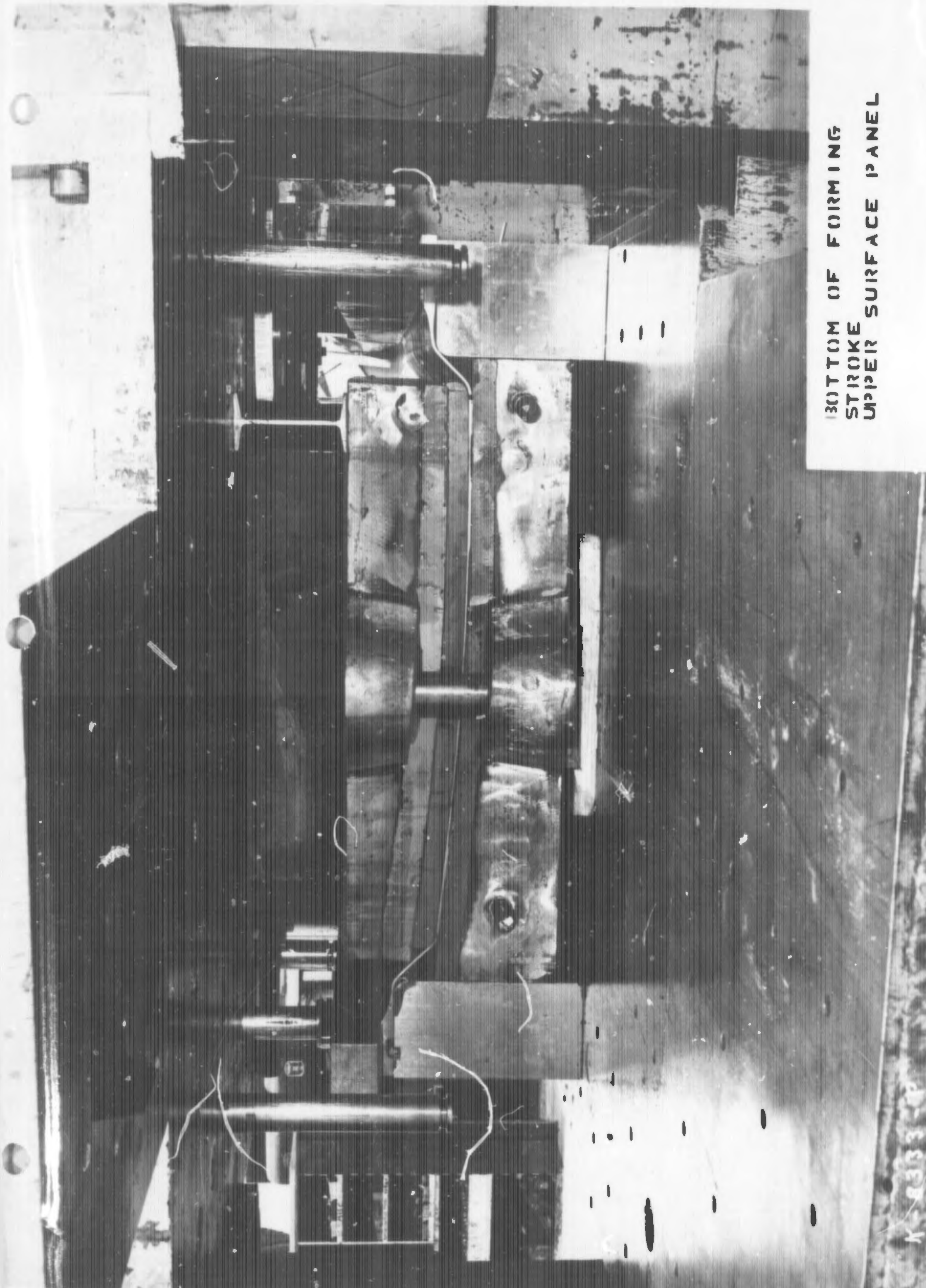


FIG.24

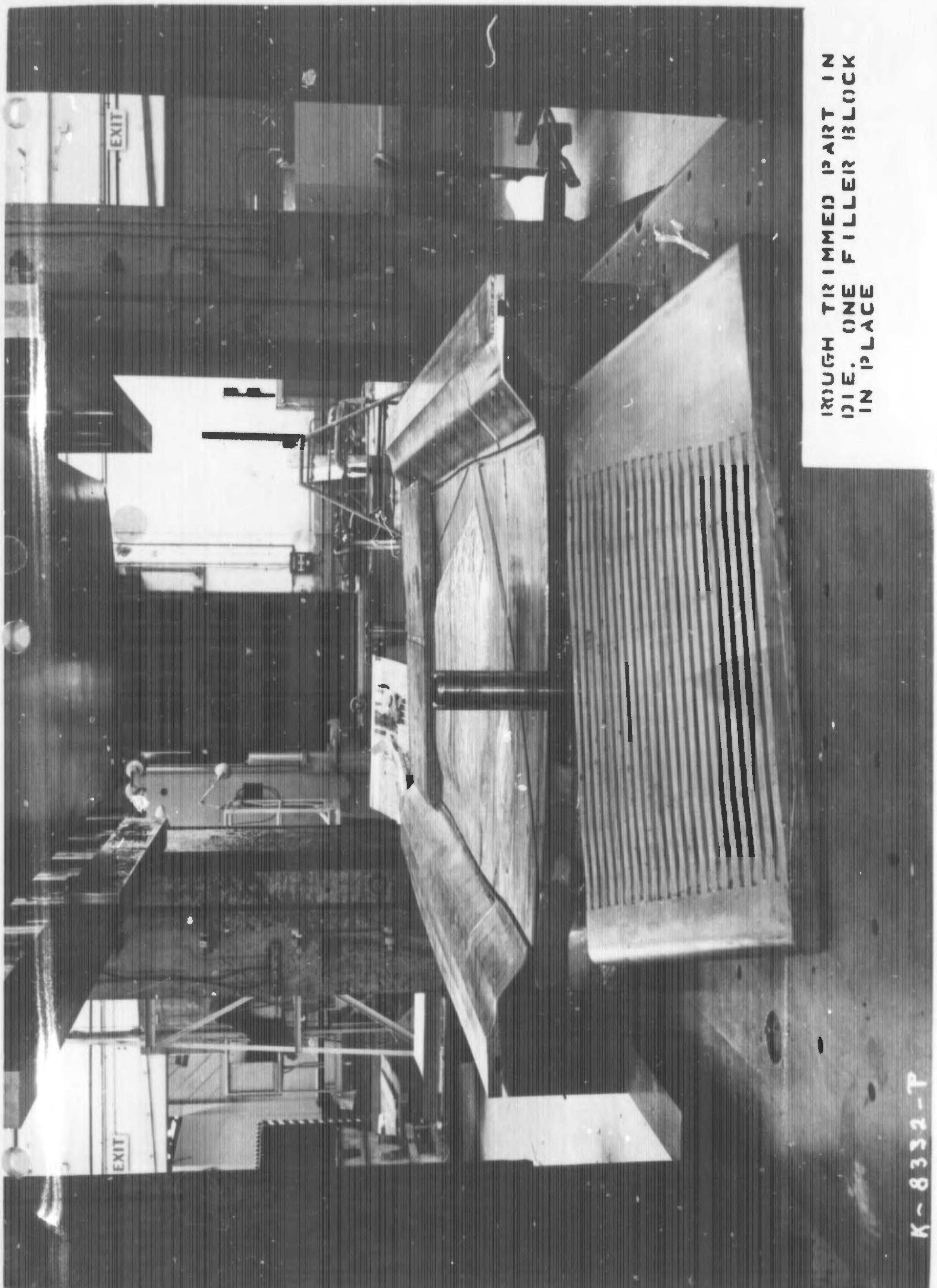

ROUGH TRIMMED PART IN
DIE. ONE FILLER BLOCK
IN PLACE
K-8332-P
EXIT
EXIT

FIG.25

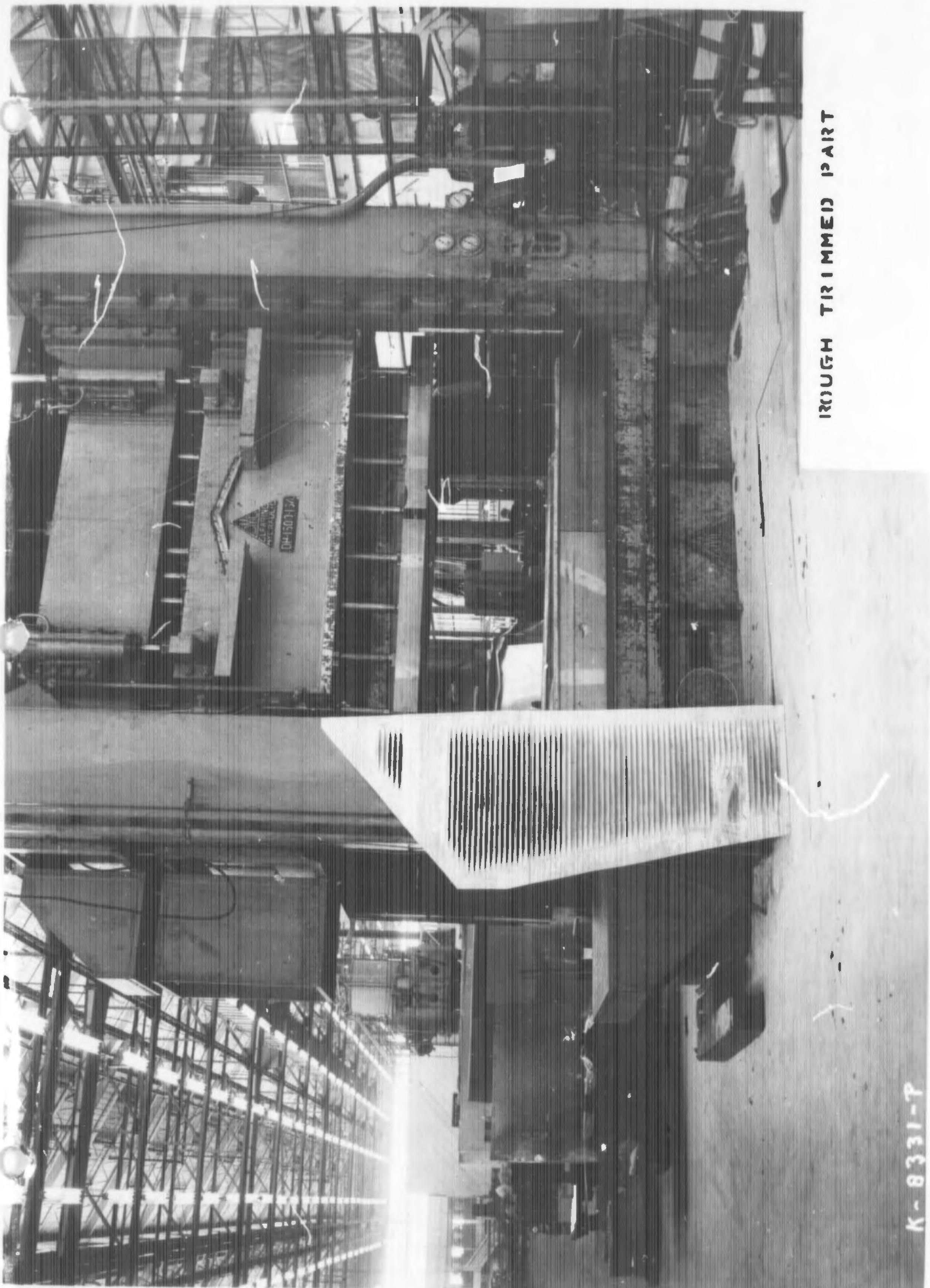


FIG. 26

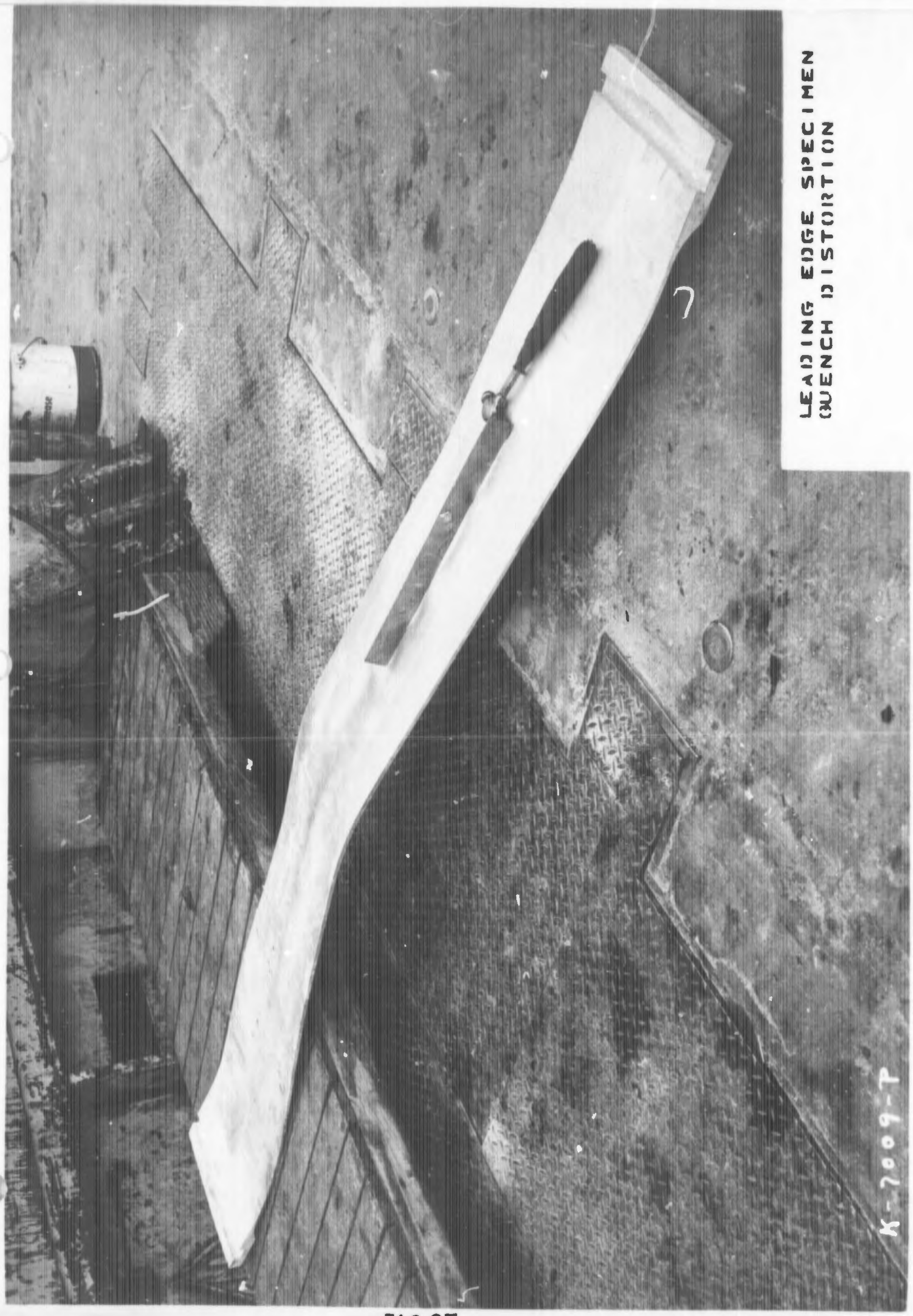
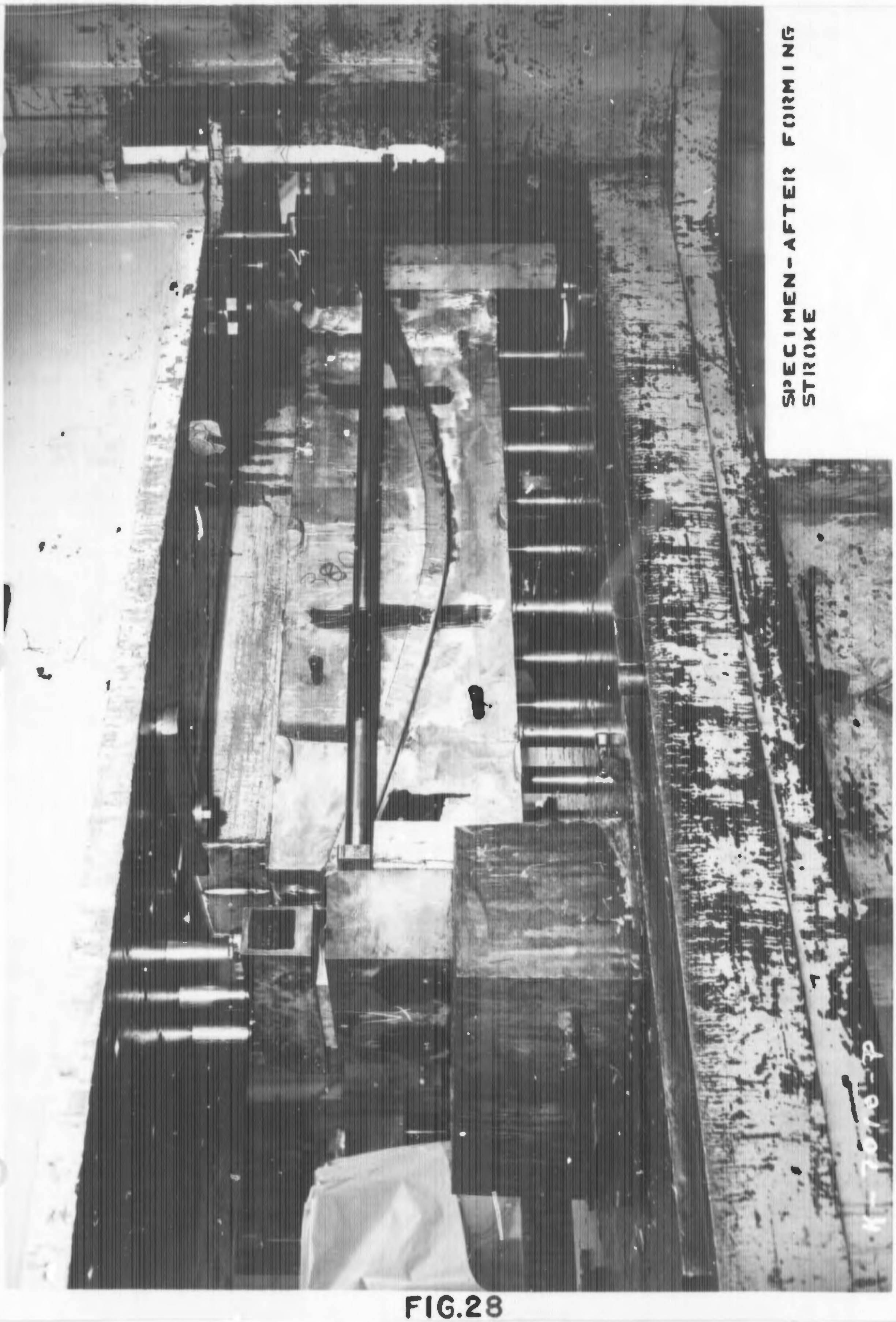
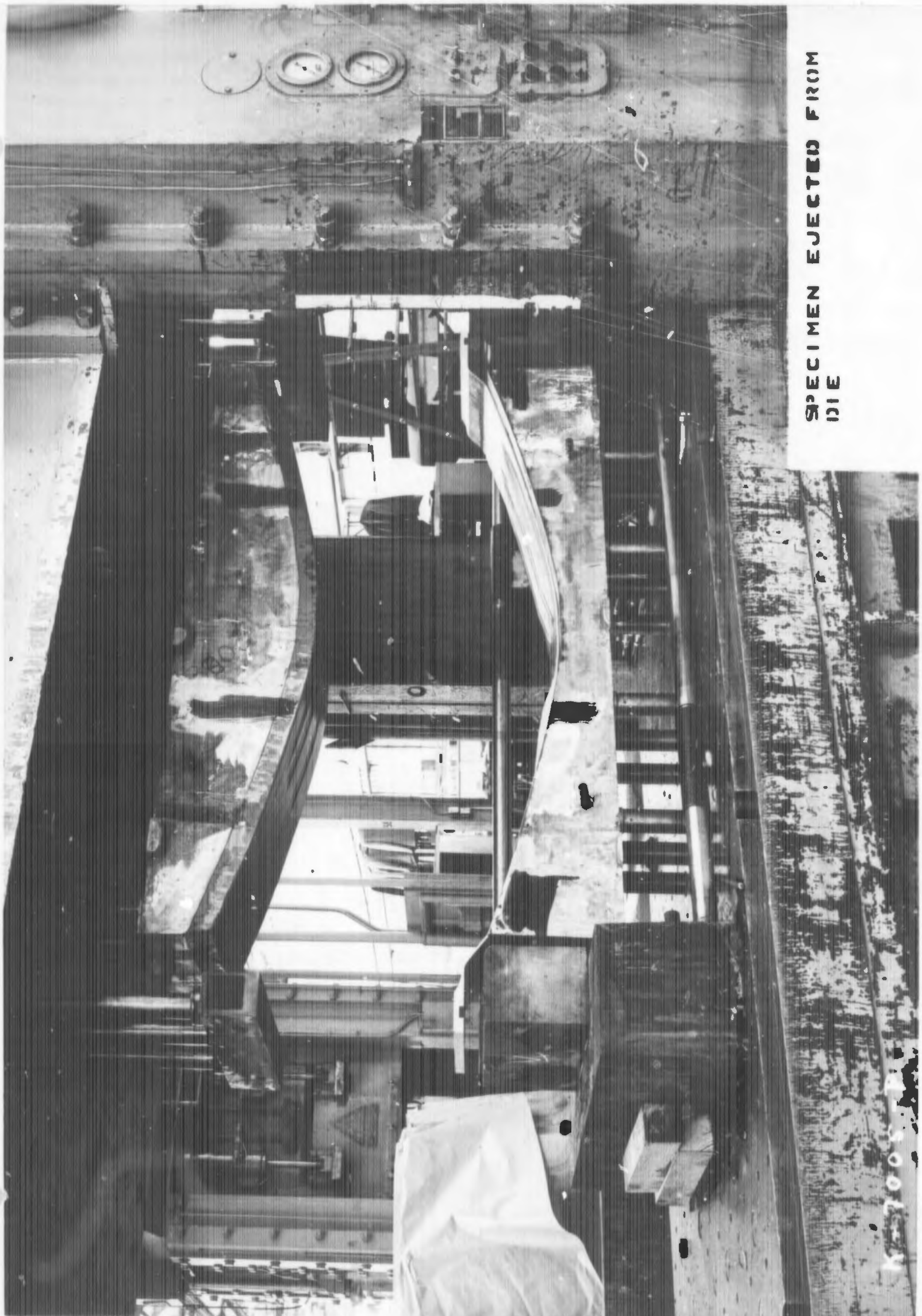


FIG 27



SPECIMEN-AFTER FORMING STROKE

FIG.28



SPECIMEN EJECTED FROM DIE

FIG 28 a

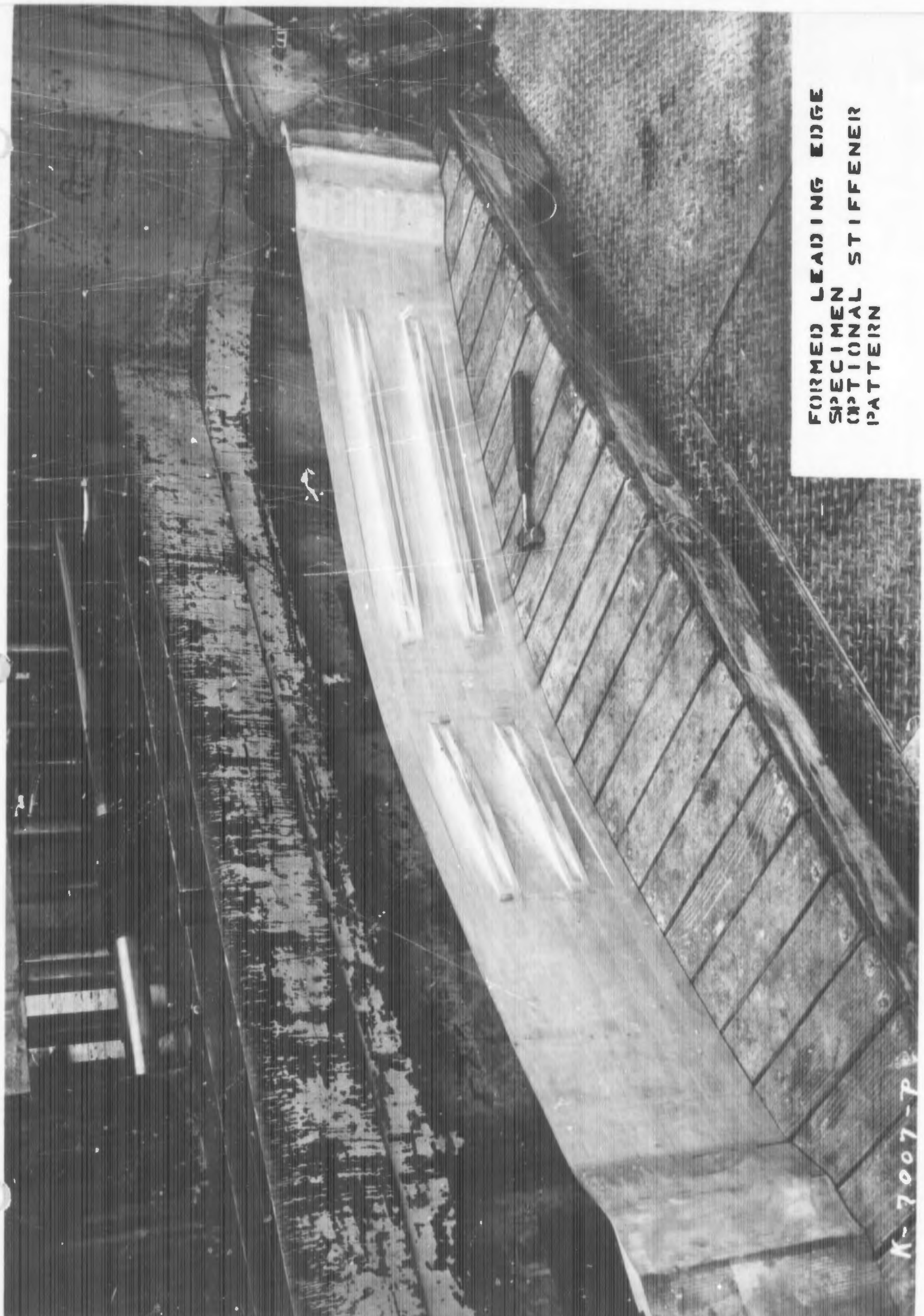

FORMED LEADING EDGE
SPECIMEN
OPTIONAL STIFFENER
PATTERN
K-7007-P

FIG.29

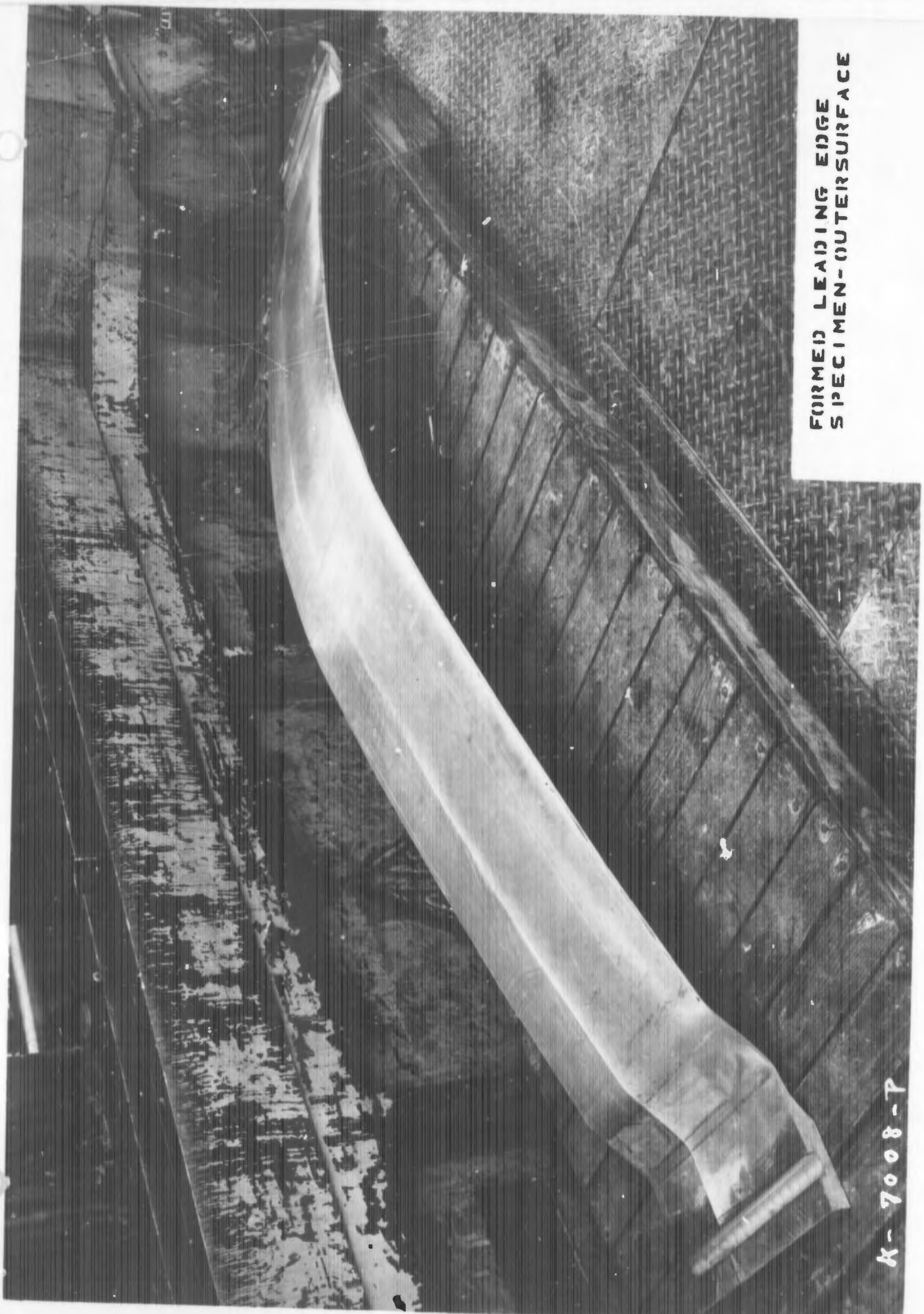
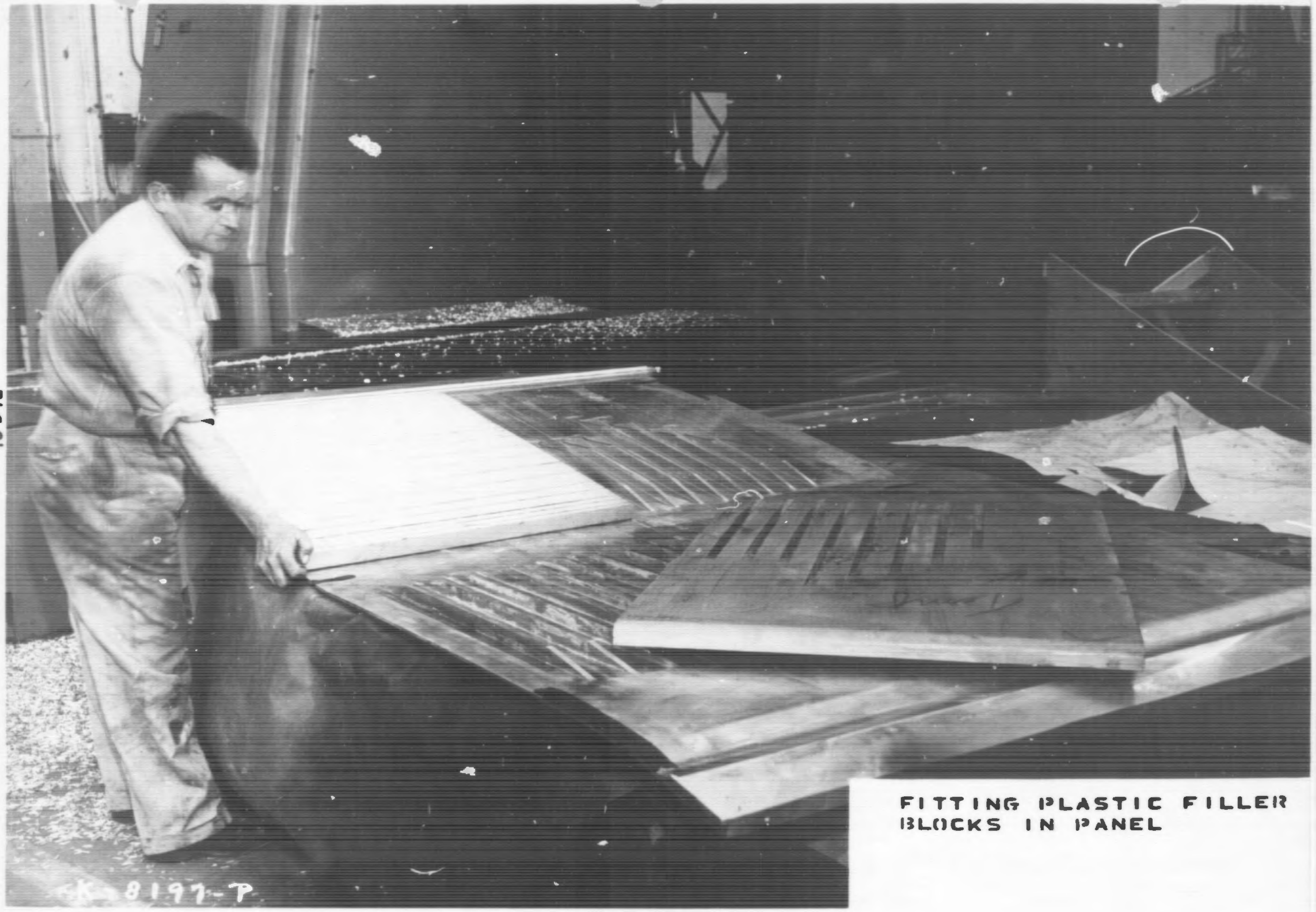


FIG. 29a


MACHINED LEADING EDGE
BLANK-755-0
PREFORMED IN BRAKE
K-8198-P

FIG 30

FIG 31



FITTING PLASTIC FILLER
BLOCKS IN PANEL

FIG 31

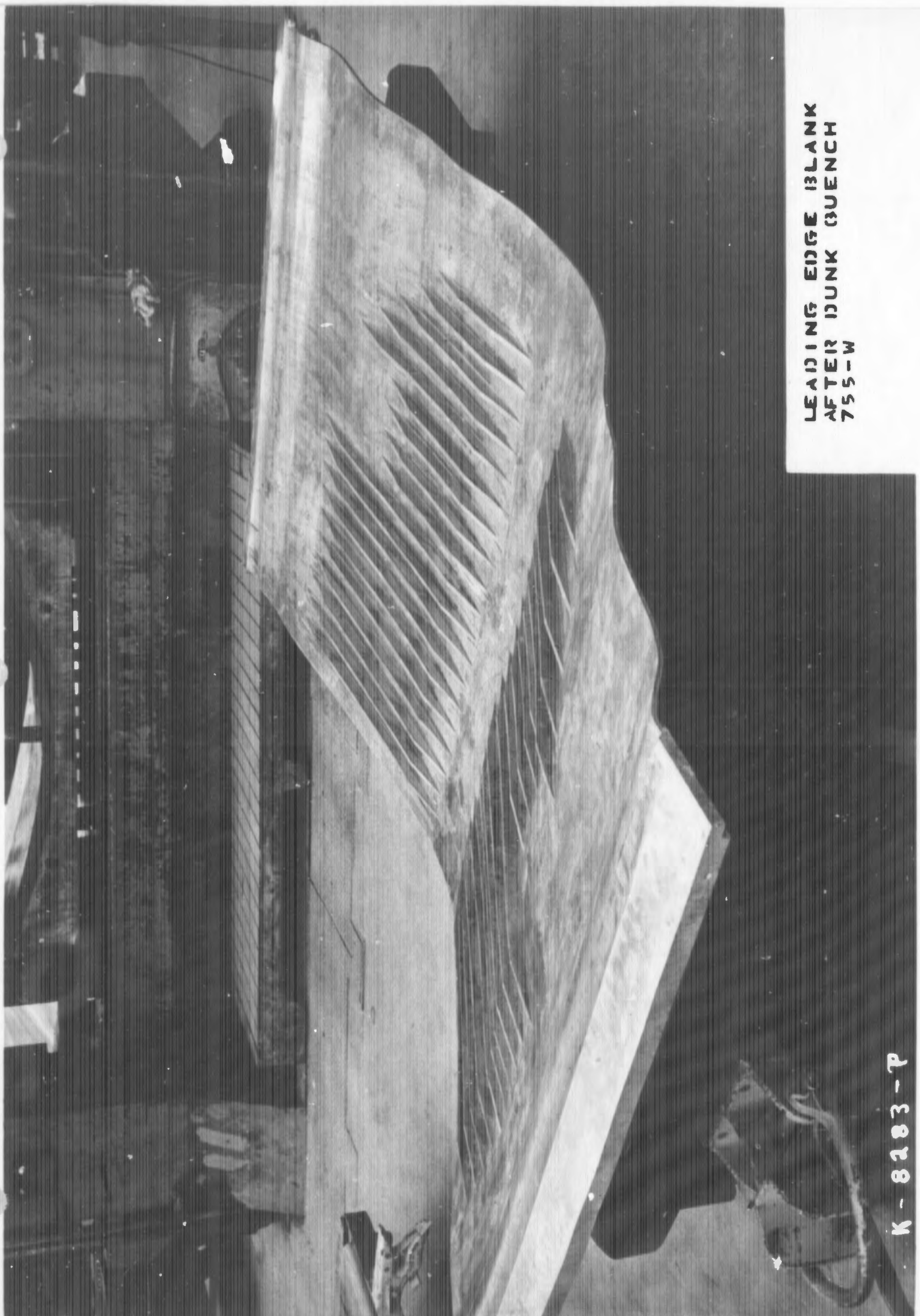
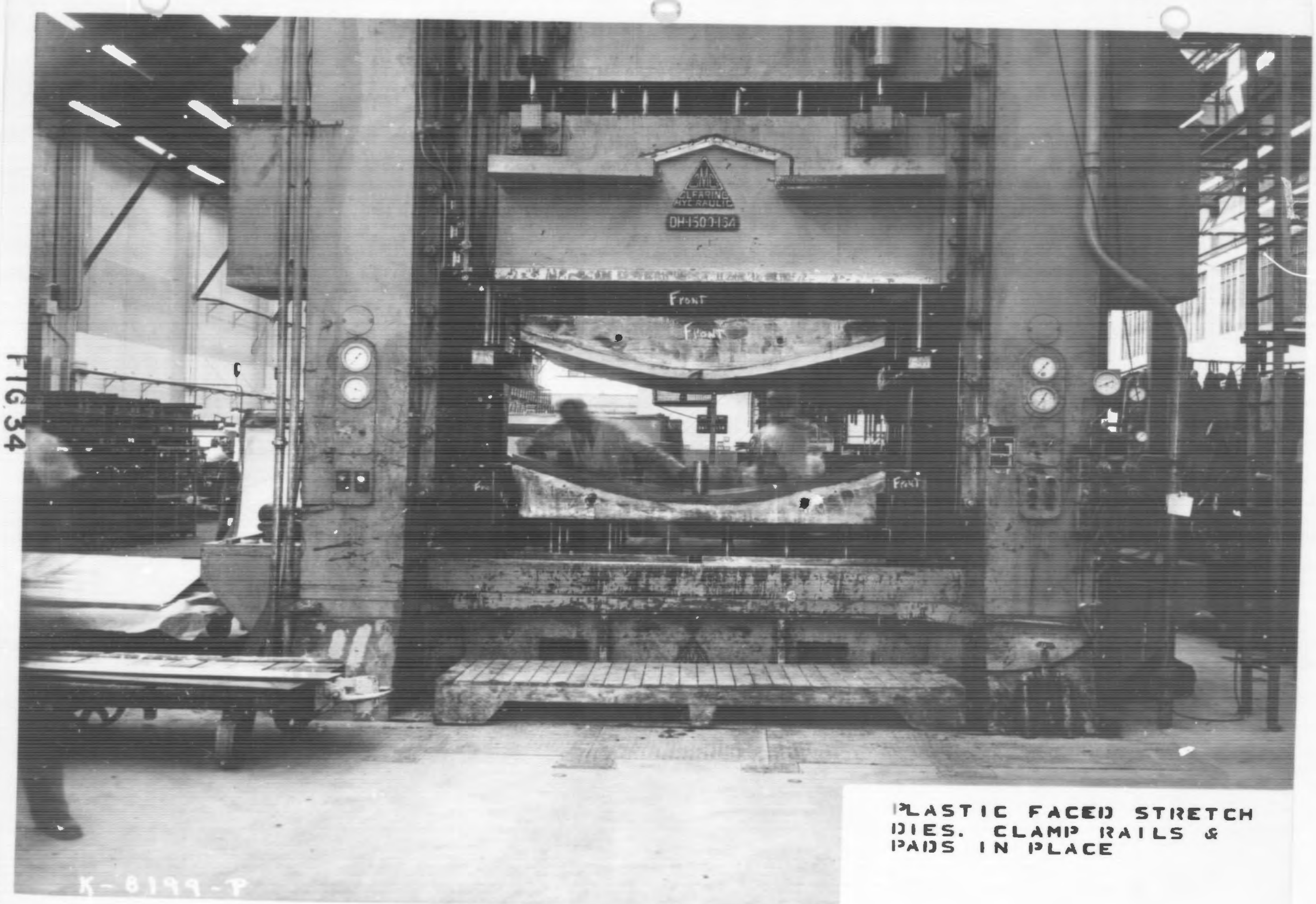


FIG 32

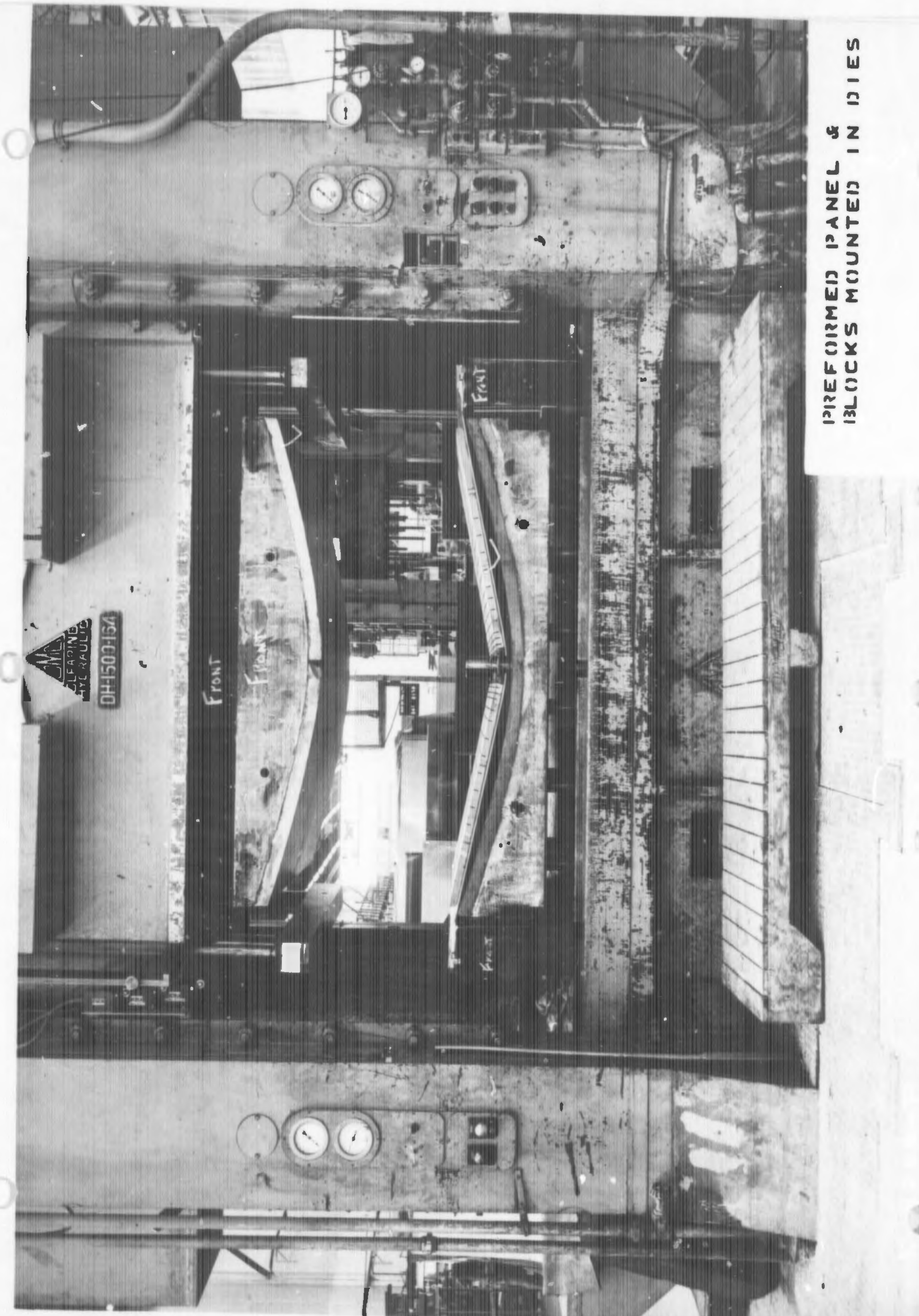
LOADING LEADING EDGE STRETCH DIES INTO PRESS

FIG 33



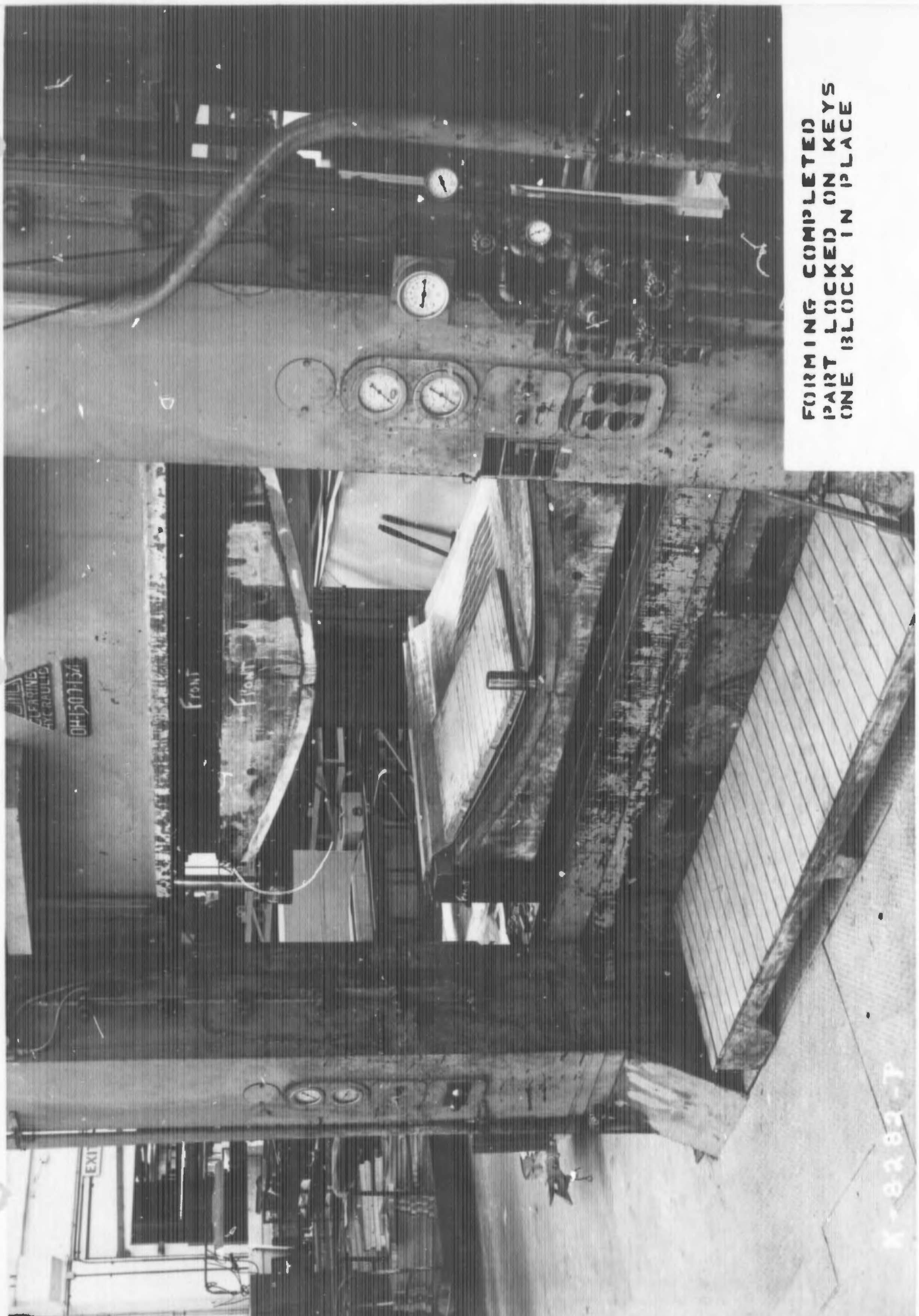
PLASTIC FACED STRETCH DIES. CLAMP RAILS & PADS IN PLACE

FIG 34



PREFORMED PANEL & BLOCKS MOUNTED IN DIES

FIG. 35



FORMING COMPLETED
PART LOCKED ON KEYS
ONE BLOCK IN PLACE

FIG. 36

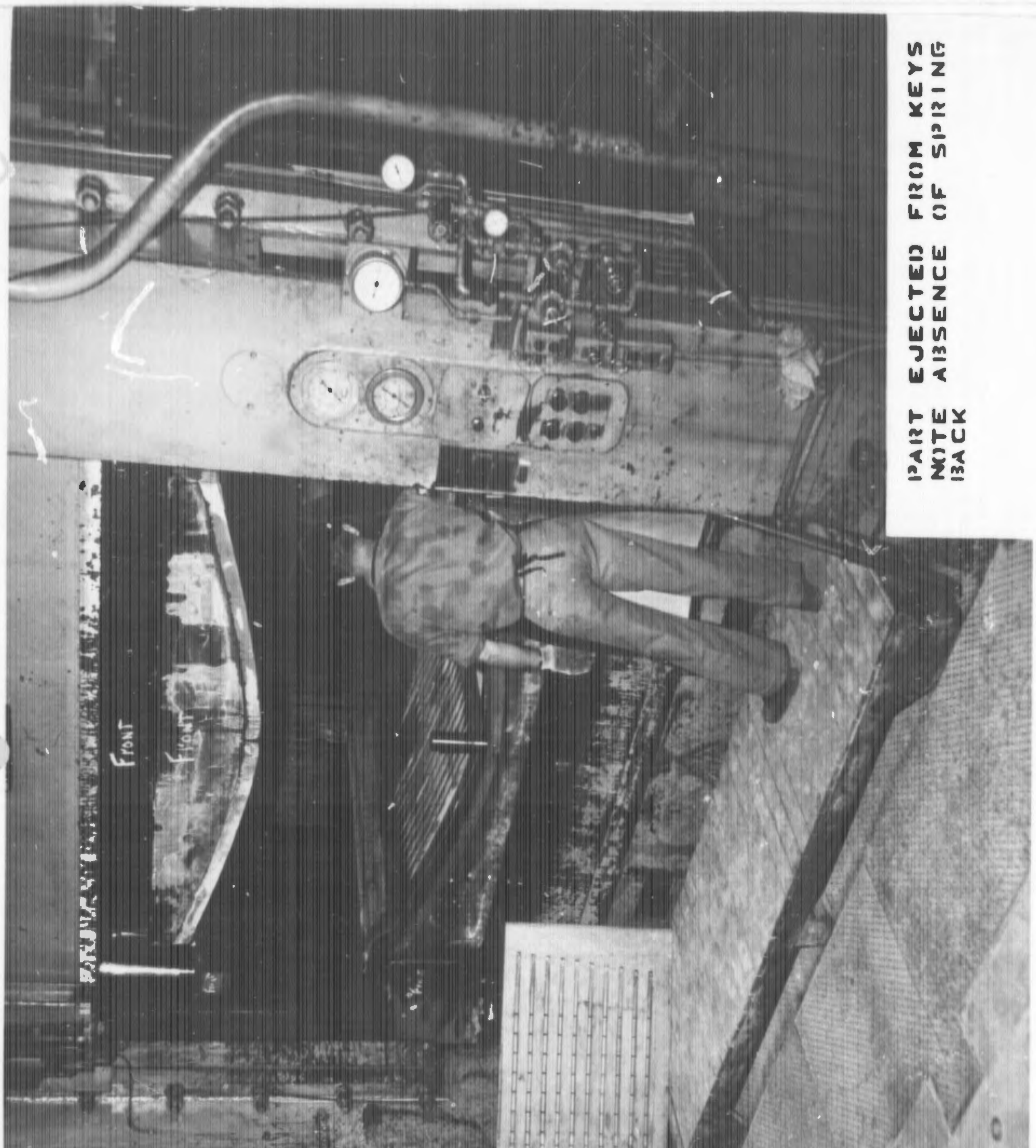

PART EJECTED FROM KEYS
NOTE ABSENCE OF SPRING
BACK
FRONT
FRONT
K-8284-P

FIG 37

3.3 TEST PROCEDURE (Cont'd.)

3.32 COMPRESSION FORMING

The basic principle of this forming method is illustrated schematically in Figure 38. A part is pre-formed (by any acceptable method) sufficiently to be inserted into the die. With this pre-formed part installed in the die, pressure is applied to the edge, thereby compressing the part and forming it to the contour of the die. The effect of the compression strain is similar to that of tension strain in stretch forming and tends to greatly reduce springback.

The favorable features of compression forming that prompted the investigation of this method were:

(a) The limited accessibility to the interior would not be a serious problem.

(b) Springback would be largely eliminated.

(c) The cost of tooling for production might be relatively less than for some of the other methods under consideration.

EQUIPMENT

Preliminary compression forming tests were conducted on a 300-ton single action hydraulic press. Full size parts, however, were compression-formed in the 1500-ton Clearing double action press since this was the only available equipment of adequate power and open height. Pre-forming of test specimens

3.32 COMPRESSION FORMING (Cont'd.)

was done on a 10-foot power brake. Pre-forming of the entering edge of the full size skins was done on the 20-ton Ceco because of the greater accessibility and freedom of obstruction afforded by this machine. (Figure 60)

TESTS

STRAIGHT COMPRESSION FORMING OF LEADING EDGE PANELS

Preliminary tests were conducted on standard test specimens possessing the typical features of the full size part such as described in 3.31. All were machined from 75S material in the O temper. Two-stiffener configurations were tested. A typical blank of the first configuration is shown in Figure 39. The second type was similar in size but had a stiffener configuration corresponding to P. D. 903-23.

The die used for the preliminary investigation, Figures 40, 41 and 42, consisted of a Kirksite die block with the cavity finished to the contour of the outside part surface and two steel compression bars for applying load to the upper edges of the part.

Three different arrangements for supporting the part against buckling were tried:

(a) A set of wooden blocks set in a horizontal position between opposing stiffeners.

3.32 COMPRESSION FORMING - Tests (Cont'd.)

(b) A composite punch consisting of a cerrobend nose punch, two plastic inserts (See 3.31, Test #2), one cast to each interior side surface, and a cerrobend central punch to support the plastic inserts. (Figures 40, 41 and 42) The plastic inserts were cast against the machined part before forming. The interior support was held in place with two stay bolts.

(c) A composite punch, similar to (b), consisting of a cerrobend nose punch, built-up inserts composed of strips of hard rubber faced with aluminum alloy sheet, and a central cerrobend punch.

TEST NO. 1

The blank, while in the O temper, was pre-formed sufficiently in the power brake to be inserted into the compression die. It was formed in the compression die to approximately 1% strain, using wooden blocks for interior support against buckling. This forming produced very satisfactory results.

The specimen was then heat treated, partially straightened to eliminate some of the heat treat distortion and re-formed in the compression die, using the above internal support.

As illustrated in Figure 43, the part was severely dis-

3.32 COMPRESSION FORMING - Test No. 1 (Cont'd.)

torted by the heat treatment. This distortion consisted not only of twisting and warping but severe buckling of the thin skinned regions. While some of the general distortion could be removed, no suitable means were available for removing the local buckles.

During the final forming, these local buckles grew and caused general buckling. (Figure 44) An unsatisfactory part resulted.

The severe buckling tendency in the webs of this specimen was attributed to the wide spacing between stiffeners. To reduce this tendency, subsequent tests were confined to parts with the typical stiffener configuration of P. D. 903-23.

TEST NO. 2

A blank with the configuration of P. D. 903-23 which utilized a somewhat narrower stiffener spacing was preformed on the power brake and compression formed in S-0 temper as described above. In order to further reduce the buckling tendency, this specimen was placed in a shroud consisting of a thin aluminum alloy sheet covering on the outside and similar sheet metal strips between stiffeners on the inside before heat treatment. (Fig. 45)

3.32 COMPRESSION FORMING - Test No. 2 Cont'd.

General distortion resulted. However, skin buckles were not present. (Figure 46)

This specimen was then partially straightened and formed to 1% strain. Although slight irregularities could be detected in the tapered areas at the ends of the stiffeners, a satisfactory part resulted. (Figures 47 and 48)

It was concluded from this test that a satisfactory part could be produced by compression forming provided (a) buckles due to heat treatment were avoided, and (b) a close fitting internal support against buckling during forming was provided.

It was not known whether the absence of skin buckles should be attributed to the closer stiffener spacing of the second configuration or to the use of the shroud.

TEST NO. 3

In forming the next specimen, the above procedure was repeated with the exception that the part was heat treated without a shroud. General distortion again resulted, but no skin buckles were present.

The part buckled in the final operation. This failure occurred at a point where the plastic inserts had ex-

3.32 COMPRESSION FORMING - Test No. 3 (Cont'd.)

cessive clearance.

The following tentative conclusions were reached:

(a) Parts with the configuration of P. D. 903-23 would not develop local skin buckles due to heat treatment, at least not in the part size used for the preliminary tests.

(b) Plastic inserts were not entirely satisfactory as a means of supporting the skin against buckling for the reason that they were too rigid to compensate for variations due to machining and other causes.

(c) A means of supporting the skin at all points with a positive outward pressure was needed. The supporting medium used should be sufficiently elastic to adjust itself to variations that might result from normal tolerances.

TEST NO. 4

Several further forming tests on small test parts were conducted in which the plastic fillers were replaced by hard rubber strips faced with sheet metal. The purpose of the sheet metal facing was to provide a surface, next to the part, that while generally flexible, would tend to concentrate force on local buckles.

3.32 COMPRESSION FORMING - Test No. 4 (Cont'd.)

None of these tests resulted in a satisfactory part; however, failure could always be traced to imperfections in the fit of the filler. The erratic support could be attributed largely to lack of precision and uniformity in the internal support.

TEST NO. 5

The results of the above specimen tests were sufficiently promising that plans were made to form full size leading edge integrally stiffened panels. Consequently, leading edge panels were machined to specifications of PD-903-23 as described in 3.31, Test #6 - "Stretch Forming". (Figure 30) The edges of the part were trimmed to a predetermined angle and dimension.

Construction was started on the compression die set. The design of this tool was markedly different than the preliminary dies, but employed the same principle of forming.

The die set (Fig. 49) consisted of (a) a welded steel die cage with plastic working face (Fig. 50), (b) a punch or compression bar assembly shown at top in Fig. 50, and (c) the internal support assembly. The internal support assembly consisted of (1) a cerrobend nose punch visible in Figure 49, (2) rubber filler pads to index with and fill

5.32 COMPRESSION FORMING - Test No. 5 (Cont'd.)

the spaces between stiffeners (Fig. 51), two inflatable and reusable steel bladders attached to a wedge-shaped punch. (Figure 52)

The compression bars were mounted on a steel plate attached to the main ram of a double acting press (Fig. 50). This plate was provided with holes which indexed with leader pins on the top of the die cage and restrained the die against spreading due to forming and internal pressures.

The filler pad consisted of 1-inch thick rubber strips (shore hardness 65), faced with ¼" aluminum sheet, all mounted on .050" thick steel sheet (Figure 51). (The selection of the above rubber hardness was based on preliminary tests conducted to establish rubber hardness and pressure loading required to prevent buckling of the .080" thick skin under simulated forming conditions.)

The pressure bladders were fabricated from two pieces of .040" thick, Type 321, stainless steel roll seam welded at the edges. Each bladder was equipped with two pipe connections, one for introducing hydraulic fluid and the other for bleeding entrapped air. When in use, one bladder was attached to each face of the wedge (Fig. 52). The wedge was actuated by the hold down ram of the forming press.

The trimmed blank in O temper was bent at the nose and

3.32 COMPRESSION FORMING - Test No. 5 (Cont'd.)

placed in the compression die. The nose bending operation was critical due to the large thickness and small radius used, but preliminary bending tests had been conducted to ascertain that such bending could be successfully accomplished. Next, the internal support assembly was inserted in the part.

The die was loaded while out of the press due to insufficient open height in the press. After loading, the die was installed in the press and the rams lowered into place. Only light loads were applied at this time. The hold down ram was used to engage the wedge and restrain it from moving upward. An hydraulic pressure of 200 P.S.I. was then applied to the interior of the two bags on the sides of the wedge, thus forcing the part into intimate contact with the die. The part was then formed to 1% compressive strain by applying force with the main ram to the pushing bars. A strain of 1% corresponded to a punch travel of approximately .4 in. The result of the O temper forming was excellent as shown in Figures 53 and 55.

The part was removed and given a solution heat treatment with cold water quench. The distortion was severe (Fig. 54) and required considerable straightening work before it could again be fitted into the die. The part was held at 0° F. in an ice-box to avoid excessive aging when delays were necessary.

3.32 COMPRESSION FORMING - Test No. 5 (Cont'd.)

The partially straightened part was re-installed in the press and given a final compressive set of 1%. A press load of approximately 600 tons was required. The part before final trimming is shown in the center of Fig. 55.

An analysis of the results indicated:

(a) Springback was slight.

(b) Local skin distortion was present (Fig. 55a). This distortion was traceable to the severe heat treatment distortion. It was concluded that 200 P.S.I. hydraulic pressure in the bladders was insufficient to remove the severe heat treat distortion.

(c) One region in the reinforced skin border, largely outside of the trim lines, had buckled slightly due to lack of internal support.

It was concluded from this test that forming by straight compression had definite possibilities, especially if heat treatment distortion could be reduced. Methods which might be explored are:

(a) Use of a hot water quench bath.

(b) Use of restraining jig.

(c) Use of a shroud designed to equalize somewhat the quenching rates of the thin and thick sections of the part.

TESTS

STRETCH-COMPRESSION FORMING OF LEADING EDGE PANELS

In compression forming, difficulties were encountered principally due to skin distortion resulting from quench after heat treatment, while in stretch forming such buckles were readily removed. On the other hand, in stretch forming a lack of accessibility was a serious barrier to forming the nose section while no real difficulty with this feature was encountered during compression forming. These offsetting characteristics suggested that a two-stage forming operation might incorporate the advantages of both methods. Such a method, described in 3.31, "Tests - Leading Edge Panels", was tested.

TEST NO. 6

This test was run in conjunction with Test #6, Section 3.31, "Stretch Forming". The blanks employed were products of the above mentioned stretching tests. Compression forming dies were those used in Tests No. 1, 2, 3, 4 and 5 of this section.

As described in 3.31, the specimens were stretched to an open contour. The upper and lower surfaces were brought to true contour but six inches of material at the entering edge were left flat. The resulting stretched specimens

3.32 COMPRESSION FORMING - Test No. 6 (Cont'd.)

were entirely free of quench distortion and buckles. The specimens, while still in the S-W temper, were trimmed to the predetermined edge angle, placed in the compression die, and yielded compressively approximately 1%.

The first specimen, compressed with no internal support, failed by buckling. This tended to verify the assumption that the force couple at the stiffener ends would induce failure by buckling regardless of the fact that the part was free of quench distortion.

The second specimen, supported with the fabricated rubber filler described in Test #4, also failed by buckling. The conclusions in this case were the same as above and pointed to the need of higher contact pressures on the filler blocks.

A third specimen was compressed which featured a reduced section at the entering edge (.100 in.). Although this part was supported with wood blocks only, it formed very satisfactorily. Contour and surface smoothness were equal to requirements. (Figures 56 and 57)

TEST NO.7

Sufficient data was available from the foregoing tests to warrant attempts to form a full size leading edge panel by

3.32 COMPRESSION FORMING - Test No. 7 (Cont'd.)

the two-stage method. As in the specimen tests above, pre-stretched panels were obtained as a result of the work done in Test #6, Section 3.31. The compression forming tools employed were those used in Test #6, 3.32. After the stretched panels had undergone initial trimming to the predetermined edge angle, the 6-inch flat area at the entering edge was milled down in thickness from .250" to .220". The purpose of this operation was to insure adequate yield in this area in view of the loss of compressive force through frictional effects over the full length of the part. The thinning operation was done while the panel was held by means of a contoured, plastic-faced vacuum hold down jig (Fig. 58), mounted in the Hydrotel (Fig. 59).

After the thinning operation, the part was rough bent in the 20-ton Ceco (Fig. 60).

The compression forming procedure was accomplished as described in Test #6, and the parts were formed while still in the S-W temper resulting from heat treatment prior to the stretch forming. The resulting part after final trim is shown in Figure 61.

An analysis of the part revealed the following:

(a) A slight corrugation effect was apparent on the outer surfaces. As described in Section 3.31, Test #6, this roughness was traced to incorrect

3.32 COMPRESSION FORMING - Test No. 7 (Cont'd.)

fit of the stretch dies, and therefore could not be attributed to inefficiency of the compression forming dies.

(b) Airfoil contour was exceptionally good.

It was therefore concluded that with properly fitting dies in the first forming stage, integrally stiffened leading edge panels of this type could be efficiently formed by the two-stage stretch-compression method.

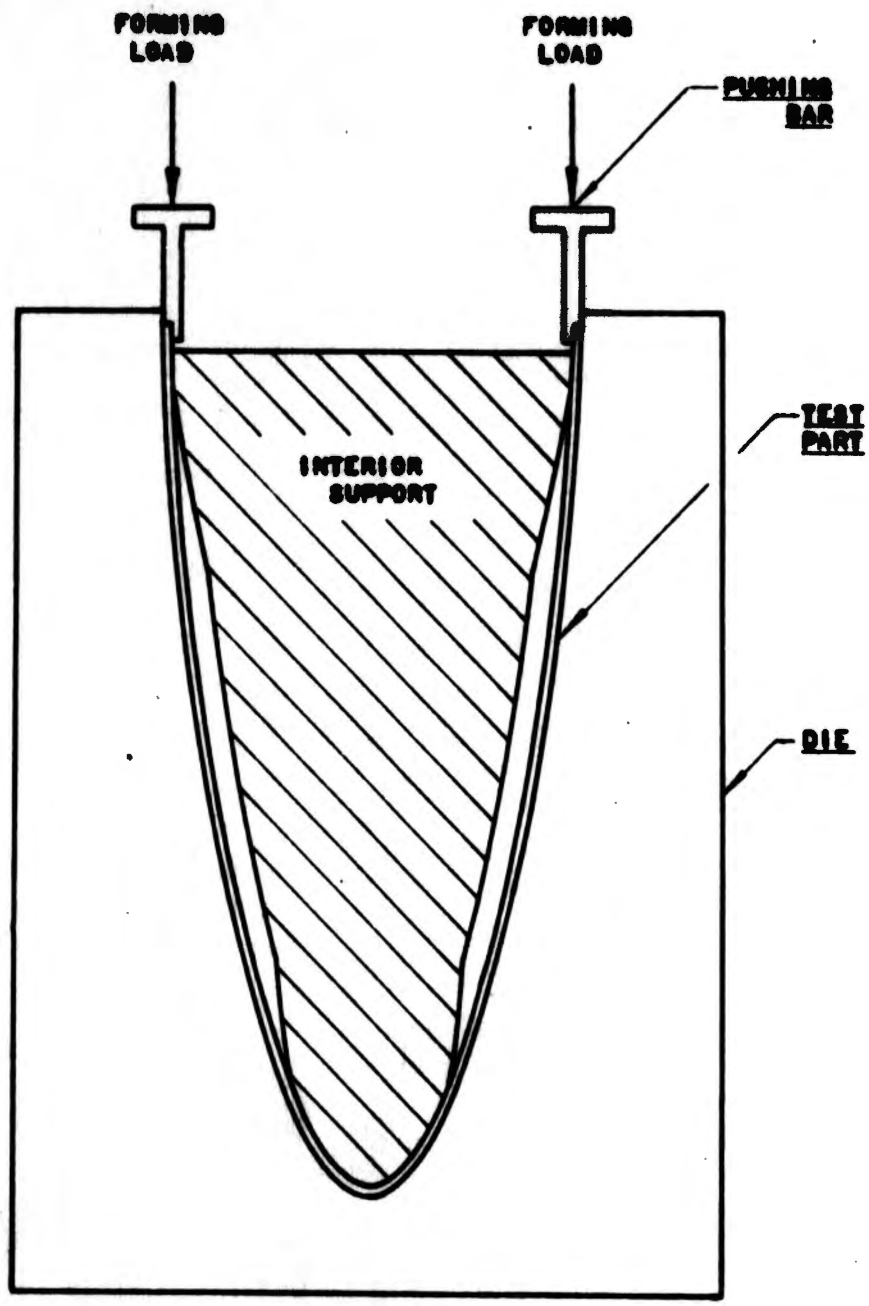

FORMING LOAD
FORMING LOAD
PUSHING BAR
TEST PART
INTERIOR SUPPORT
DIE

FIG. 38

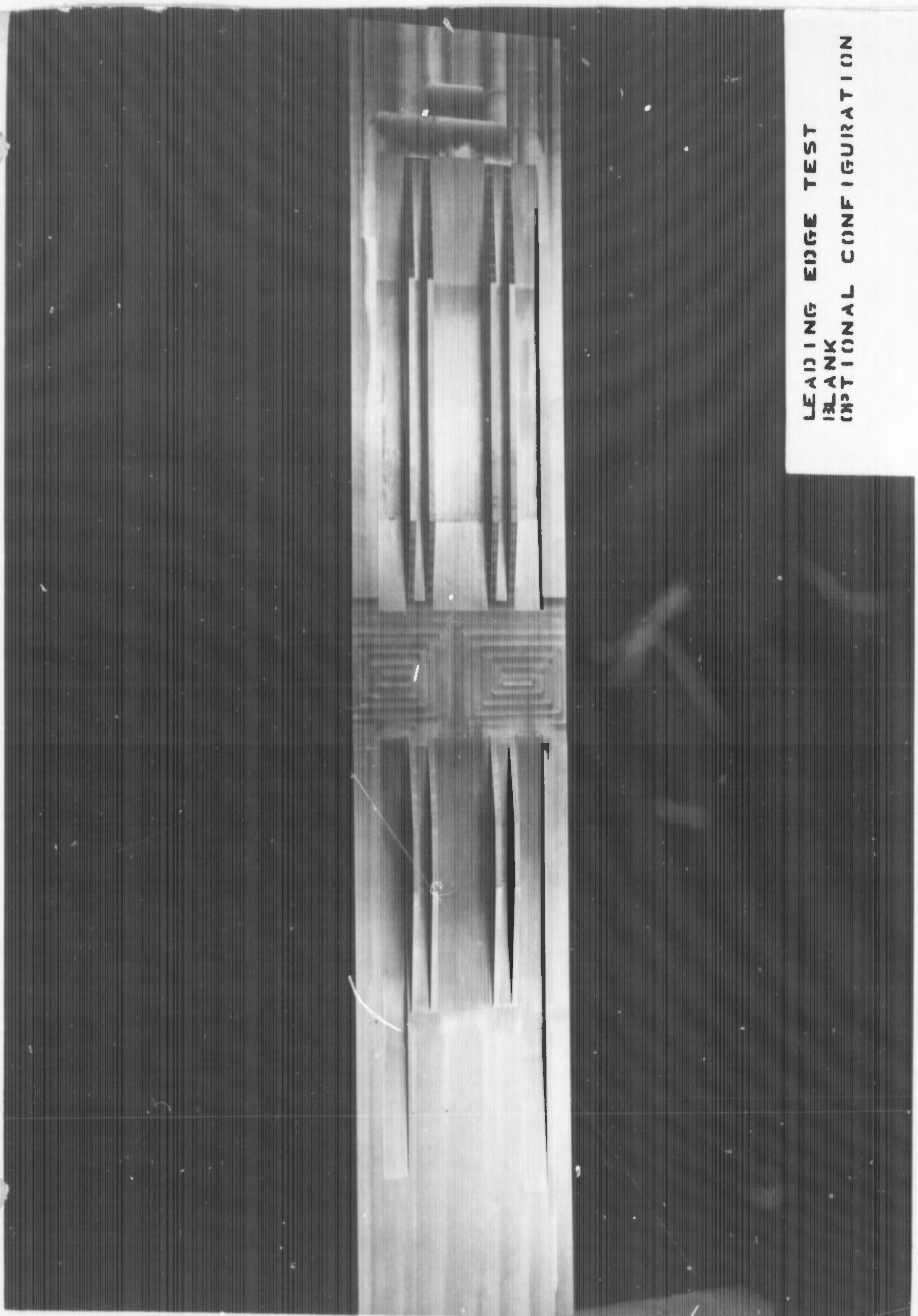
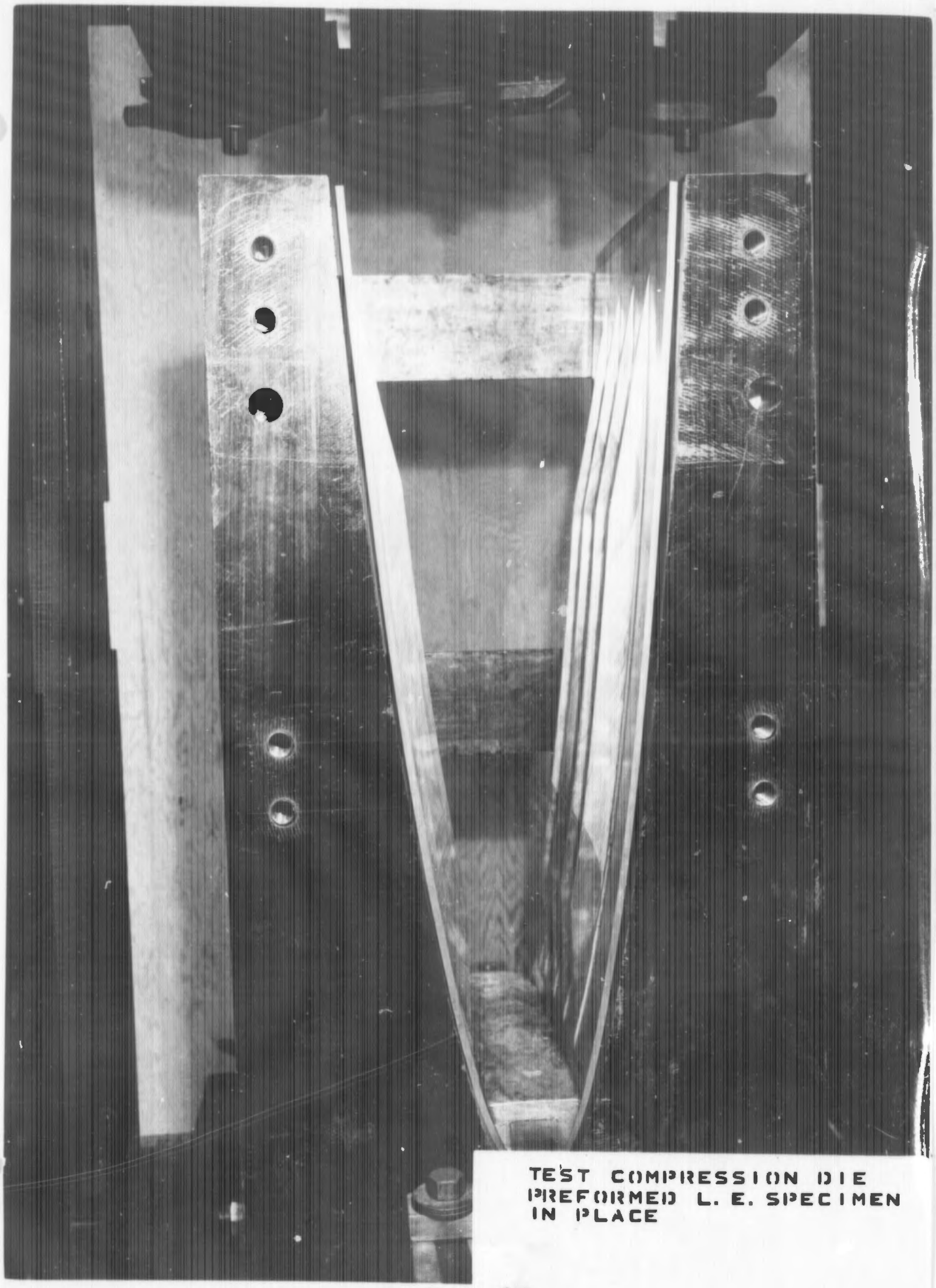
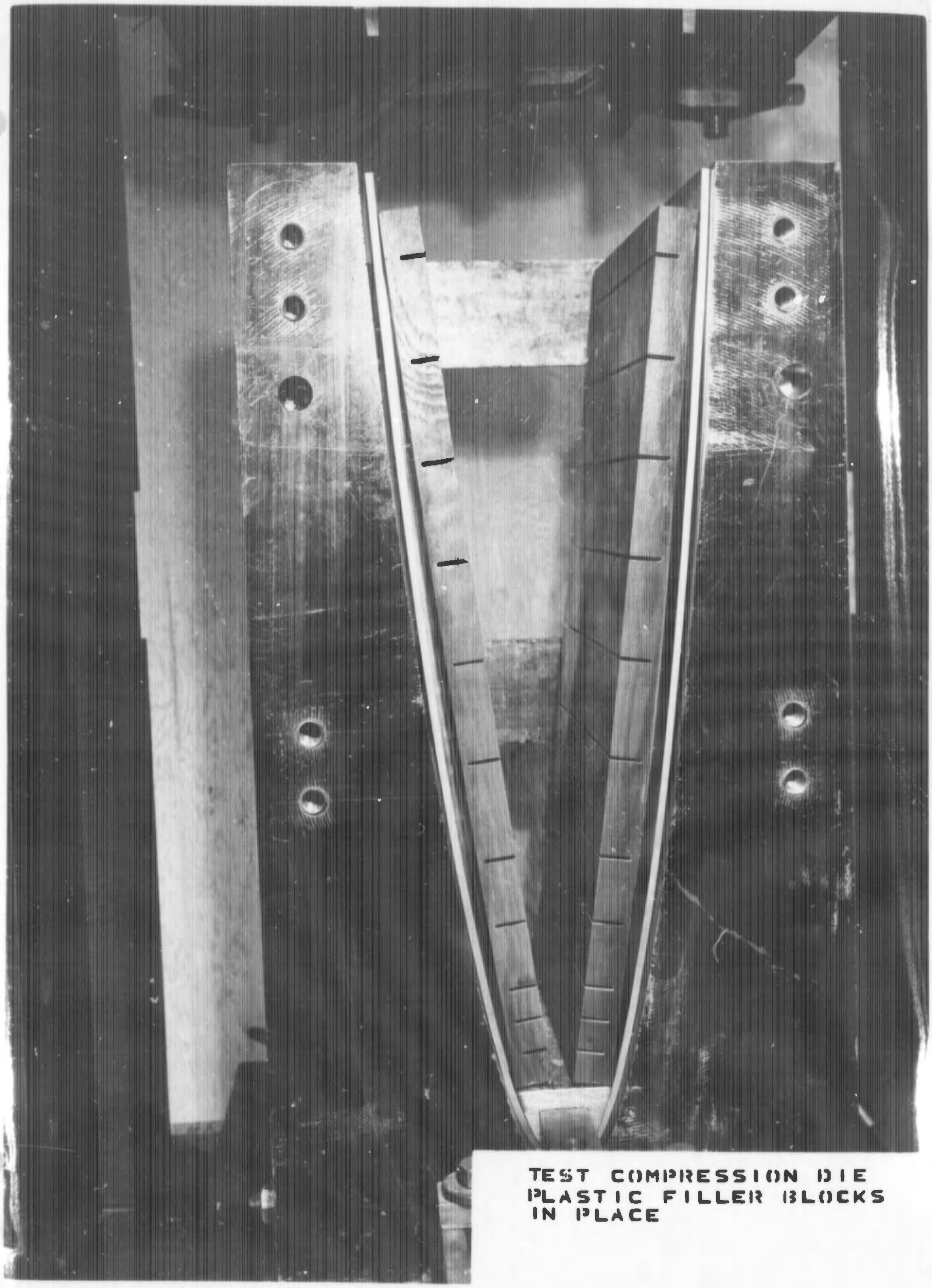


FIG.39



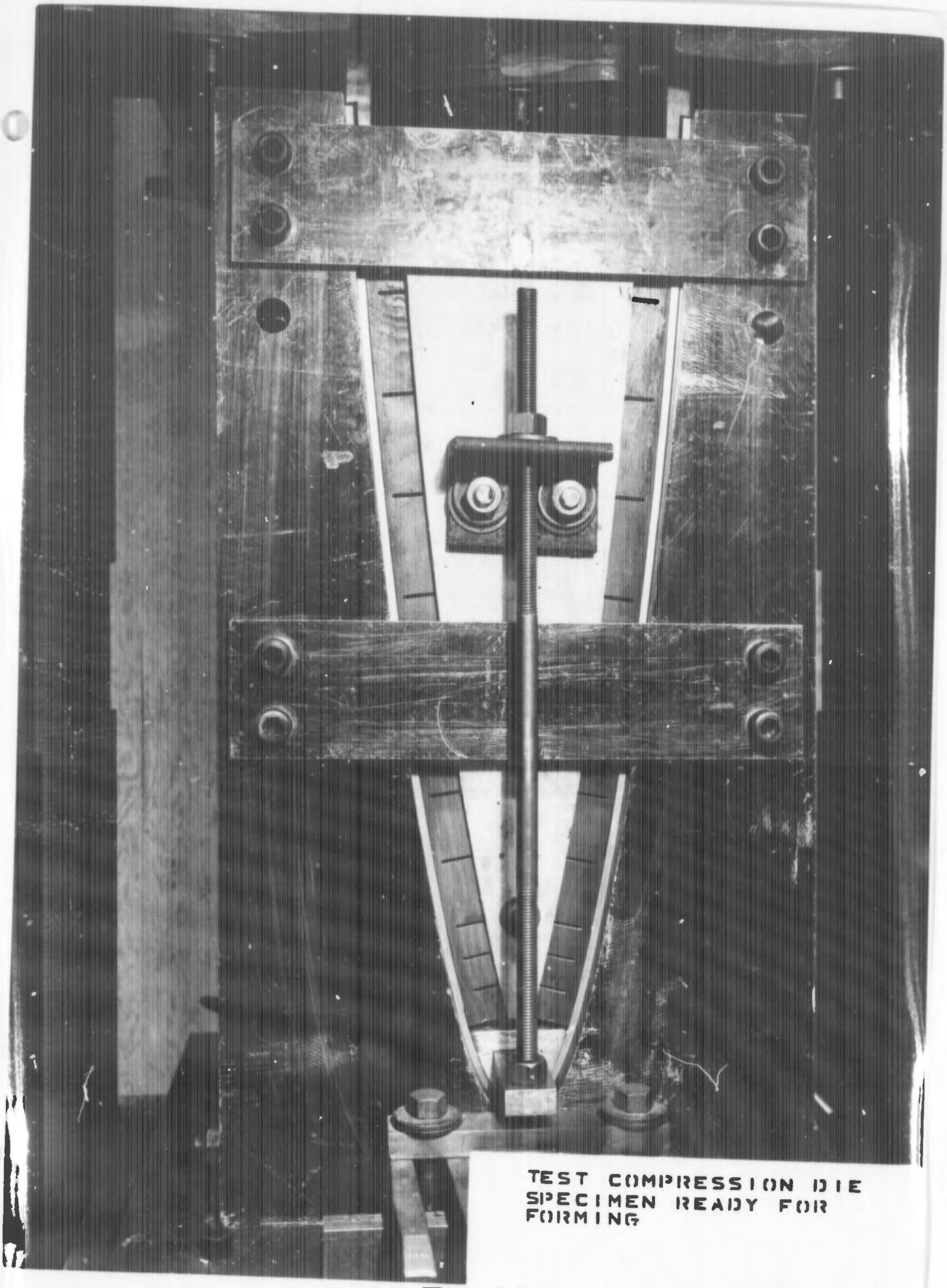
TEST COMPRESSION DIE
PREFORMED L. E. SPECIMEN
IN PLACE

FIG.40



TEST COMPRESSION DIE
PLASTIC FILLER BLOCKS
IN PLACE

FIG 41



TEST COMPRESSION DIE
SPECIMEN READY FOR
FORMING

FIG. 42

TEST SPECIMEN SHOWING
QUENCH BUCKLES IN WEB

FIG 43

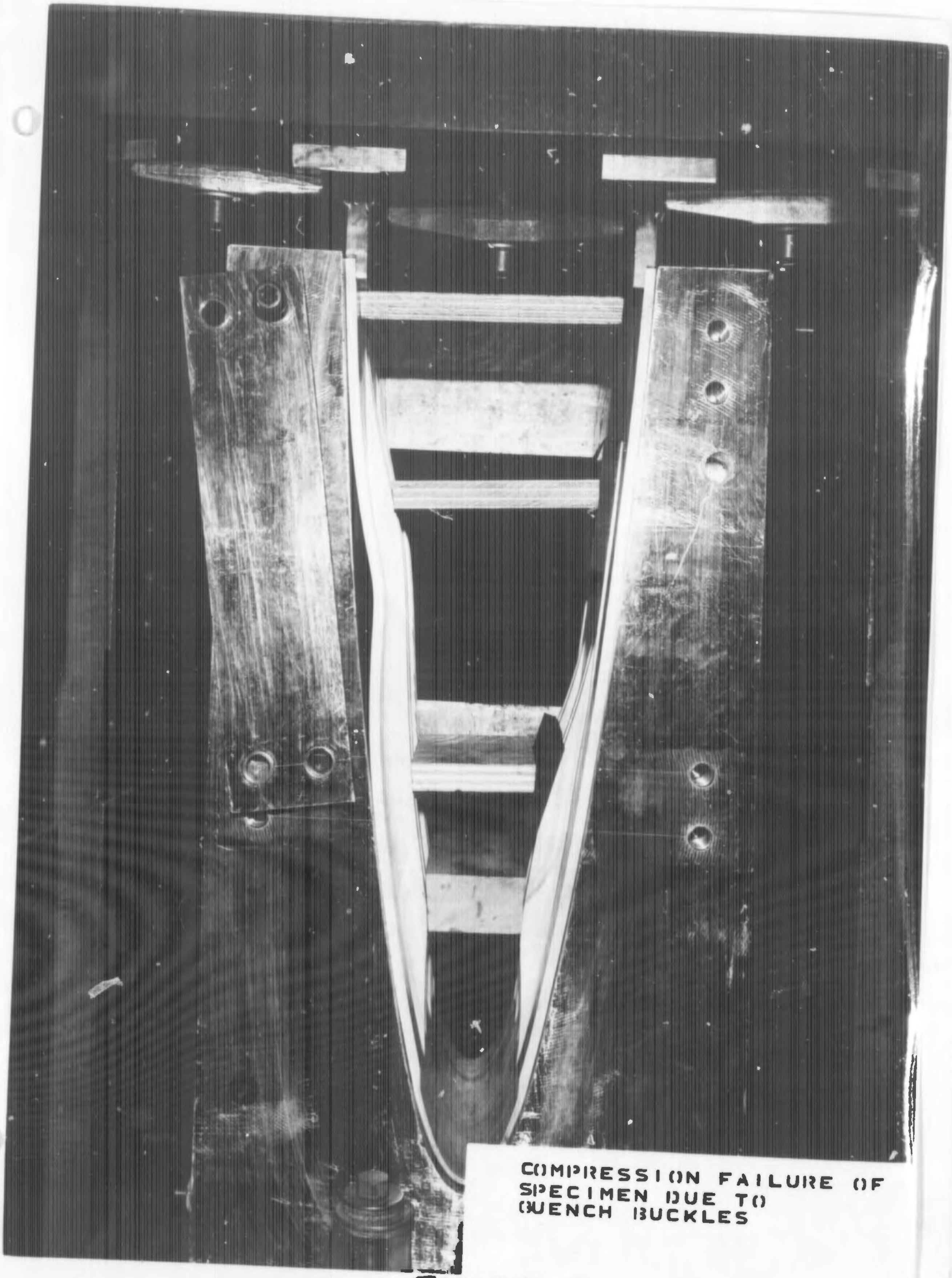


FIG. 44

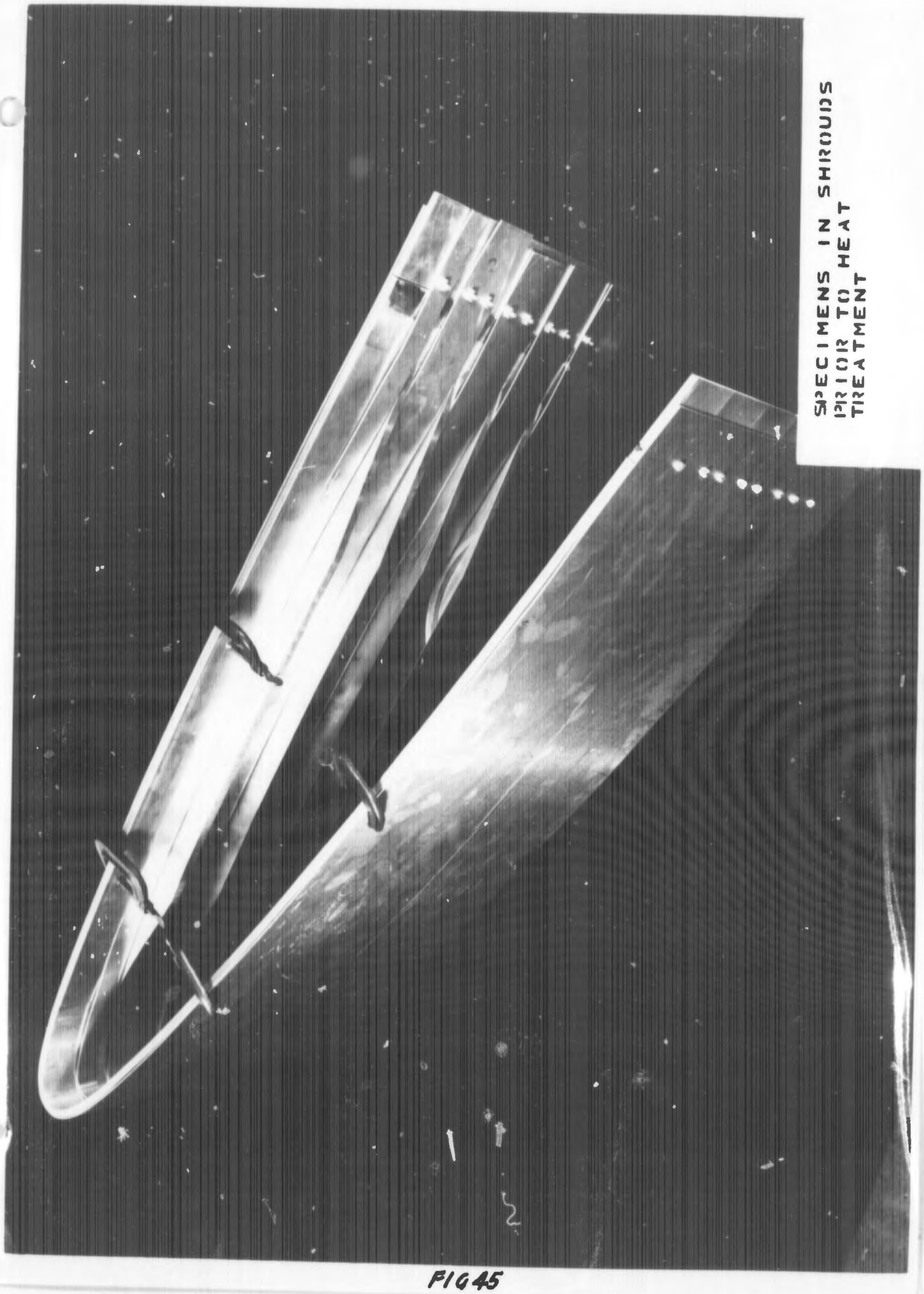


FIG 45

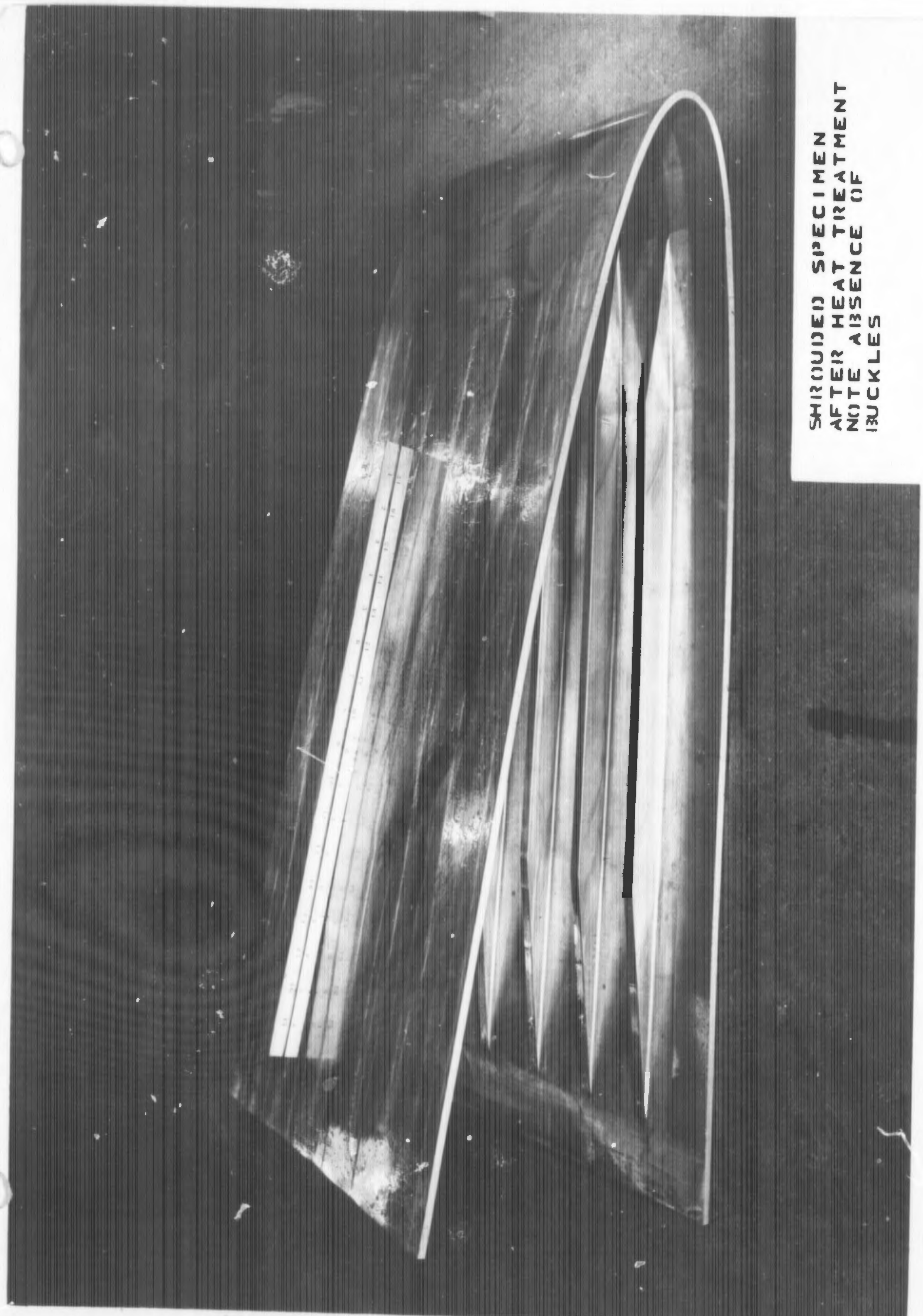

SHROUDED SPECIMEN
AFTER HEAT TREATMENT
NOTE ABSENCE OF
BUCKLES

FIG.46

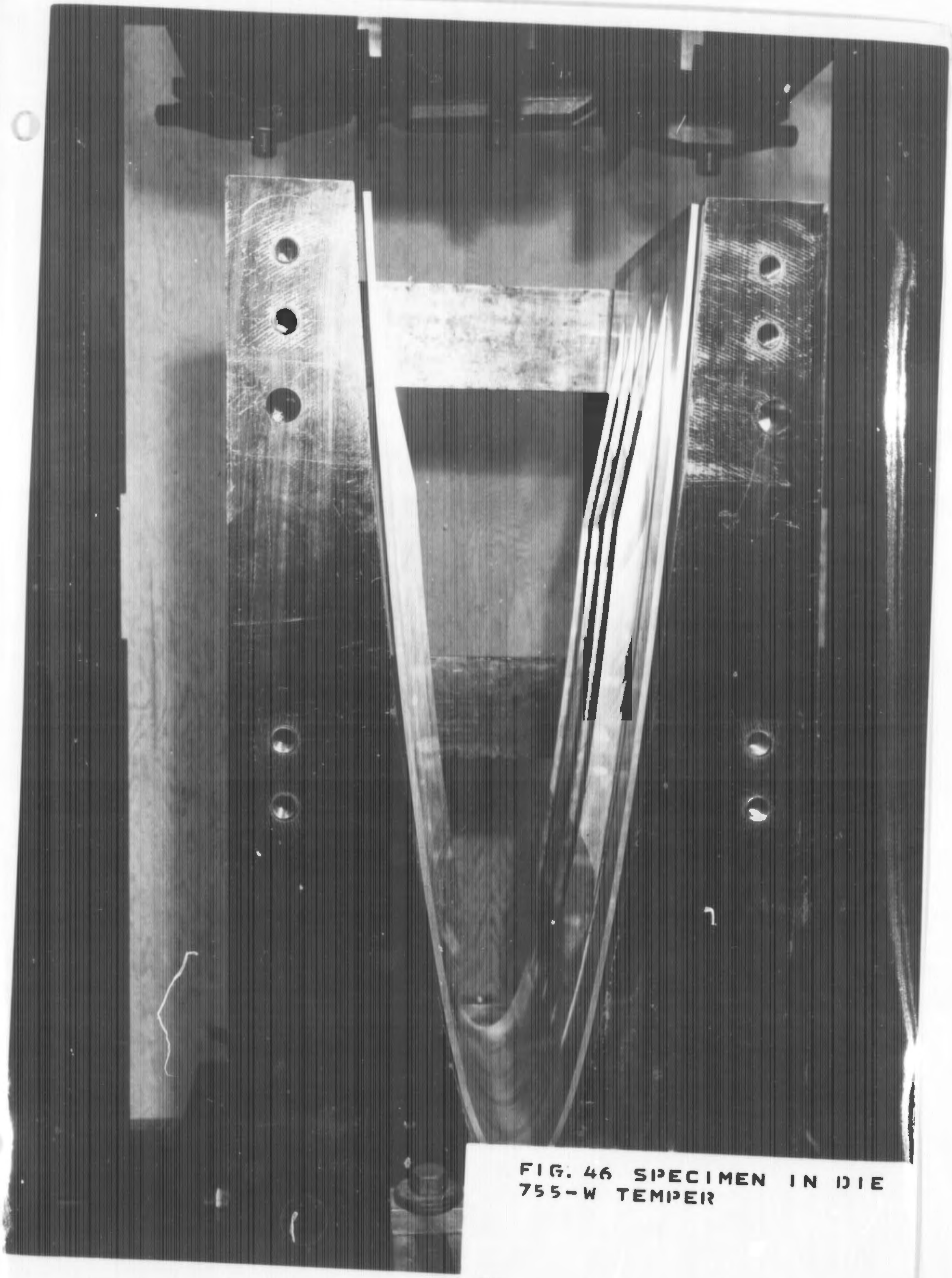


FIG. 46 SPECIMEN IN DIE
75S-W TEMPER

FIG 47

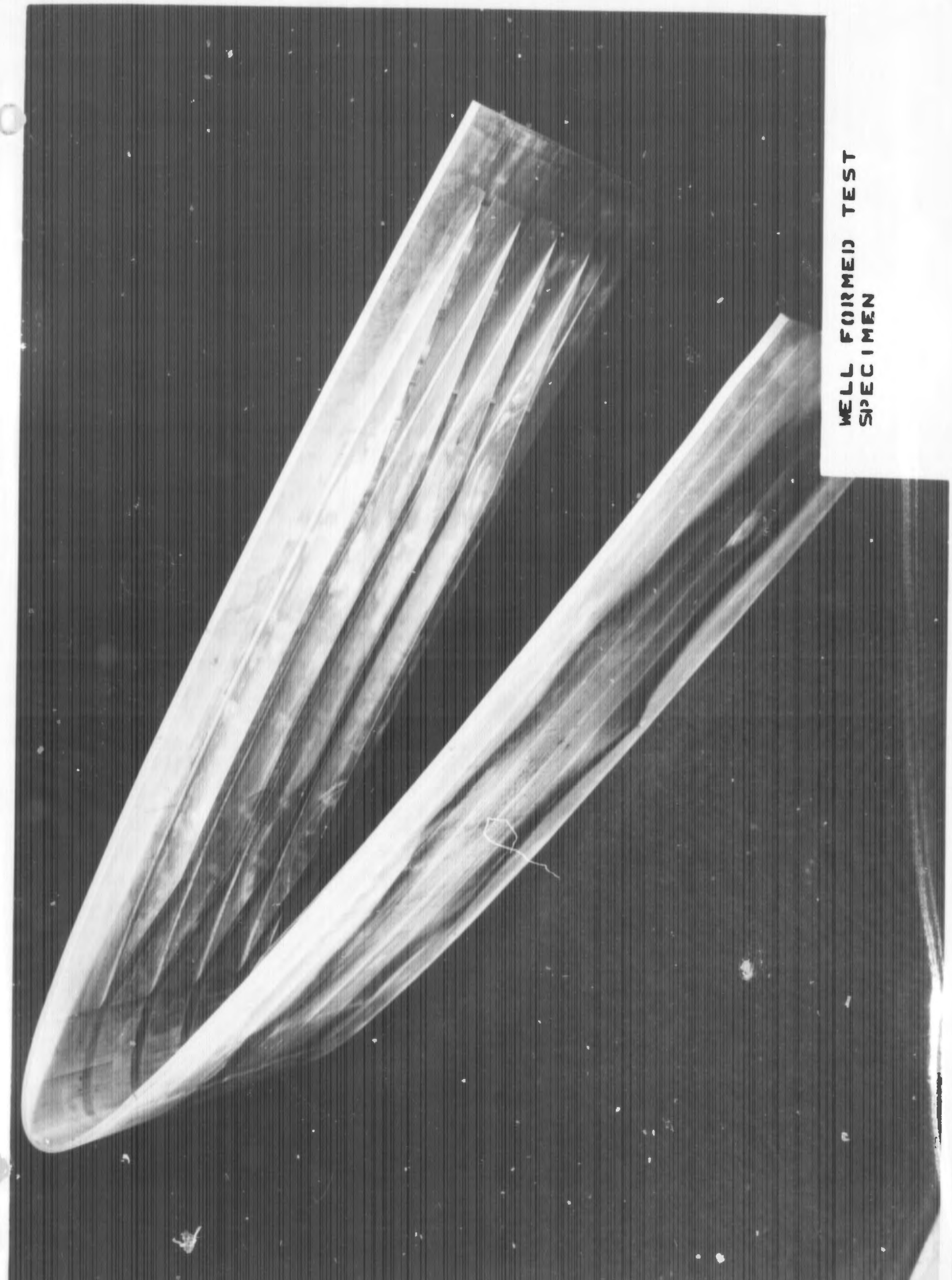


FIG 48

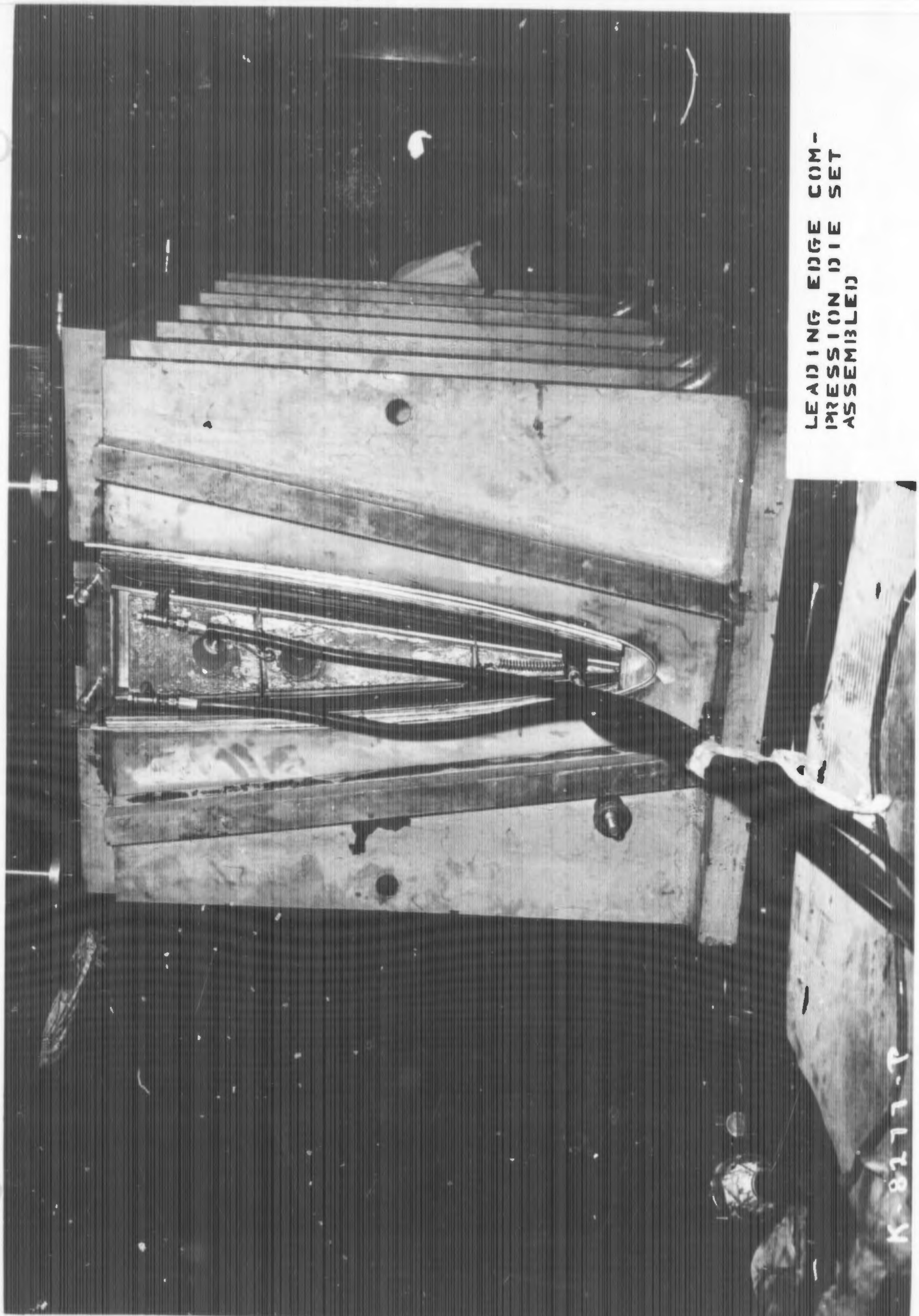
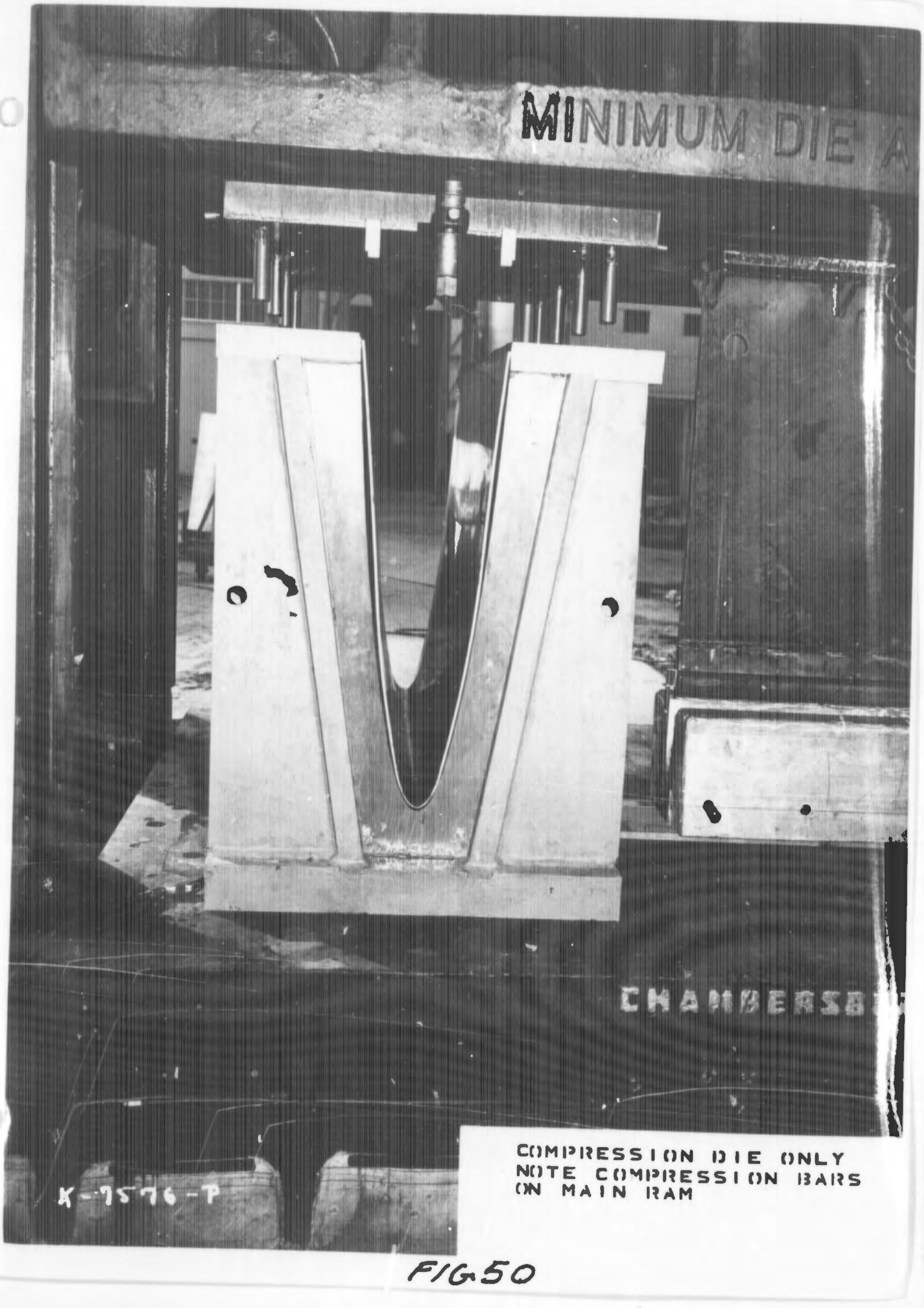


FIG 49



COMPRESSION DIE ONLY
NOTE COMPRESSION BARS
ON MAIN RAM

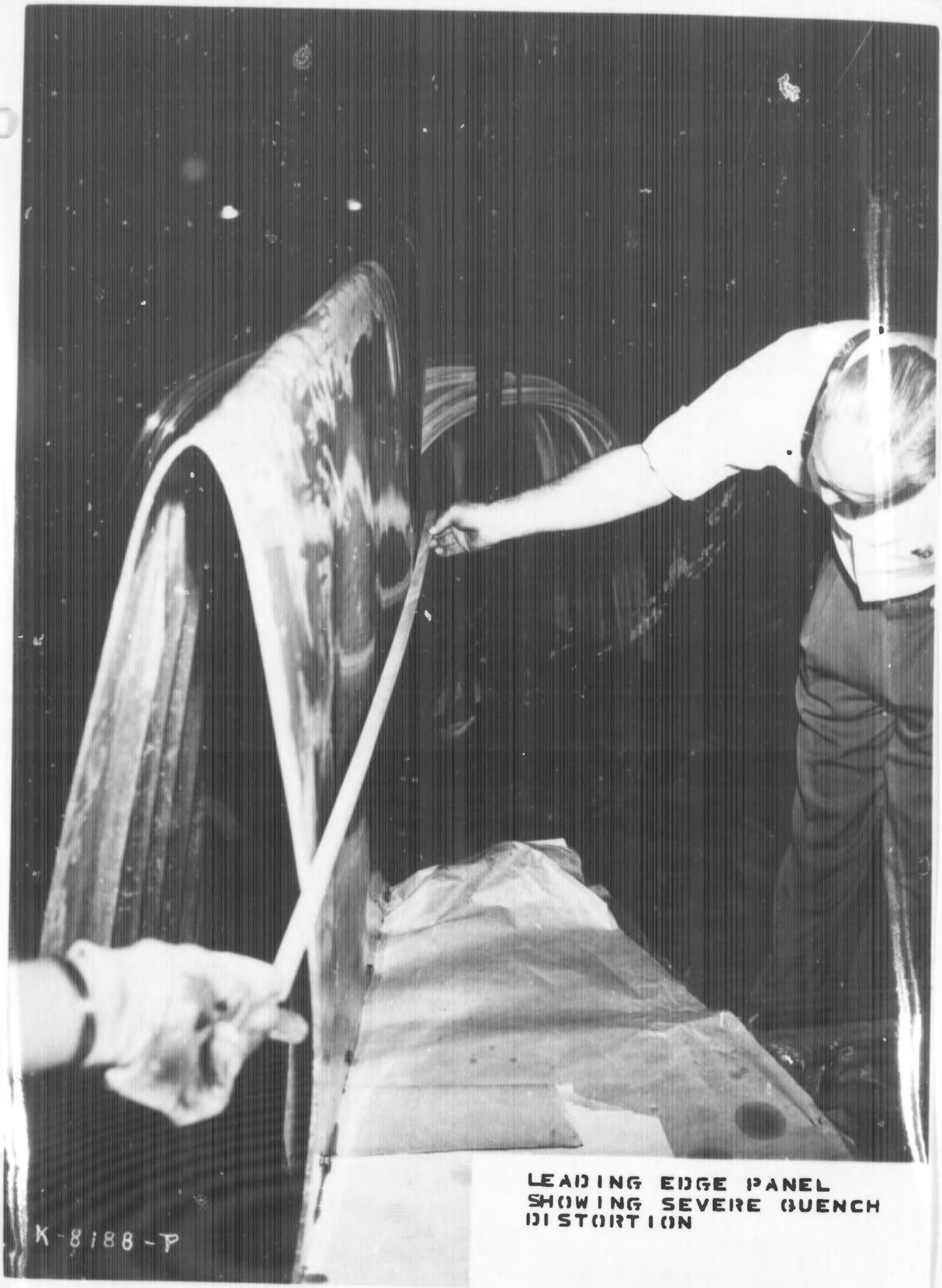
FIG 50

FIG. 51

FIG. 52

LEADING EDGE PANEL
FORMED IN 'O' TEMPER
NOTE CONFORMATION TO
CONTOUR

FIG.53



LEADING EDGE PANEL
SHOWING SEVERE QUENCH
DISTORTION

FIG 54

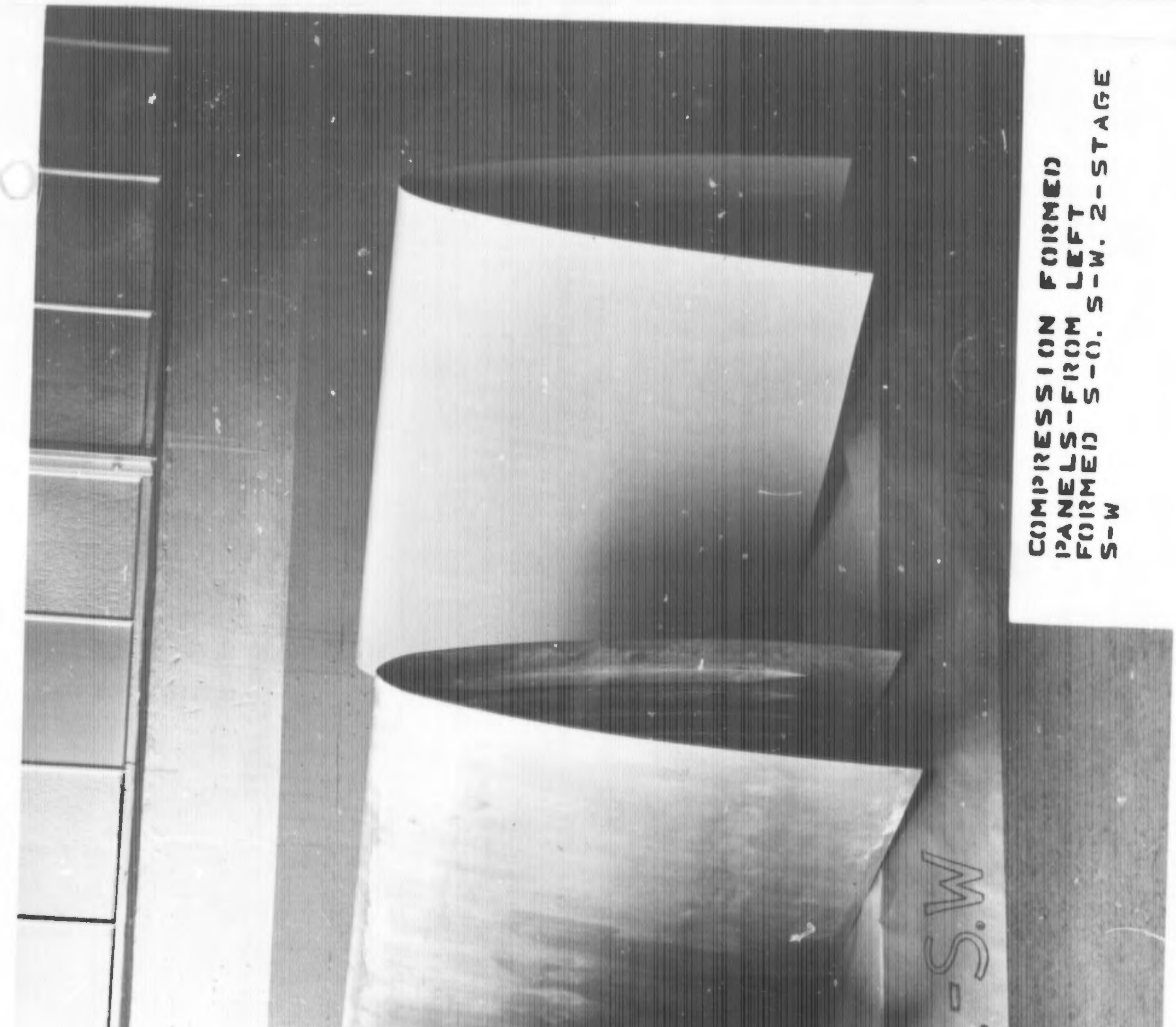
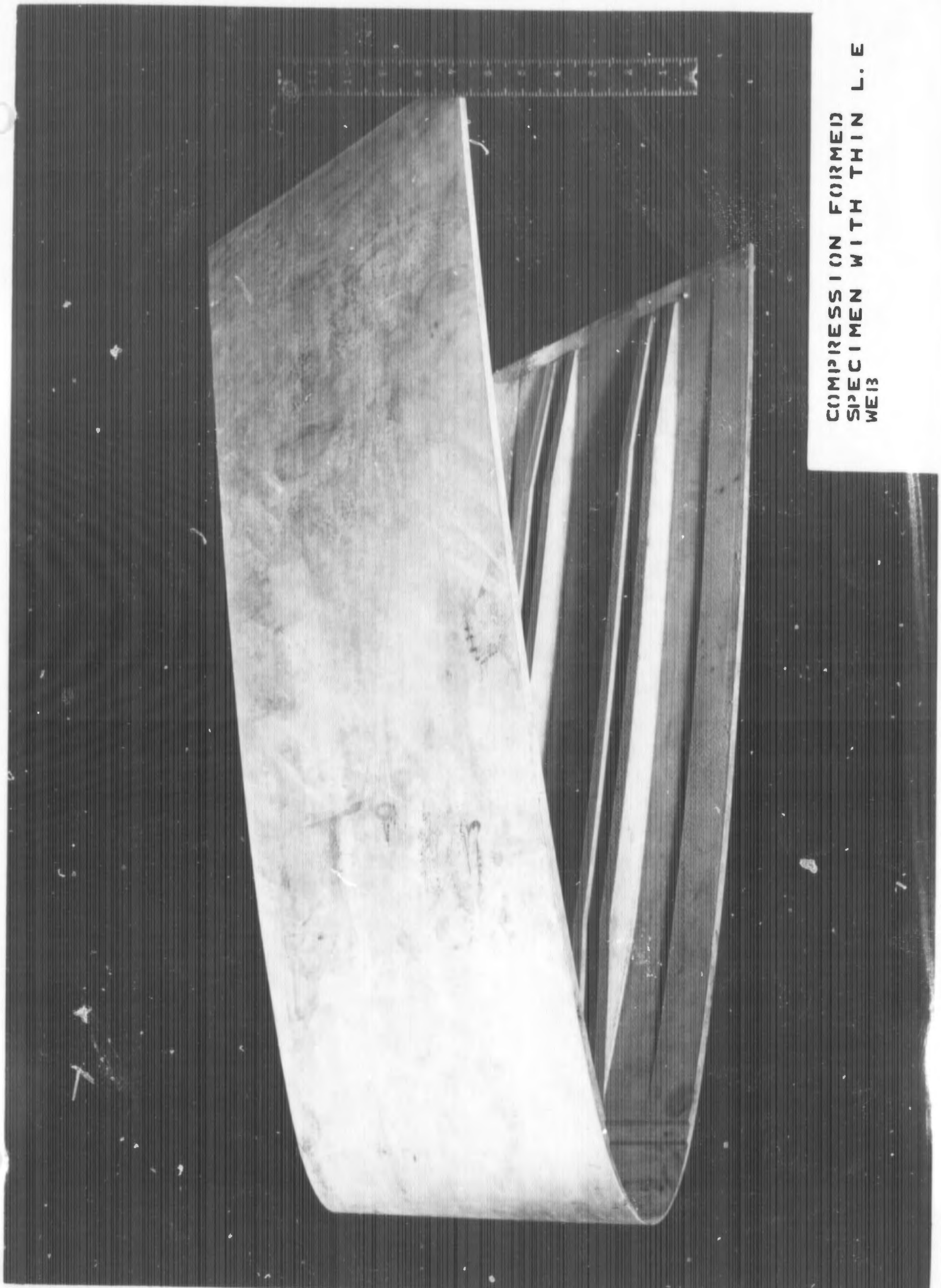

COMPRESSION FORMED
PANELS-FROM LEFT
FORMED S-O. S-W. 2-STAGE
S-W
S.O.-S.W
K-8360-T

FIG. 55


REMAINING DISTORTION
AFTER FIG. 54 SPECIMEN
WAS COMPRESSION FORMED
K-8180-P

FIG 55A



COMPRESSION FORMED SPECIMEN WITH THIN L. E WEB

FIG 56

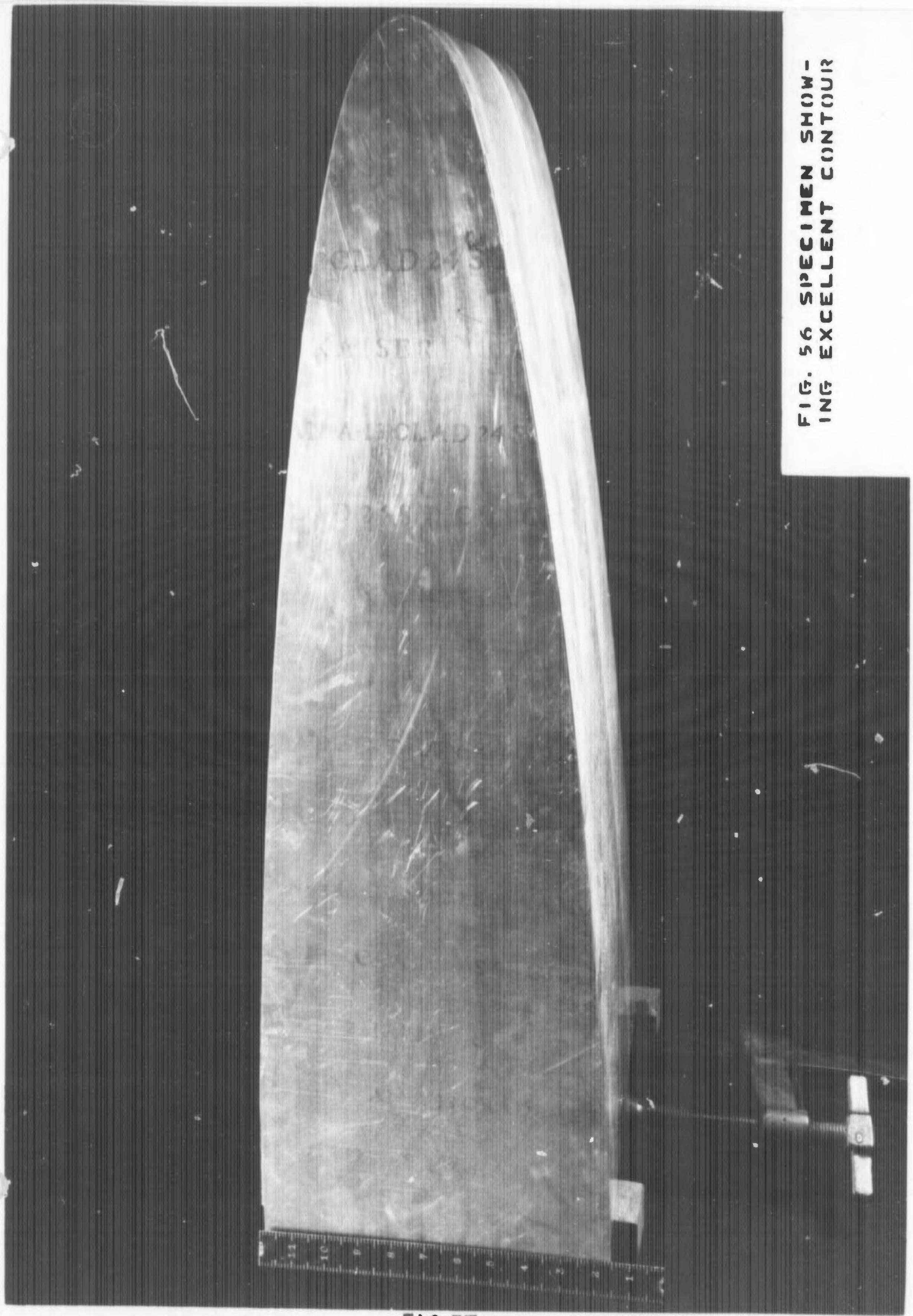


FIG. 56 SPECIMEN SHOWING EXCELLENT CONTOUR

FIG 57

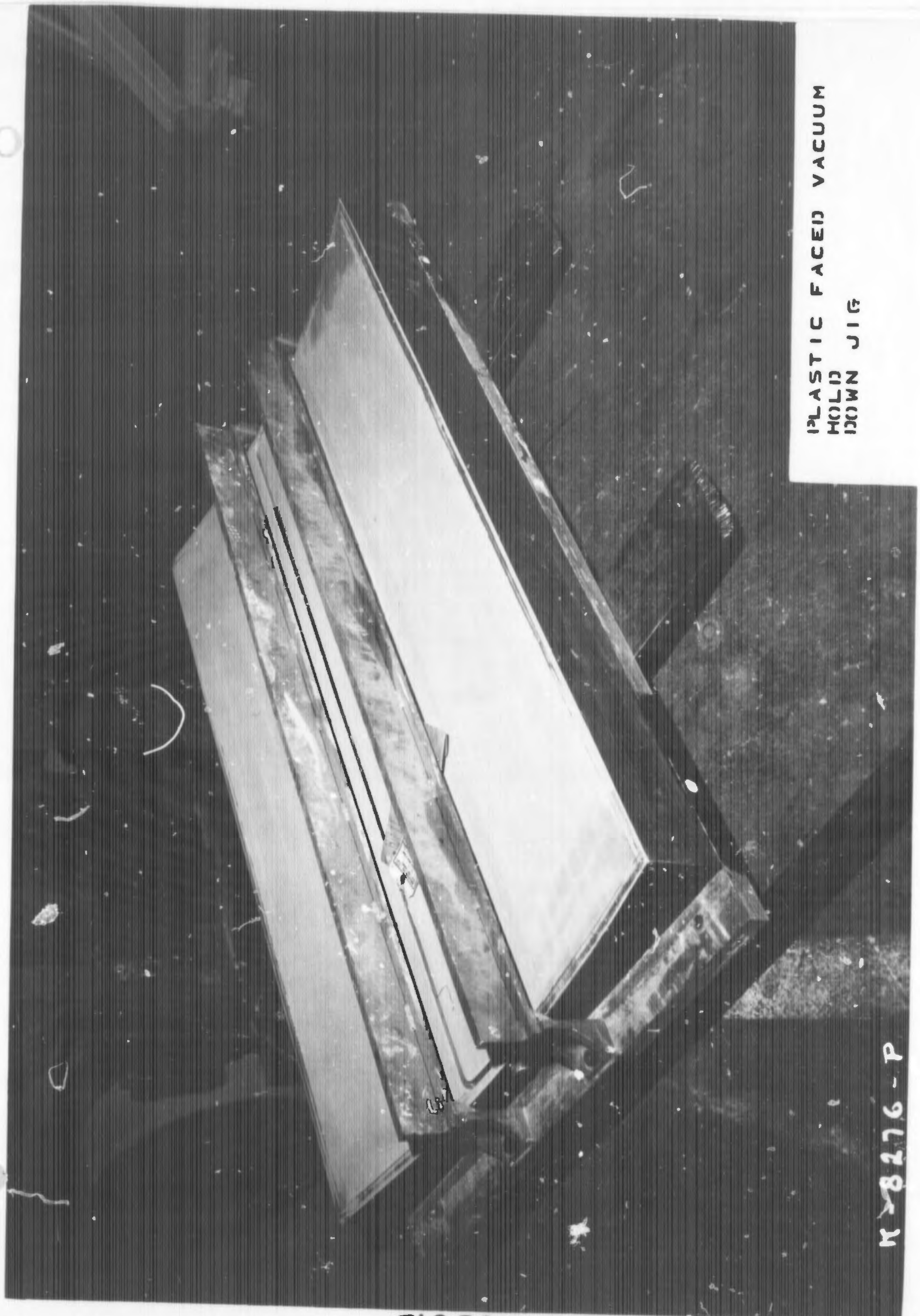


FIG.58

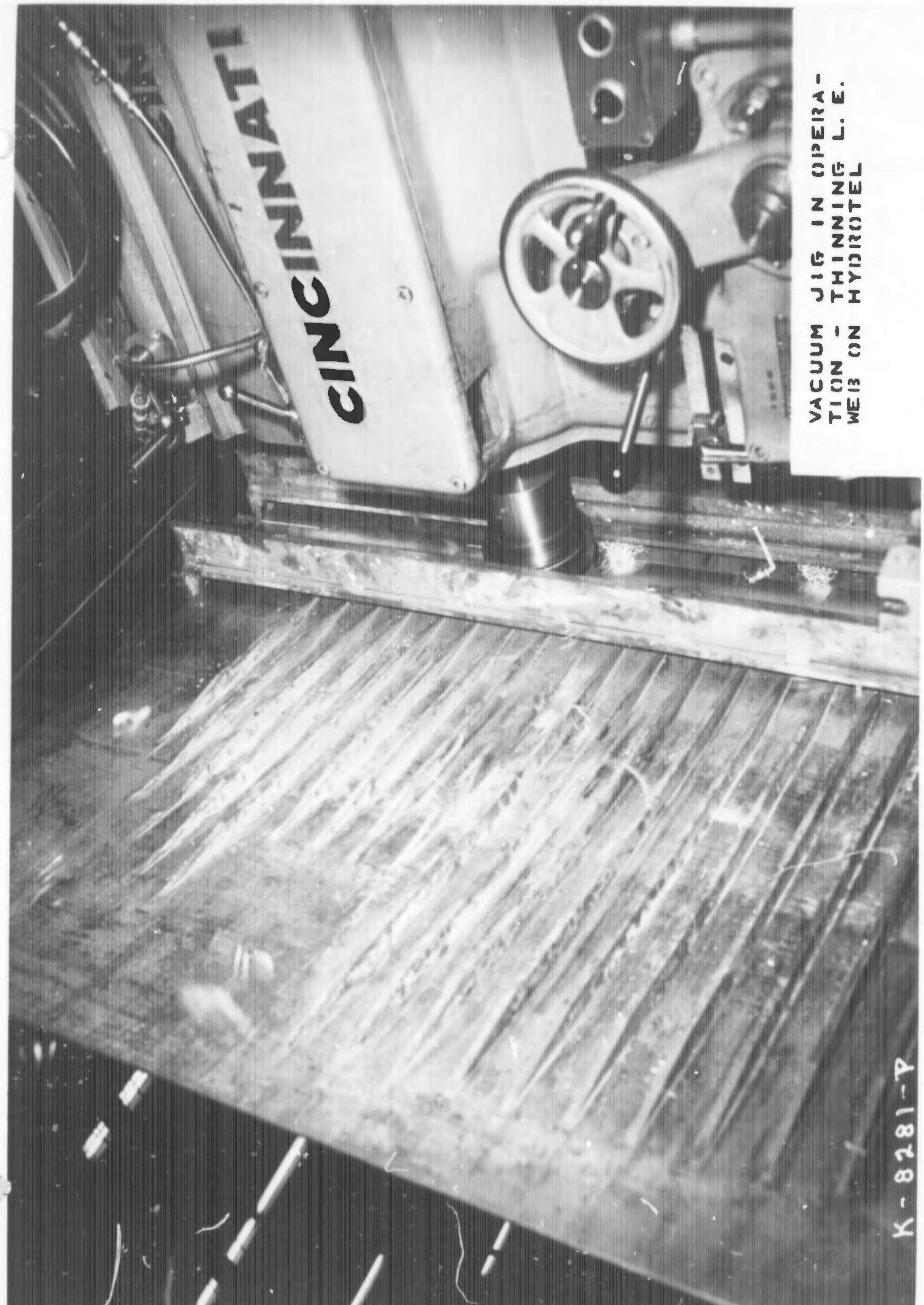

CINCINNATI
VACUUM JIG IN OPERATION - THINNING L. E. WEB ON HYDROTEL
K-8281-P

FIG.59


BENDING ENTERING EDGE
IN 20 TON CECO
PRE-STRETCHED PANEL
K-8285-T

FIG 60


LEADING EDGE INTEGRAL-
LY STIFFENED PANEL
STRETCH-COMPRESSION
FORMED
K-8359-P

FIG.61

3.3 TEST PROCEDURE (Cont'd.)

3.33 RUBBER FORMING

The principle feature that prompted this investigation was the simplicity and low cost of rubber forming as a production method. The original plan for investigation of rubber forming was to conduct tests utilizing the fluid pressure of a rubber platen, single action press to form parts by bending them to a contoured die surface. This technique is similar to the one commonly employed by the industry to bead and flange sheet metal detail parts. Tests were made exploring the possibilities of the method.

During the course of the program, however, the keyed clamping rail for stretch forming was developed (3.31). The practicality of the key as a method of restraining part movement, plus the obvious advantage to be gained from inducing some permanent elongation in the inner fibers of the section, led to the investigation of a combination method known as rubber stretch forming.

EQUIPMENT

All rubber forming tests were conducted on a 2250-ton HPM, rubber platen, single action press and 1500-ton Clearing double action press.

TESTS

All tests were conducted using the standard 75S-0 or 75S-W upper surface test specimens, as described in 3.31, altered to suit the conditions of the particular test.

3.33 RUBBER FORMING - Tests (Cont'd.)

TEST NO. 1

Three specimens of considerably reduced area were machined. The forming tool employed was a Kirksite die block of 100-inch radius.

The die block was placed on the bolster of the HPM rubber platen press and the specimen placed over the contoured surface. (Fig. 62) Plywood strips equal to the stiffener heights were placed between the stiffeners to protect the rubber faced platen. On the pressing stroke a rubber pressure of approximately 1000 P.S.I. was exerted.

Specimens were formed in S-O, fresh S-W and 16-hour S-W tempers. The resulting springback confirmed predictions that die compensation for this factor would be difficult. (See 3.34, Die Forming Test No. 2) It was also found that warpage and distortions caused from machining and heat treatment were not removed by forming in pure bending.

TEST NO. 2

As a result of the above findings, it was decided to discontinue the investigation of straight rubber bending and to explore a new technique known as rubber-stretch forming. This process utilizes the fluid force of the rubber platen to bend and bulge the part against a female form die. The part ends are restrained from movement and as a result, in the process of conforming to the die contour, uni-axial stretching occurs and some permanent elongation is imparted to all fibers of the cross section.

3.33 RUBBER FORMING - Test No. 2 (Cont'd.)

Standard test specimens were machined which embodied a version of the key-type ends described in 3.31, Test No. 2, "Stretch Forming". A die set consisting of the following parts was constructed;

1. A Kirksite retaining ring and clamping rail.
2. Cast plastic die containing desired forming radius.
3. Steel restraining clamps or hooks.
4. Fillers or pressure pads between stiffeners.

The ring or rail structure was cast from Kirksite. The plastic die was cast to a plaster mold containing a 150-inch radius forming surface. Shims were provided to adjust the die up or down in the Kirksite cavity in order to obtain various degrees of elongation in the stretch specimen. Two restraining clamps or hooks were machined from steel. Both aluminum and rubber filler strips were used to protect the rubber platen as well as to impart forming pressure on the web areas. (Figs. 63 and 64)

The 75S-W specimen was mounted in the die and the steel clamping hooks engaged with the keyed ends of the specimen. This assembly (Fig. 65) was placed in the HPM press and subjected to rubber pressure of 1000 P.S.I.

Measurements of the resulting formed specimens revealed;

(a) Springback of .070 in. measured at the midpoint of the specimen.

(b) Very slight elongation in inner fibers.

3.33 RUBBER FORMING - Test No. 2 (Cont'd.)

(c) Some distortion remaining from heat treatment.

(d) Distortions at the stiffener ends caused by the force couple set up at this point.

These results indicated, however, that rubber pressures somewhat greater than 1000 P.S.I. might reasonably be expected to give good results.

TEST NO. 3

A new steel die set based on the design principle of that used in Test No. 2, but of considerably heavier construction was made. (Fig. 66) Standard, keyed-end specimens were machined. These were, however, 24-inches wide, or twice the normal width.

This die set was placed in the 1500-ton, double action Clearing press. To the main ram of the press was affixed a special flat punch which, when lowered, fitted closely into the opening of the retaining ring.

The parts were placed in the die with the ends engaging the die keys. Rubber fillers were placed between the stiffeners. Over the part was placed a blanket of rubber 3-inches thick which closely fit the confines of the retaining ring.

On the forming stroke, rubber pressures of 1000 P.S.I. to 2200 P.S.I. were applied in several tests.

3.33 RUBBER FORMING - Test No. 3 (Cont'd.)

Measurements of the resulting formed specimens showed that the contour achieved was good. Some distortion from heat treatment remained, and it was evident that the available pressures, while producing moderate elongation (1%), were not sufficient to flatten and hold these buckles during forming while the part was in the plastic range. (Fig. 67)

It was concluded that considerably higher unit pressures would be required before adequate forming could be achieved. It was estimated that these unit pressures would be in the neighborhood of 3500 P.S.I., or beyond the capacity of the largest press at Lockheed. It was estimated that to form the full size integrally stiffened upper surface panel, press capacity of 8000 to 10,000 tons would be required.

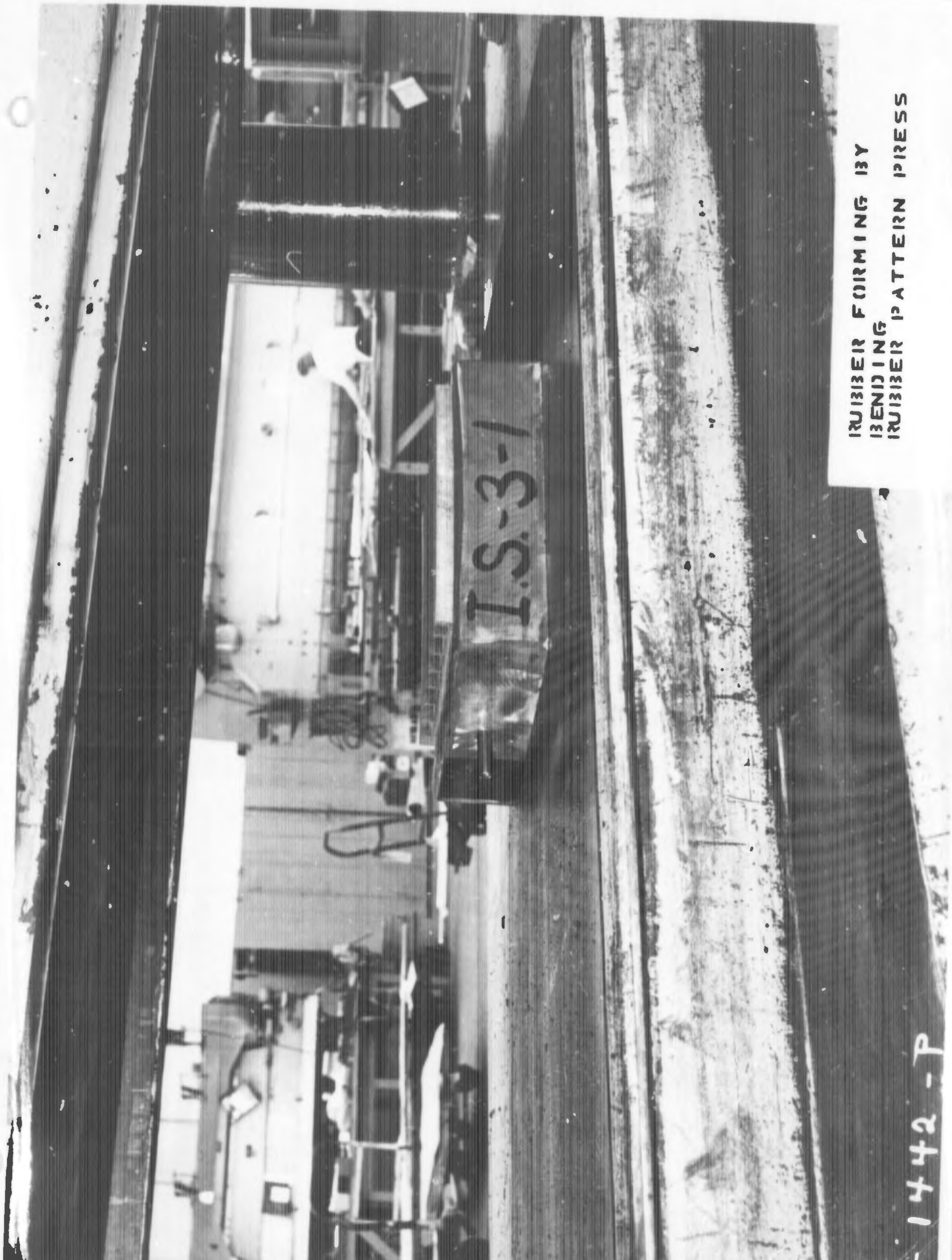

RUBBER FORMING BY
BENDING
RUBBER PATTERN PRESS
I.S.-3-1
K-1442-P

FIG. 62


RUBBER-STRETCH FORMING
TEST DIE-NOTE BLANK &
FORMED SPECIMENS
K-2250-P

FIG. 63

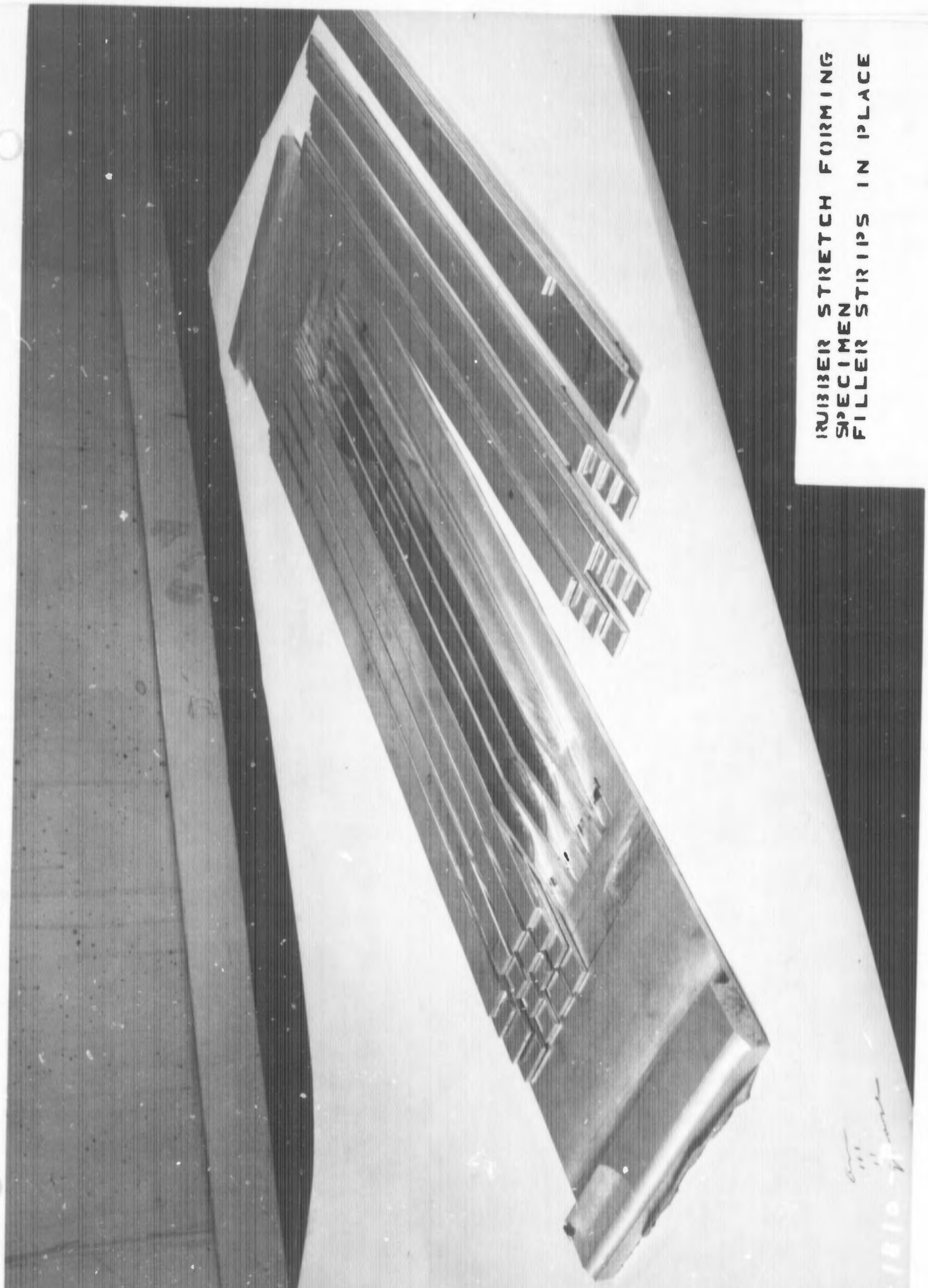
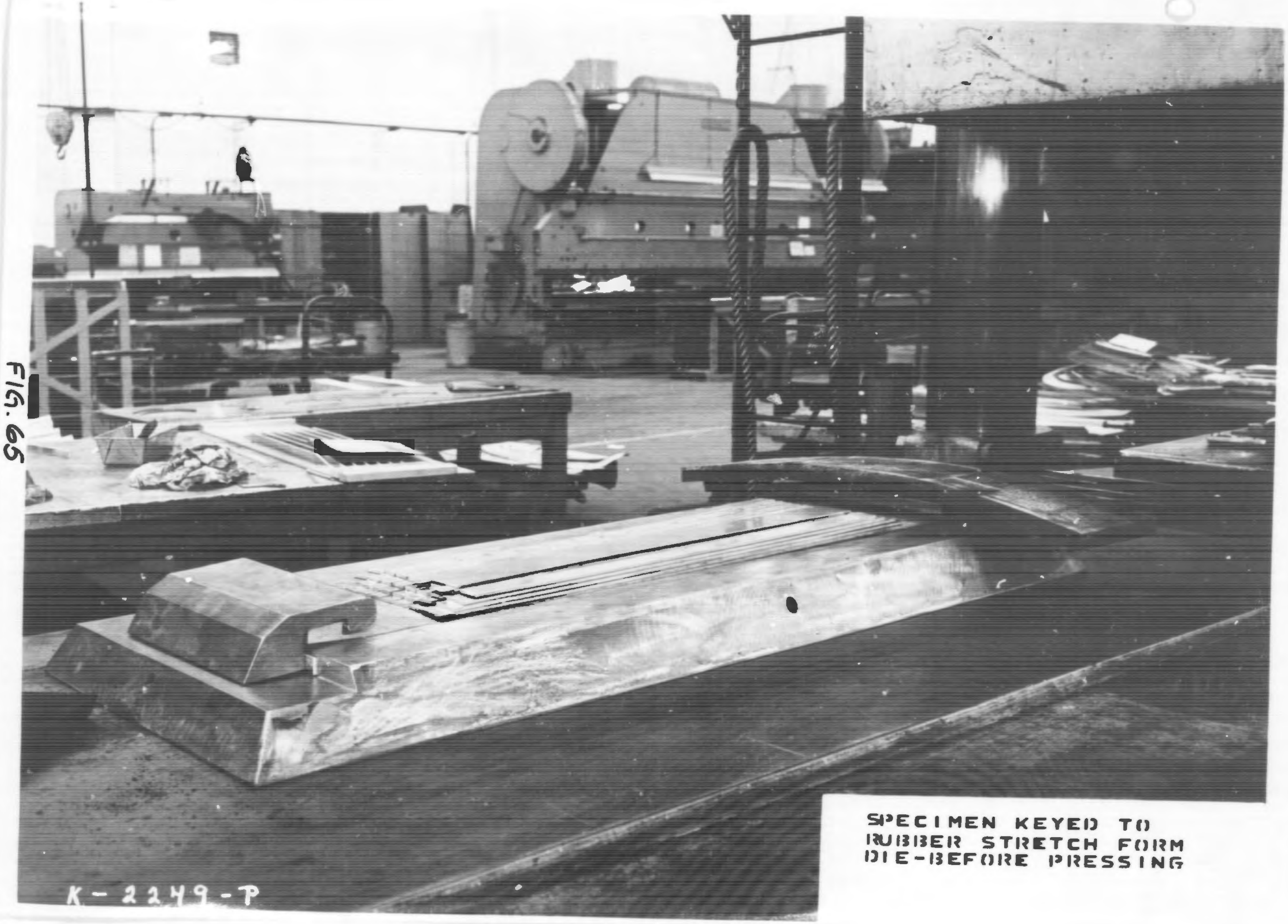


FIG. 64



SPECIMEN KEYED TO
RUBBER STRETCH FORM
DIE-BEFORE PRESSING

K-2249-P

FIG. 65

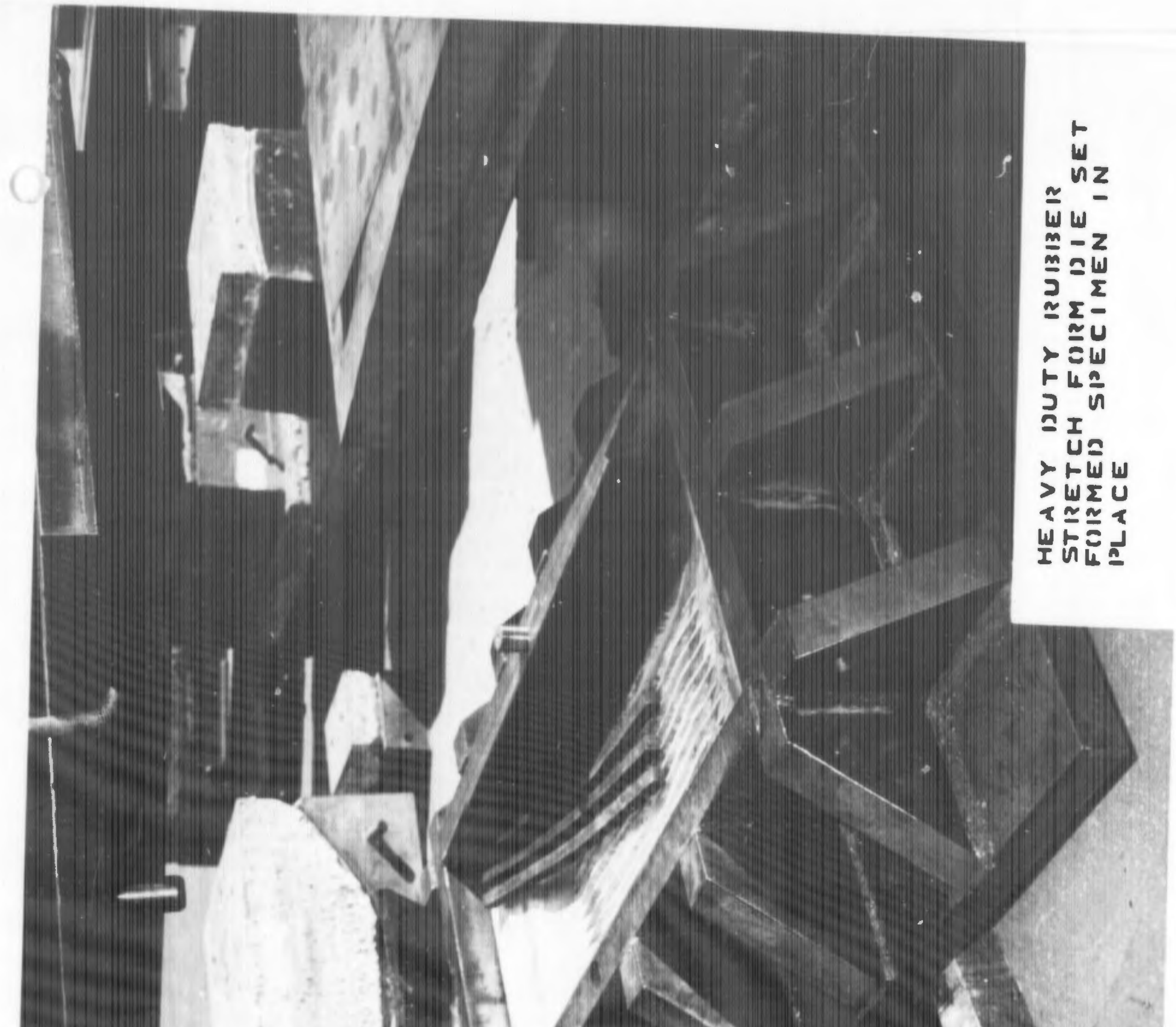

HEAVY DUTY RUBBER
STRETCH FORM DIE SET
FORMED SPECIMEN IN
PLACE

FIG. 66

FIG. 67

3.3 TEST PROCEDURE (Cont'd.)

3.34 DIE FORMING

An integrally stiffened skin forming die, which utilizes bending as the only forming action, presents a multiplicity of forming problems involved in forming a final smooth surface. There are different amounts of springback and hence different die radii required to form each element of the part. Two approaches were made. First, to find out how good a part could be produced by dies developed for average springback for the entire part, and second, to determine just how complex a die would have to be in order to produce acceptable parts.

EQUIPMENT

Adequate press, drop hammer and Ceco stamp facilities were available at Lockheed to die form or stamp integrally stiffened skins of the proposed size and stiffener structure. It was convenient to use the 75-ton hydraulic press in the Modification Shop (Fig. 68), and to use cerrobend dies manufactured in the same department for all experimental studies, short of producing a full size skin.

The forces required to firmly bottom the proposed integrally stiffened skins did not exceed 10 tons per square foot, thus a 150 sq. ft. skin could definitely be formed on the 1500-ton press. The preliminary work described here was done on a

3.34 DIE FORMING - Equipment (Cont'd.)

75-ton press.

TESTS: UPPER SURFACE PANELS

TEST NO. 1

Three cerrobend dies, cast 12 inches square of radii 30, 60 and 90 inches, were used to form standard specimens of the proposed upper surface skin to determine average values of springback and discontinuities at stiffener ends. The spaces between stiffeners were filled with cerrobend as a means of providing support.

The results of this test showed that die development would be necessary from point to point in a forming die and that considerable error would be introduced were there any aging or material variation in the S-W heat treated condition.

The fact that die formed parts contained locked up stresses and were distorted when formed on undeveloped dies is clearly illustrated in Figures 69 and 70.

Figure 69 shows that when the part was sawed apart, the edge portion sprung back considerably. The adjacent stiffener showed some flattening due to the edge effect. The break in contour at stiffener ends was not too apparent but it exceeded allowable deviations from skin contour.

3.34 DIE FORMING - Test (Cont'd.)

TEST NO. 2

A set of try dies and punches each 2 inches wide and 6 inches long were cast in cerrobend to measure the actual springback of all sections in the proposed integrally stiffened skins.

These dies had radii of 90, 60, 30, 15, 8, 4, 2, 1 and 1/2 inches, and were used on miniature specimens machined from 75S-O aluminum.

Discussion: The results of these tests on miniature specimens amplified the findings of Test #1. It was found that a properly designed die would have to incorporate springback compensation for each variation in the bending modulus of the part. In terms of the full size upper surface panel, this would involve calculated and distinct compensations in 100 or more areas of the die. From a practical point of view this procedure would impose an impossible die making problem. The multitudinous compensations, even if predictable, would result in vertical steps in a longitudinal direction at the transition points from one area of compensation to the next.

As in roll forming, there was a serious difficulty in die forming that could best be described as "beam action". This is the tendency of all forming to occur at the loca-

3.34 DIE FORMING - Test No. 2 (Cont'd.)

tion of first plastic deformation which is typical of beam failures. The results of beam action are shown in Figure 71.

This beam action requires that certain portions of dies be first filled with rubber or be made double acting with hold downs on the ends, or that similar precautions be taken to prevent overforming before bottoming takes place. Rubber can be used in several stages, but if hold down of edges is attempted, the die forming becomes a stretching operation which falls into an entirely different category. This phenomenon seriously interferes with forming long sweeping contours where the radii of curvature are insufficient to take out overforming due to "beam action".

Die forming of 75S material must be done in cold S-W or hot S-T tempers. Tests on specimens in S-W temper showed that simple die forming does not remove the warpage that invariably occurred on quench.

From the results obtained in the above described tests, the following preliminary conclusions can be drawn:

(a) Ordinary die forming will not remove warpage resulting from heat treat and machining.

(b) Single action die forming without blocks, rubber or similar aids during the closing of the die is seriously hampered by the overforming of those stiffened

3.34 DIE FORMING - Conclusions (Cont'd.)

portions where plastic flow first occurs -- that is, all the curvature tends to occur at the first break.

(c) Dies cannot be developed for widely differing degrees of springback in closely adjoining sections of a given integrally stiffened skin.

In view of these limitations, it was apparent that any bending process, such as single action die forming, could not be considered suitable as a means of forming the subject integrally stiffened skins. Consequently, no attempt was made to die form a full scale skin panel.

TESTS: LEADING EDGE PANEL

The upper and lower surfaces of the leading edge panel are similar in many respects to the upper surface panel. Therefore, it was assumed the results of die forming these areas would be equivalent to those obtained above. However, tests were made to explore methods of die forming the entering edge radius. This problem represented nothing more than bending heavy plate of uniform section to a predetermined curve. From previous experience with this technique, it was possible to produce satisfactory contours for a distance of approximately 4 inches back of the entering edge of wing leading edge panels. The method employed is described in 3.32, Test #7, and illustrated in Figure 60.

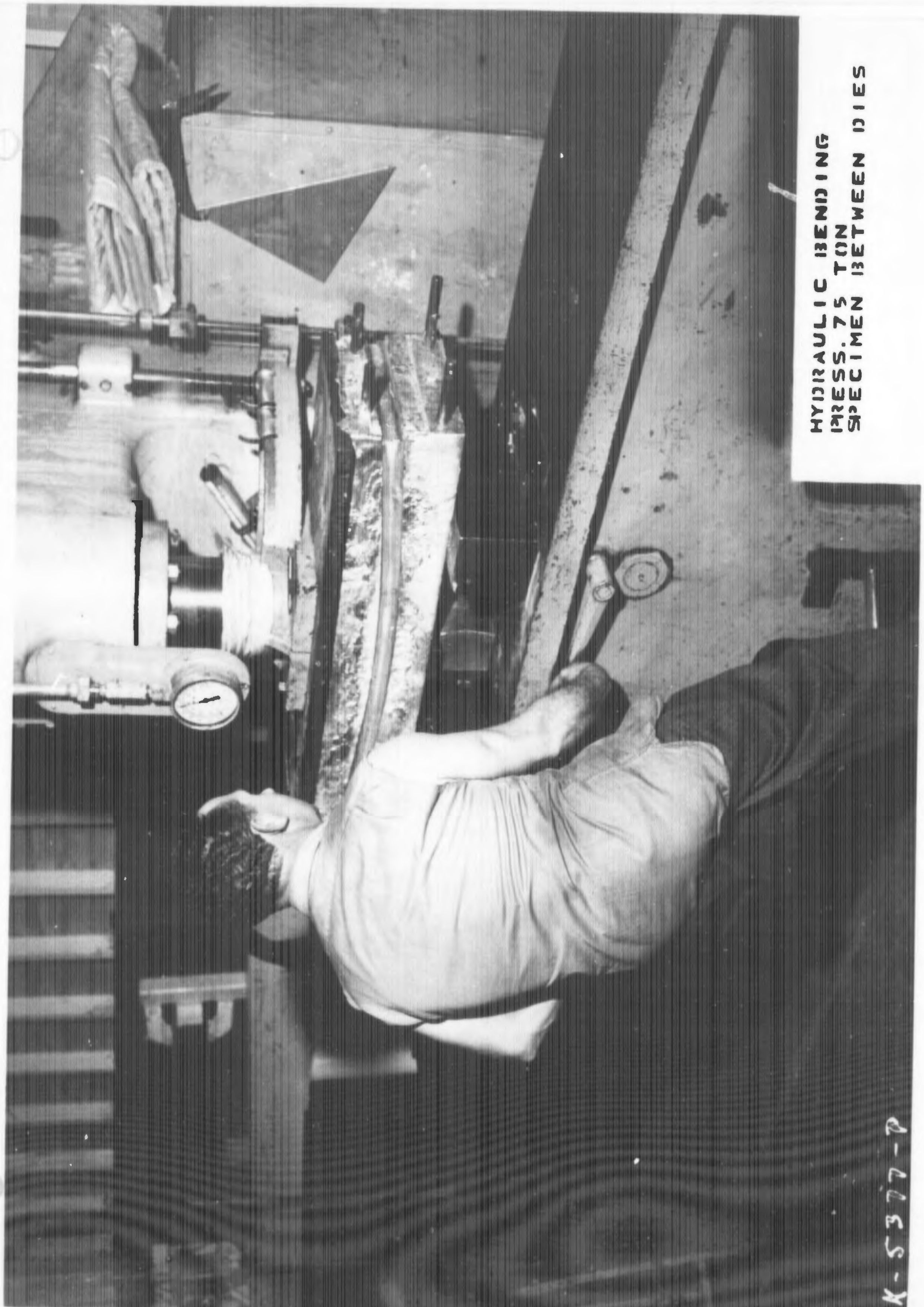

HYDRAULIC BENDING
PRESS. 75 TON
SPECIMEN BETWEEN DIES
K-5377-P

FIG. 68

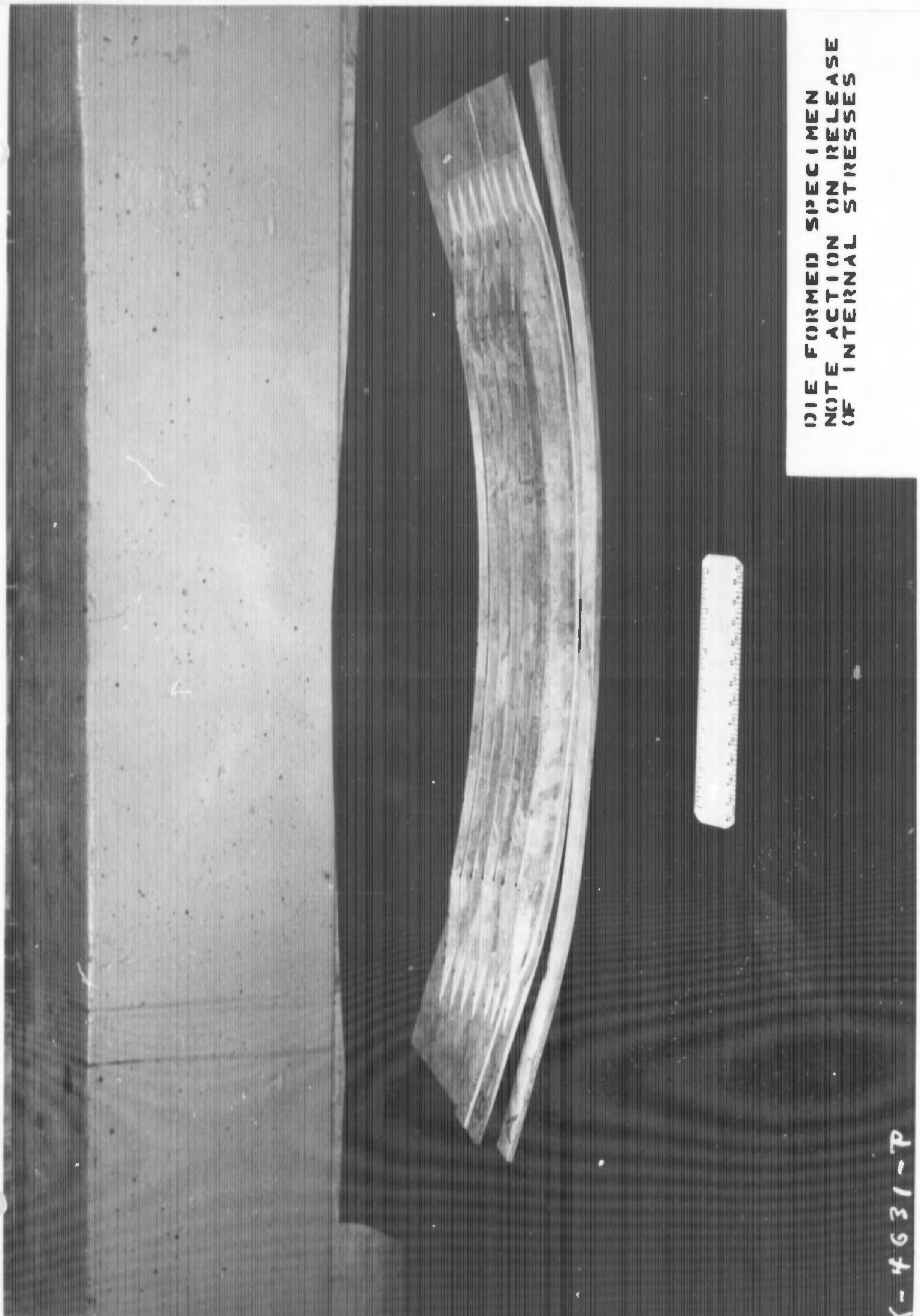

DIE FORMED SPECIMEN
NOTE ACTION ON RELEASE
OF INTERNAL STRESSES
K-4631-P

FIG. 69

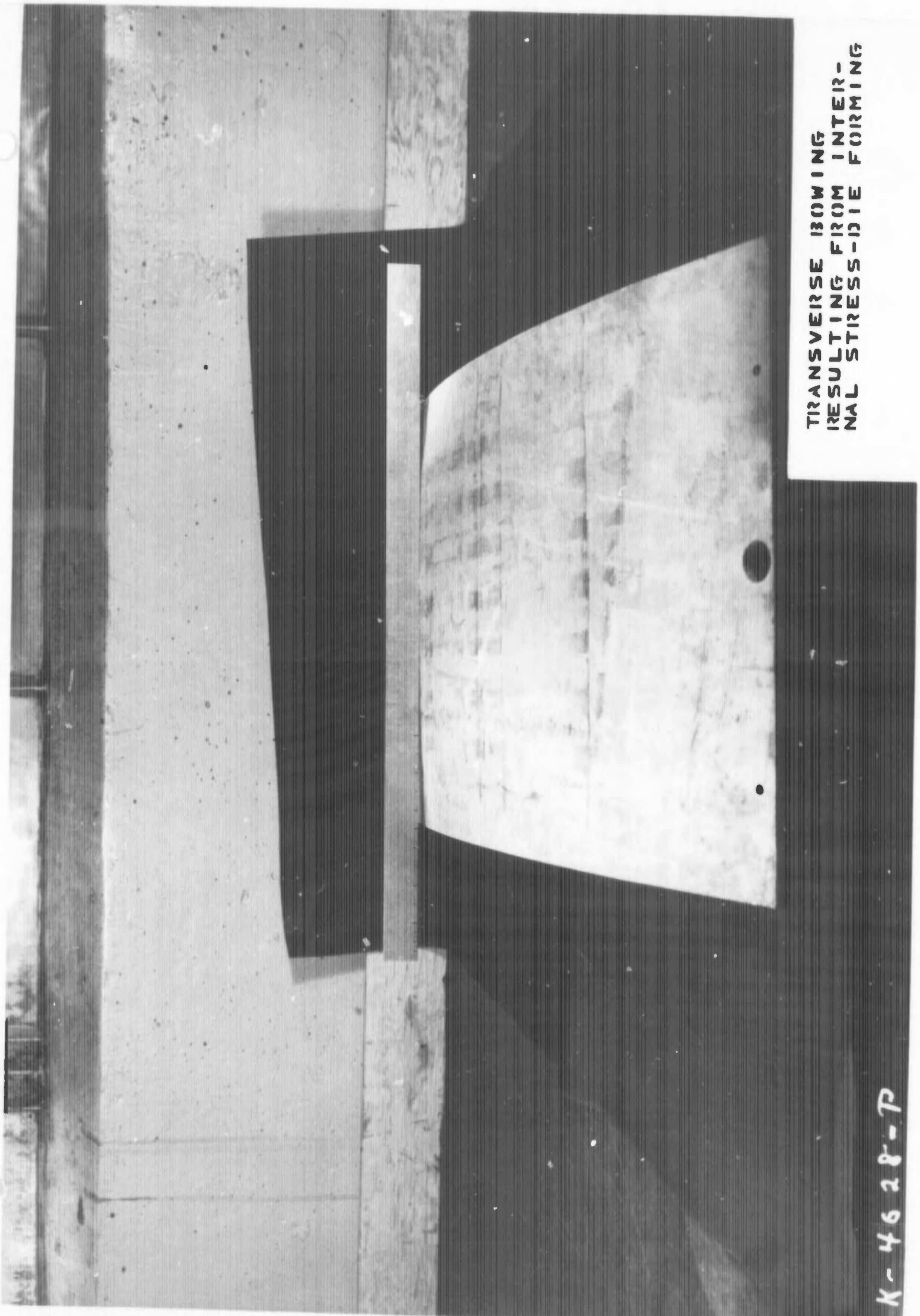

TRANSVERSE BOWING
RESULTING FROM INTER-
NAL STRESS-DIE FORMING
K-4628-P

FIG. 70


DIE FORMED SPECIMEN
NOTE 'BEAM ACTION' OR
SHARP BEND IN CENTER
OF PART
K-5375-P

FIG 71

3.3 TEST PROCEDURE (Cont'd.)

3.36 ROLL FORMING

It was anticipated that the inherent problems of rolling would prove to be similar to those of die forming. A series of tests was conducted on this method.

EQUIPMENT

Lockheed has no rolls that will form integrally stiffened skins of the full proposed size. Therefore, tests of rolling methods were conducted upon representative segments of the proposed skins and upon miniature model sections using the equipment available. This equipment consisted of:

Niagara Slip Rolls, 48-inches wide. Three rolls, 4-inch diameter, adjustable for conical section, no precision in set up, limited to 1/4" steel.

Buffalo No. 2 Rolls, 10-inches wide, three rolls, 12-inch diameter, only one roll adjustable and no conical adjustment or precision set up.

No action was taken to obtain rolls capable of forming full size skin panels because of the unsatisfactory results obtained on the following tests.

FORM 4609-8

3.35 ROLL FORMING - Tests.(Cont'd.)

TESTS: SUPPORT AND ALLIED PROBLEMS

TEST NO. 1

In order to determine if any filler was required between the stiffeners of integrally stiffened skins during rolling, a 12" x 12" x 1/2" plate of 75S-W, thirty days out of quench, was machined with six stiffeners, .12" wide and .38" high, equally spaced between side stiffeners .50" wide, all upon a skin .12" thick. (Figure 72)

This was rolled in the 4-inch diameter Niagara Rolls with no filler as shown in Figure 73.

A detailed study of the transverse and longitudinal contours before and after rolling showed that a longitudinal contour at the middle of the part of 167" radius had been accompanied by an undesirable transverse bowing of each web, concave in respect to the outside surface and an over-all bow of the entire part, convex to the outside skin surface that averaged .05" deflection from the chord at the center of the 12" cross section.

TEST NO. 2

Cerrobend, a low melting alloy which is applied and removed

3.36 ROLL FORMING - Test No. 2 (Cont'd.)

at temperatures of 180° and 200° F., was used as a filler material to support the skin web during subsequent rolling tests.

An experiment was conducted to measure the effect of melted cerrobend temperature on refrigerated freshly quenched 75S-W stiffened panels.

It was found that the brief exposure to the heat of the molten cerrobend accelerated the aging effect considerably. The amount of aging and resultant increase in yield strength could not be controlled. For these reasons, the springback factor was erratic and unreliable.

Regardless of this disadvantage of cerrobend, it was decided to use it to investigate material behavior with the thought in mind that plastic or some other material could be substituted as a filler if results warranted using this method of forming.

TEST NO. 3

A second 12" x 12" x 1/2" plate, identical to the one used in Test #1, was clamped to a cover plate and all the groove space was filled to overflow with cerrobend which was allowed to solidify as shown in Figure 74. The cerrobend at

3.35 ROLL FORMING - Test No. 3 (Cont'd.)

180° F. did not alter the properties of this particular material because it had already aged for thirty days.

The rolling operation (Figure 75) resulted in detachment of the filler for two inches at the ends of the stiffeners after several passes. This was the only location at which there was such separation, or where any transverse distortion occurred. The cerrobend was melted out before final analysis was made of the contour produced.

A considerable improvement in the forming characteristics of this specimen was obtained by the use of the cerrobend filler. Transverse distortion was reduced 90% and skin distortion between stiffeners was not measurable

TEST NO. 4

A narrow panel (12-inches wide) representing a portion of the upper wing panel was rolled in the Buffalo No. 2 machine.

This panel was rolled with a filler of thin aluminum strips riveted between top and bottom cover plates to form a dimensionally uniform sandwich. A definite break in contour occurred at the ends of the stiffeners as shown in Figure 76. In addition, there was some transverse bow at the middle.

3.35 ROLL FORMING - Test No. 4 (Cont'd.)

A duplicate specimen of the leading edge panel was also rolled in the Buffalo No. 2 machine after have been embedded in cerrobend and placed between two ½" aluminum plates. (Figures 77 and 78) The cerrobend broke away from the part at the thin nose section and at the ends. A very good contour was obtained except that there was a 17° break in contour at the stiffener ends at the entering edge. Detailed analysis of the formed part after removal from cerrobend confirmed the fact that rolling with a cerrobend filler produced better results in preserving flatness of cross section than the same operation with a strictly mechanical filler.

Both of these panels were rolled in 0 condition and were subsequently heat treated and age hardened. Attempts to hand straighten the parts in W temper after quench distortion were not successful. Particular trouble was had in ironing out wrinkles between stiffeners.

Discussion: The behavior of stiffened panels during rolling depends upon the configurations of the various areas just as in die forming. The over-all problem of the resultant variable springback is the same except that whereas the die might be developed to some extent, the roll is even more limited in that it cannot be made to compensate transversely for variable springback during rolling.

3.36 ROLL FORMING - Discussion (Cont'd.)

There is one difference between die forming and rolling in that the roll spacing has a bearing upon the bending that takes place where there is a change of sectional properties. When two varieties of cross section such as a stiffened and an unstiffened portion each partly span the rolls, all the break occurs at the end of the stiffeners. There is almost no way to keep this from happening unless a discardable support is used on thin sections, or a form plate is rolled with the part. The form plate method could be classed as die forming, which is covered in another part of this report.

In all the experiments with heat treating, none has yielded a method of quench that does not distort integrally stiffened skins, hence, a critical test of a forming method is whether or not it will remove heat treat warpage. Rolling fails the test. Reverse, cross and combination rolling methods make the situation worse and add ripples to the web between the stiffeners.

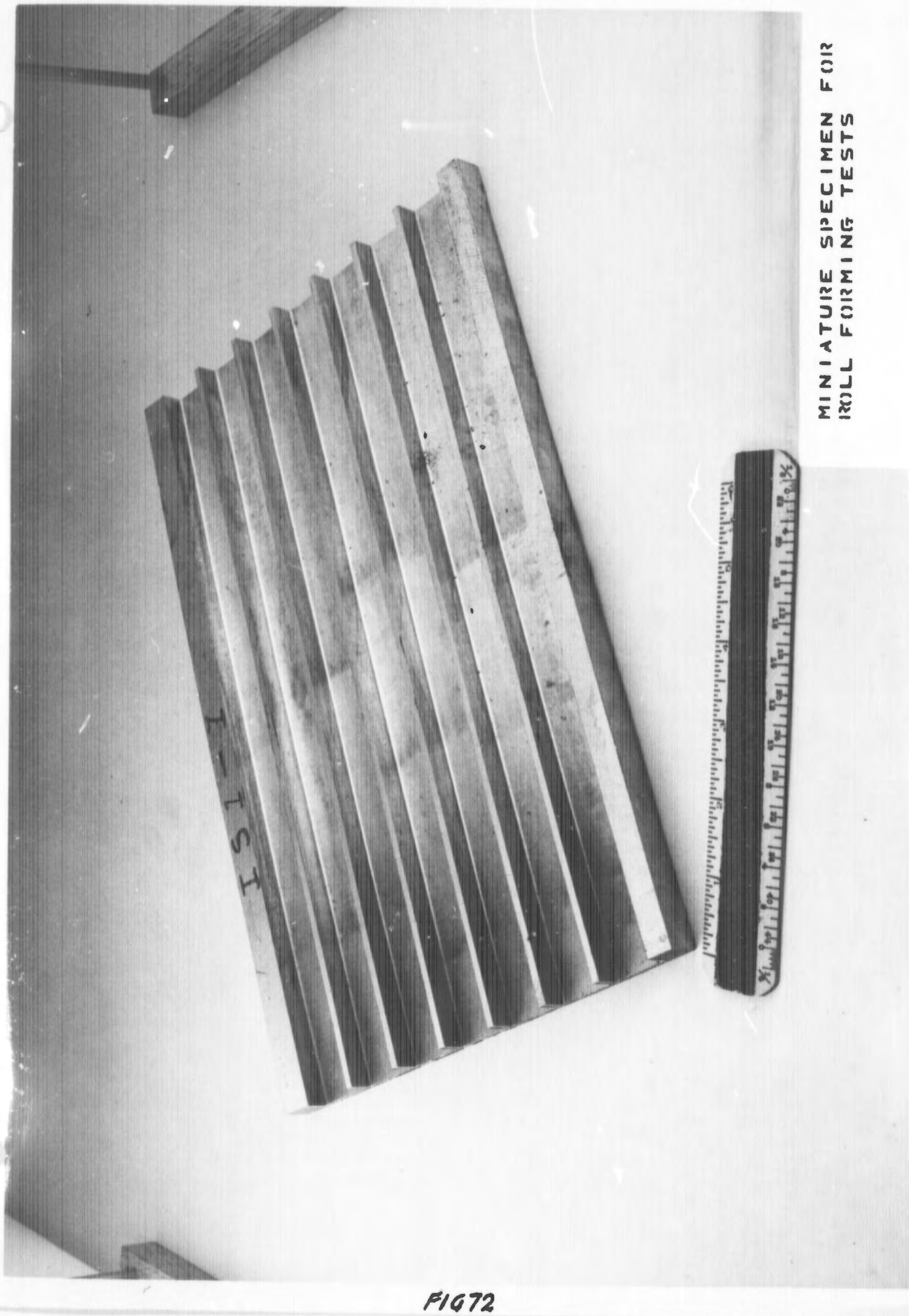
The results of the above described tests point to the following preliminary conclusions:

(a) Roll forming is limited to material which is initially flat or uniformly curved and is free of heat treat and machining stresses.

(b) Roll forming is limited to parts of uniform bending modulus or so supported as to effectively have uniform modulus.

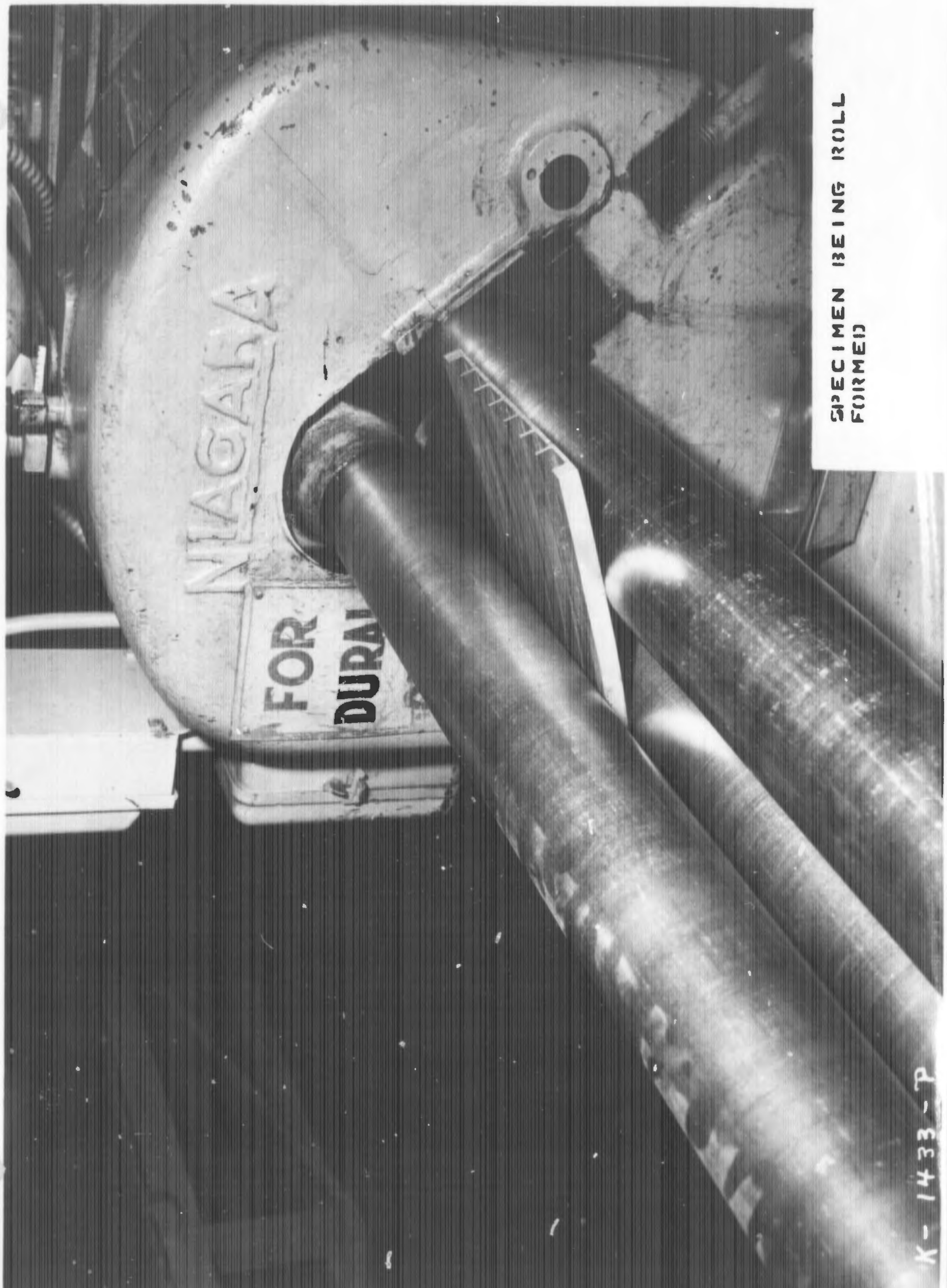
3.35 ROLL FORMING - Discussion (Cont'd.)

In view of the limitations stated above, no attempt was made to roll a full size panel as it is apparent that no form of rolling can be considered suitable as a means of forming integrally stiffened skins, such as P. D. 115 and P. D. 903-23.



MINIATURE SPECIMEN FOR ROLL FORMING TESTS

FIG 72

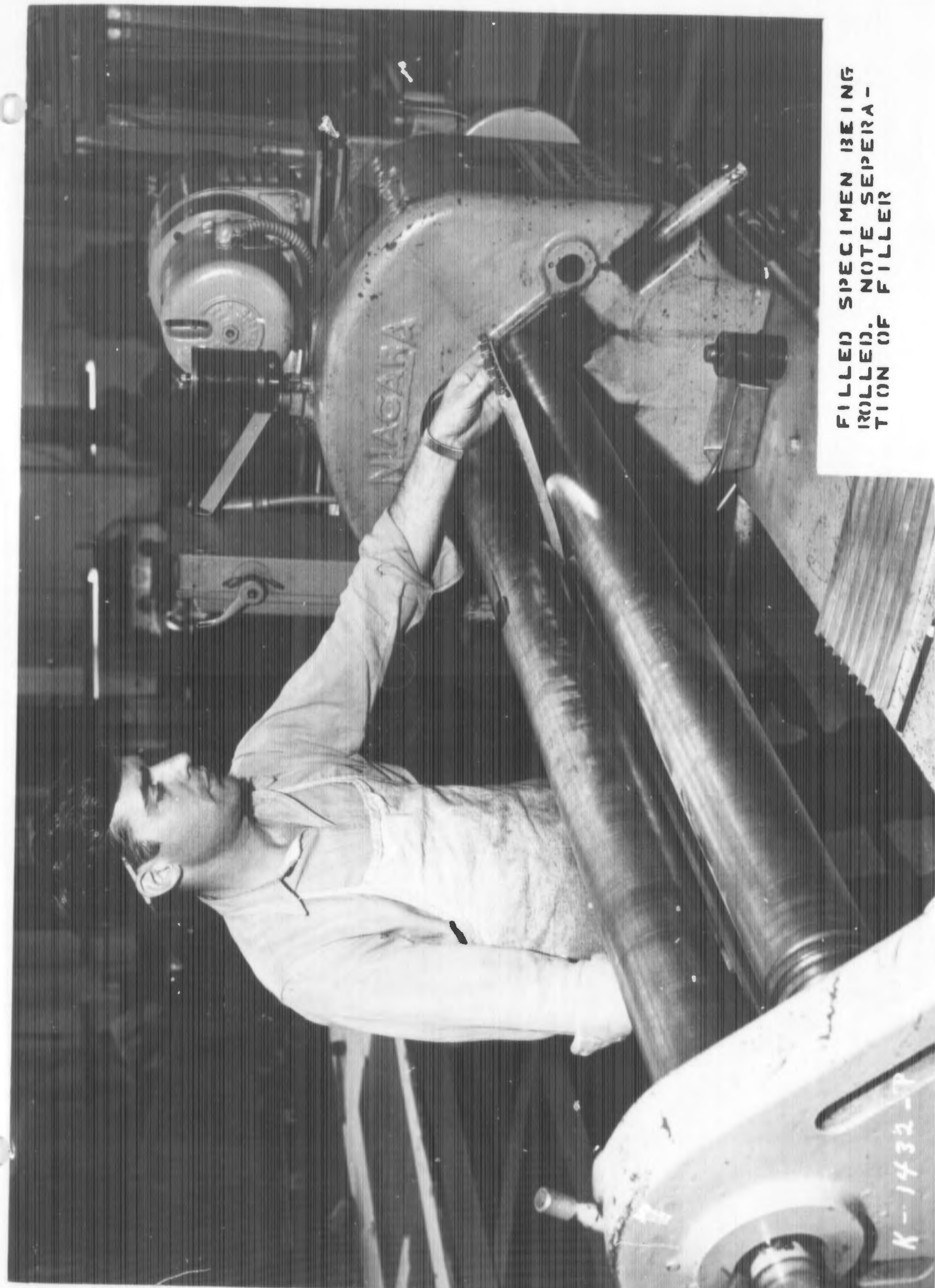


SPECIMEN BEING ROLL FORMED

FIG 73

SPECIMEN FILLED WITH
CERROBEND FOR SUPPORT

FIG. 74



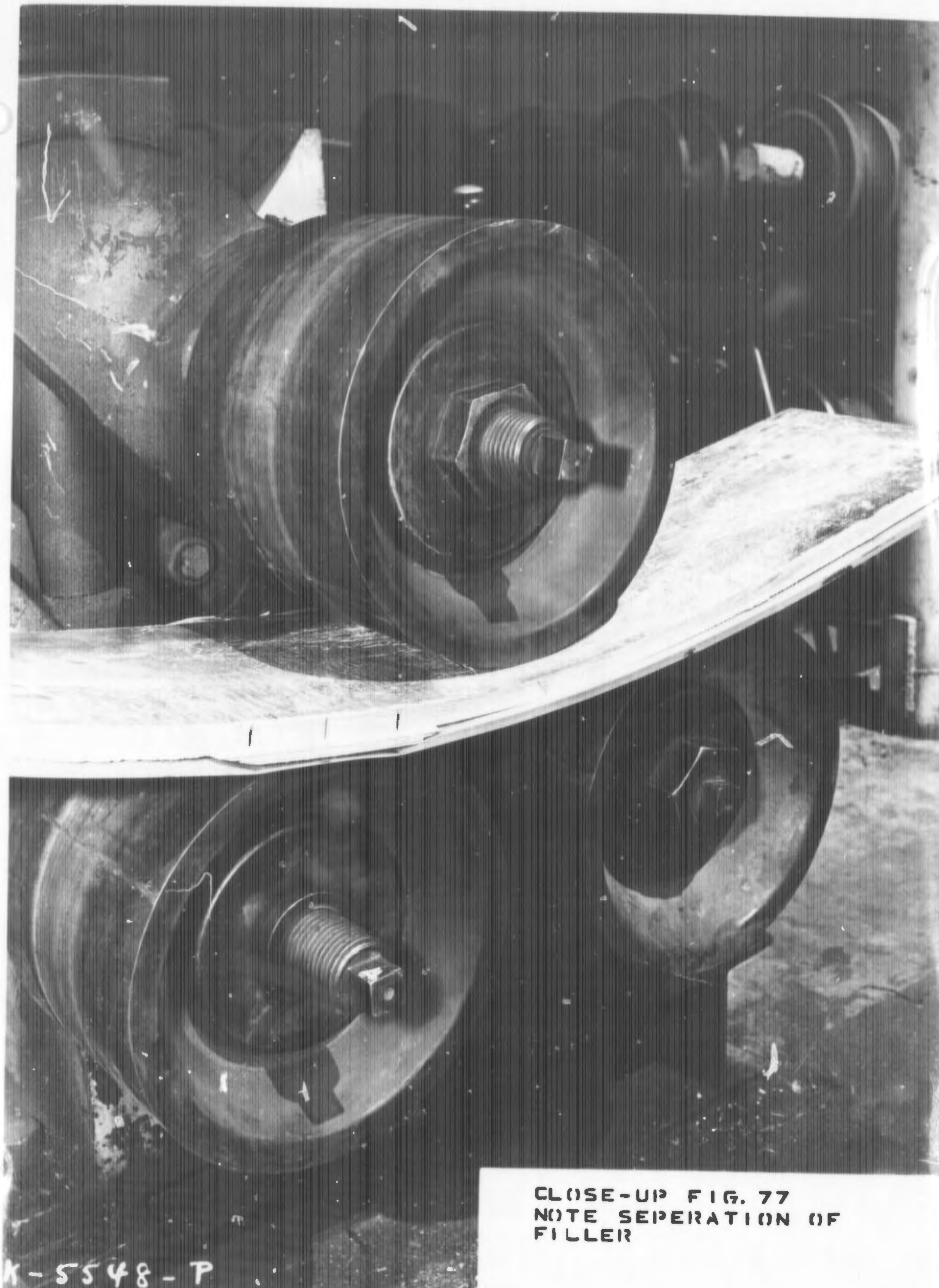
FILLED SPECIMEN BEING ROLLED. NOTE SEPERA-TION OF FILLER

FIG. 75


STANDARD SPECIMEN
ROLLED WITH MECHANICAL
FILLER. NOTE BREAKS AT
ENDS OF RIBS
K-4627-P

FIG. 76

FIG. 77



CLOSE-UP FIG. 77
NOTE SEPERATION OF
FILLER

FIG. 78

3.3 TEST PROCEDURE (Cont'd.)

3.36 POWER BRAKE FORMING (BUMPING)

This method had been found to be suitable for forming various prototype integrally stiffened parts and was, therefore, considered as a possible method of forming the subject panels. For contour forming on the power brake a punch with generous radius is used in conjunction with a rubber pad or channel-shaped bottom die (Figure 79).

The punch is adjusted to produce a slight bend on each stroke and the part is moved forward a small amount after each stroke, with the result that the series of small bends tend to blend together to produce a smooth contour. In most cases a number of phases, with periodic checking of the contour with template, are required to produce the formed part.

EQUIPMENT

Figure 80 illustrates typical power brake dies as used for the forming tests. Slotted or solid bars were used for punches operating with a bottom die with hinged bearing plates.

In practice it was actually possible and generally desirable to operate inverted with the so-called bottom die attached to the ram and the punch in place at the bottom.

All forming tests were performed on a 10-foot Chicago power brake.

3.36 POWER BRAKE FORMING (BUMPING) - (Cont'd.)

TESTS: UPPER SURFACE PANEL

For reasons that will be discussed later, only preliminary forming tests were conducted. The standard test specimens were approximately 12 inches wide and 36 inches long, and incorporated the typical web thickness, stiffener configuration and web reinforcement border near the edges (Figure 81).

One part was machined in the O temper, heat treated and formed in the W temper. However, in general, the power brake bending operation is not effective for removing distortion that results from heat treatment; and it is, therefore, considered desirable practice to do the machining and forming either in the W or T temper. Since W temper plate was not available, all other test parts were machined and formed in the T temper.

TEST NO. 1

Several forming techniques were explored, starting with a solid unnotched punch making contact on the top of the stiffener only. This was followed by experiments with a recessed punch designed to make simultaneous contact on stiffener and skin. Views of the forming process are shown in Figures 82 and 83.

Due to discontinuities in the section, it was necessary to change punches at places where the cross section of the part changed when forming with notched punches. The ta-

3.36 POWER BRAKE FORMING (BUMPING) - Test No. 1 (Cont'd.)

pered transition region could actually not be traversed at all. It was necessary to form up to such a region with one punch and then skip the transition and continue from there with another punch.

The results of the tests may be summarised as follows:

(a) Both local and general transverse curvatures resulted (Figure 84). All the non-stiffened regions tended to be depressed relative to the web surface opposite the stiffeners. This distortion was reduced by the use of recessed or notched punches, but not eliminated, and occurred in both the W and T temper parts. Somewhat less distortion of this type may have resulted in the W temper. However, this difference was not very significant and was obscured by distortion resulting from heat treatment.

(b) Small but noticeable discontinuities in contour resulted at all the chordwise discontinuities or stiffener run-outs and changes in web thickness. These discontinuities resulted from (1) the relatively abrupt changes in stiffness of the section to bending, and (2) the fact that no adequate technique has been found for forming the transition regions, where stiffener heights and/or web thicknesses taper.

3.36 POWER BRAKE FORMING (BUMPING) - Tests (Cont'd.)

(c) Difficulty with cracking of the web at fillets adjacent to the stiffeners was found to be troublesome when forming in the T temper. For this reason, it was necessary to use notched punches that would bear on both stiffener and web. It was furthermore necessary to relieve the punch surfaces so that they would not contact the fillet areas.

The following general conclusions on upper panel forming were drawn from the test results and from past experience with the power brake forming method:

(a) Tooling costs are low which makes the method attractive for prototype work provided the results are acceptable otherwise.

(b) Power brake forming is not well adapted to forming the reference wing panel type part. The difficulties experienced are generally traceable to the large ratio between stiffener height and web thickness encountered in this part.

(c) Parts formed by this method are lacking in aerodynamic smoothness.

(d) Power brake forming is a slow process and the results are largely dependent upon the skill and care exercised by the operator. For these reasons the method is not a good production method.

3.36 POWER BRAKE FORMING (BUMPING) - Tests (Cont'd.)

TESTS: LEADING EDGE PANEL

The technique and method of power brake forming, as applied to the leading edge part, was generally similar to that of power brake forming of the upper surface panel already discussed. The main differences in the forming problem resulted from the the following facts:

(a) The configuration of the cross section was different. The ratio between stiffener height and skin thickness was slightly lower which was a favorable difference. To offset this difference, the spacing between stiffeners was greater and this accentuated the tendency for distortion of the intervening web.

(b) The contour curvature was greater for the leading edge part, particularly in the vicinity of the leading edge.

For these reasons, power brake forming of a leading edge part was considered a more difficult operation than the upper surface panel forming.

TEST NO. 2

A standard test specimen was selected for the preliminary investigation. The dies used were similar to those shown in Figure 80.

The technique employed was similar to that used for forming

3.36 POWER BRAKE FORMING (BUMPING) - Test No. 2 (Cont'd.)

the upper surface panels. The results were approximately the same as obtained in bumping upper panels and it was not found possible to completely form the entering edge by this method due to equipment interferences and a lack of accessibility as the forming neared completion. Several parts were formed in the O temper using bumping as a pre-forming method for final forming by the compression method. Such a part is shown in Figure 85. Bumping produced sufficiently adequate forming to permit the parts to be placed in the compression die.

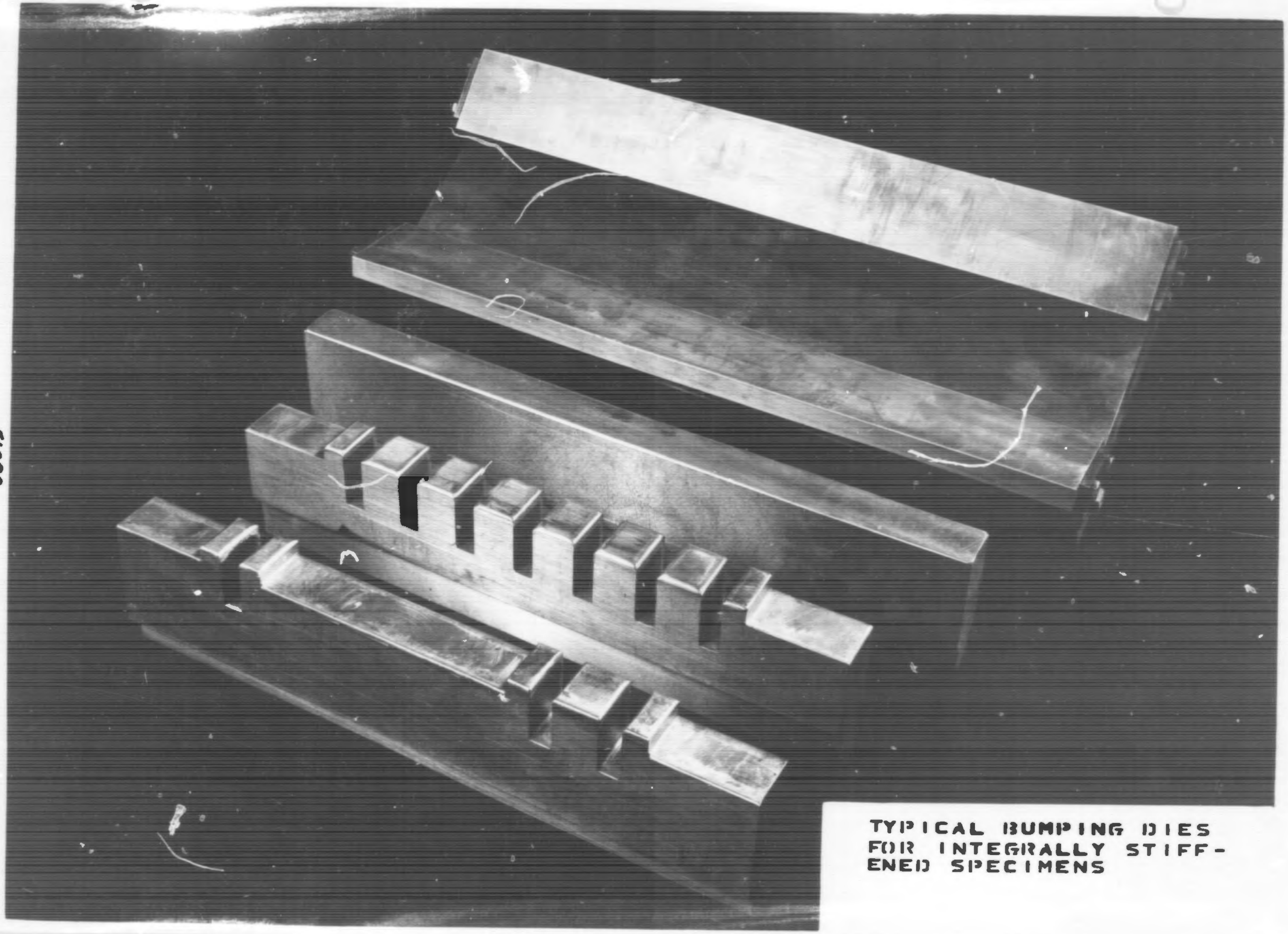
All other bumping tests were confined to test parts in the T temper, none of which could be successfully completed due to cracking of the skin adjacent to the stiffeners.

Conclusions: The conclusions that were drawn from the attempts to form the upper surface panel by bumping also apply generally to forming of the leading edge panel. Summarizing briefly: While power brake forming might have some value for prototype forming of a few parts due to the low cost of the tooling that is required, it does not offer a satisfactory production forming method. Tests were discontinued after the above preliminary investigation.

FORM 4229-5

POWER BRAKE SPECIMEN
DIE SET-UP
NOTE FLEXIBLE DIE
EDGES

FIG. 79



TYPICAL BUMPING DIES FOR INTEGRALLY STIFFENED SPECIMENS

FIG80

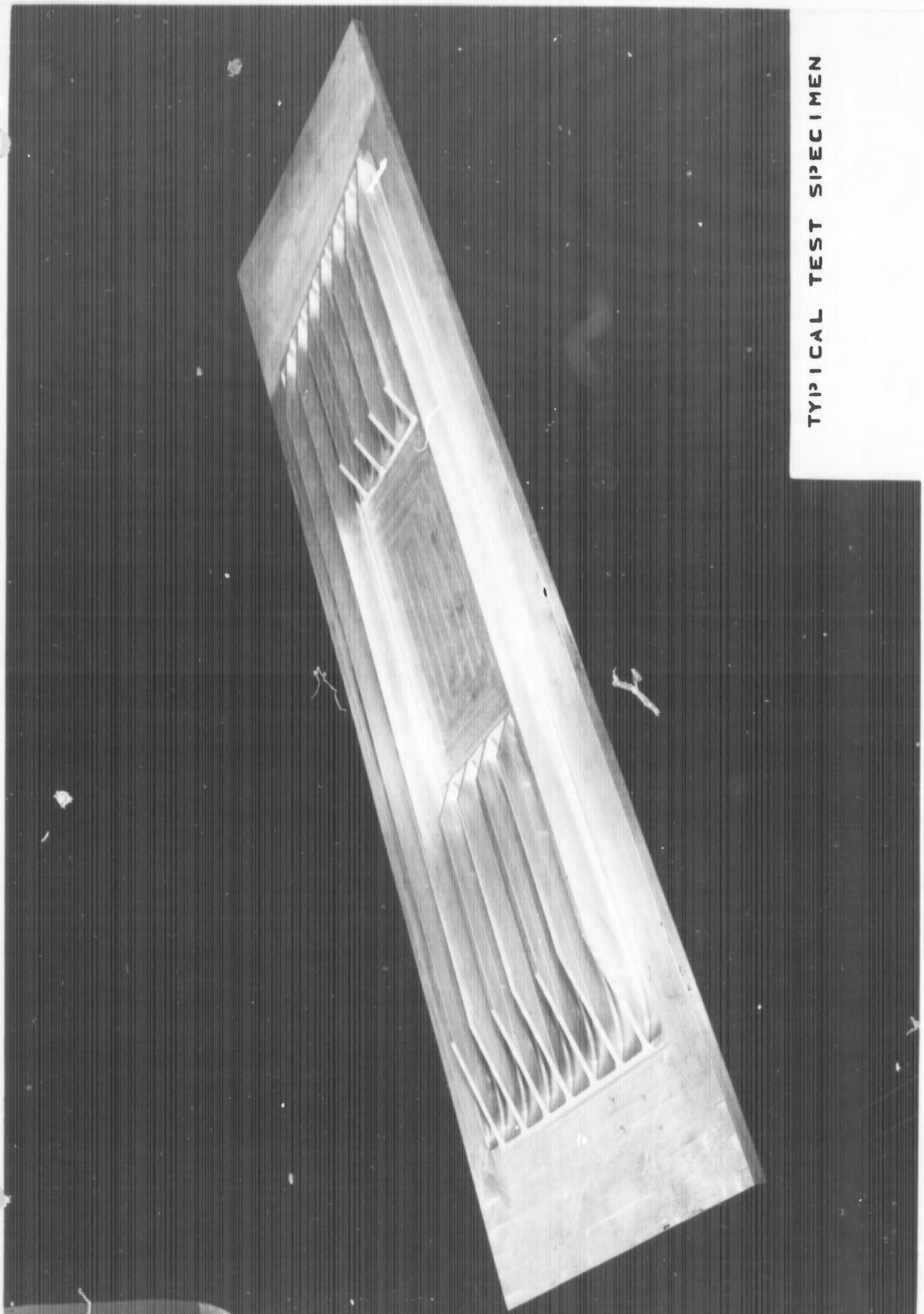


FIG 81

TEST SPECIMEN IN PROCESS OF BRAKE-BUMP-FORMING

FIG 82

FIG 83

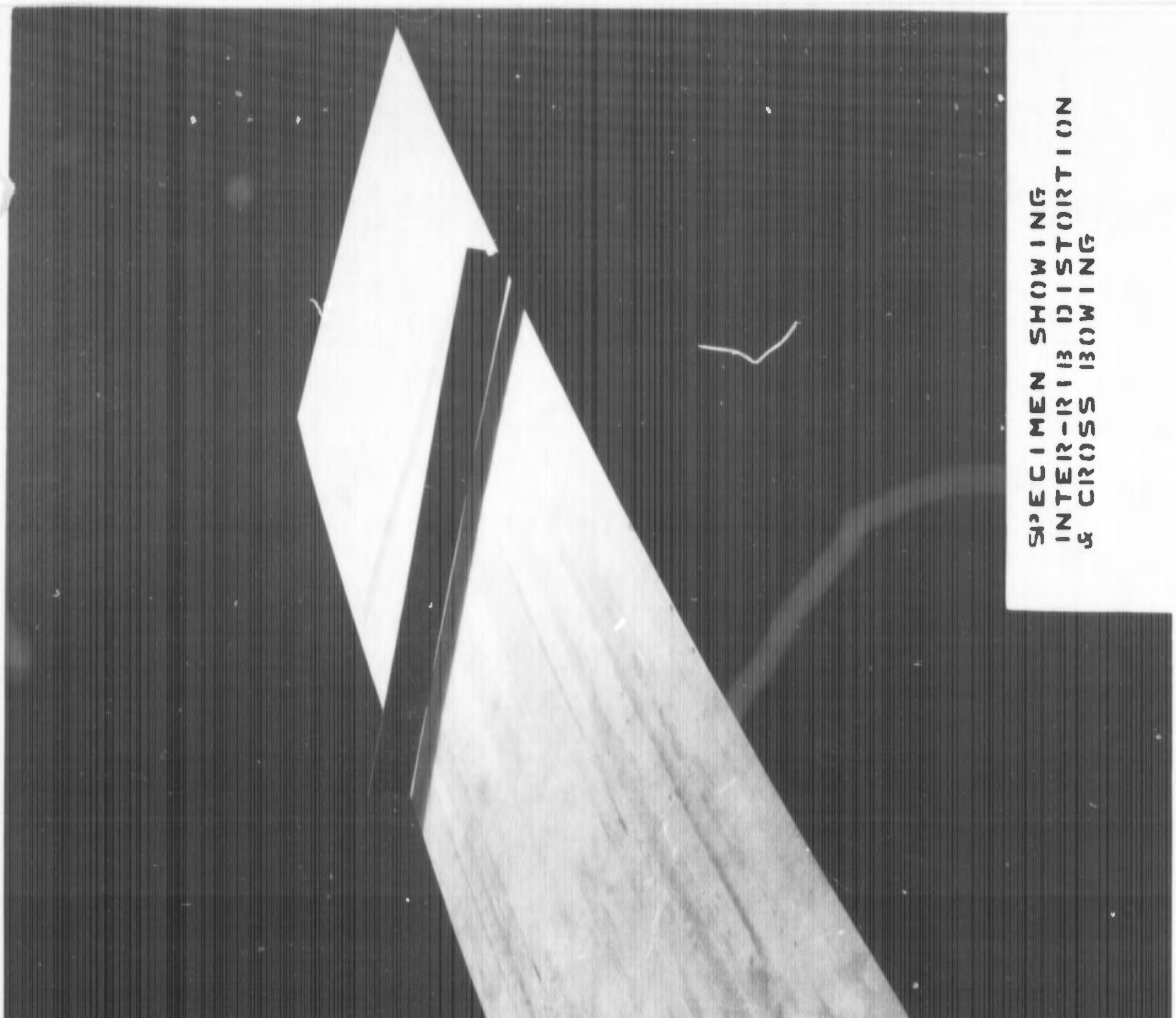
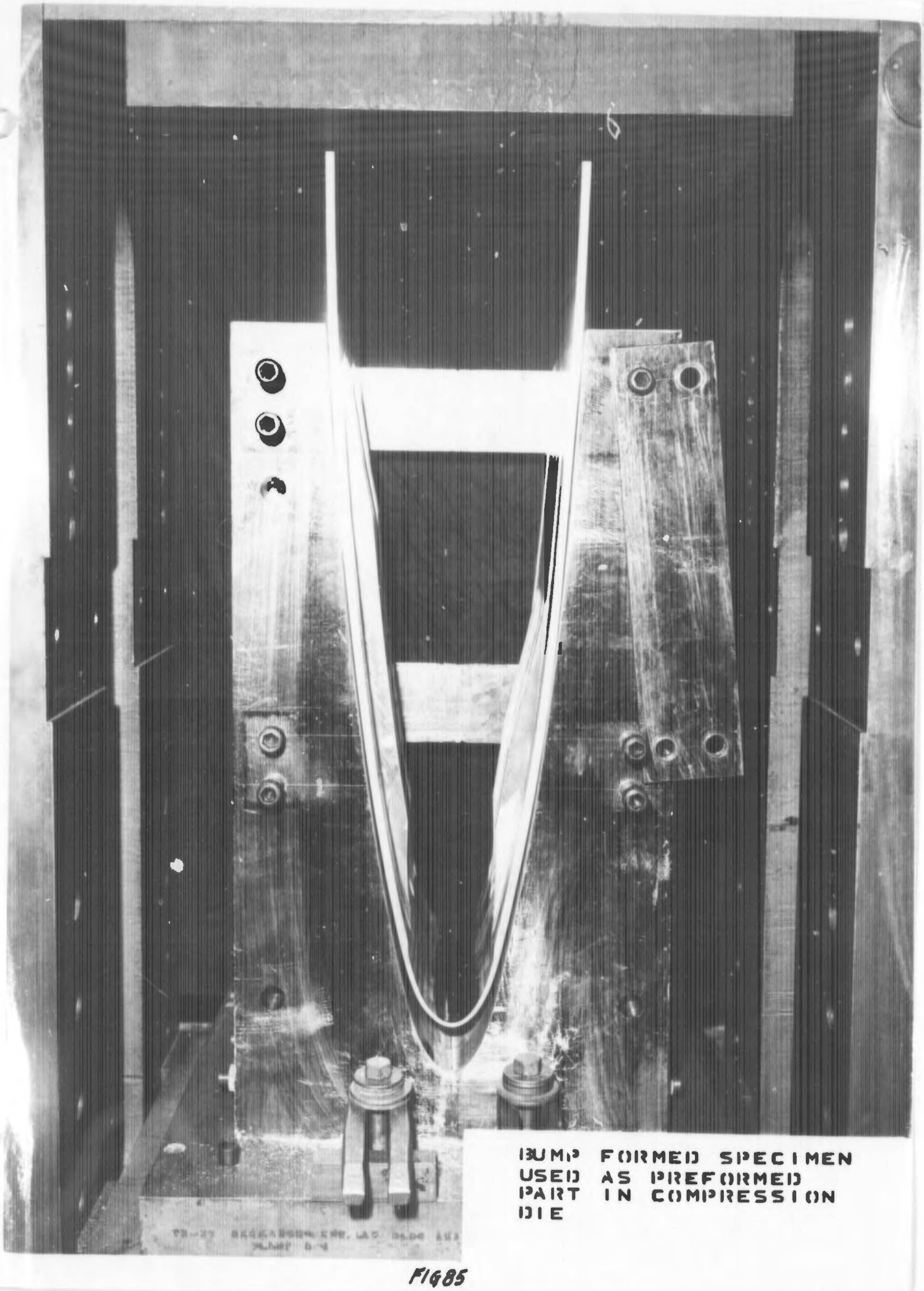
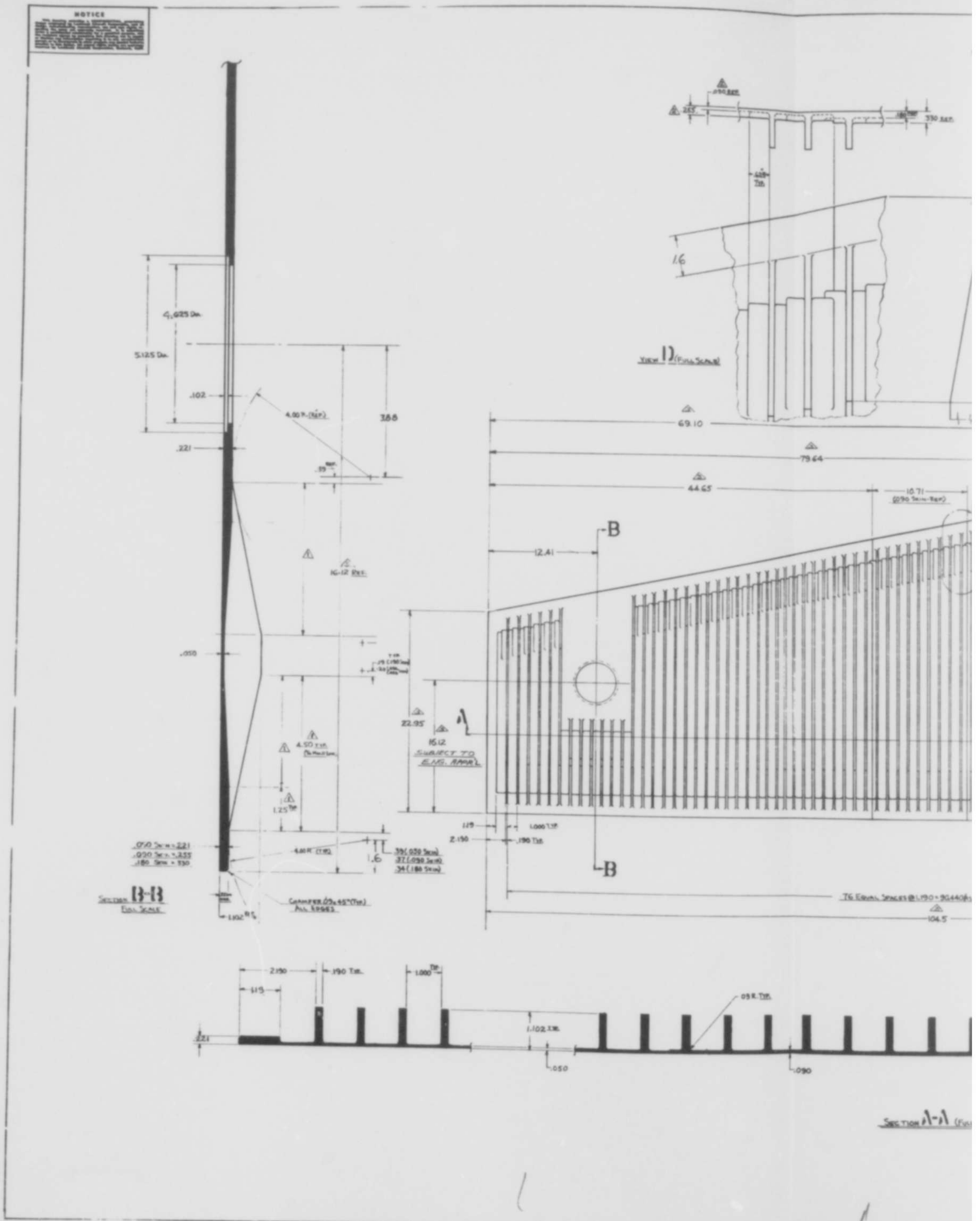


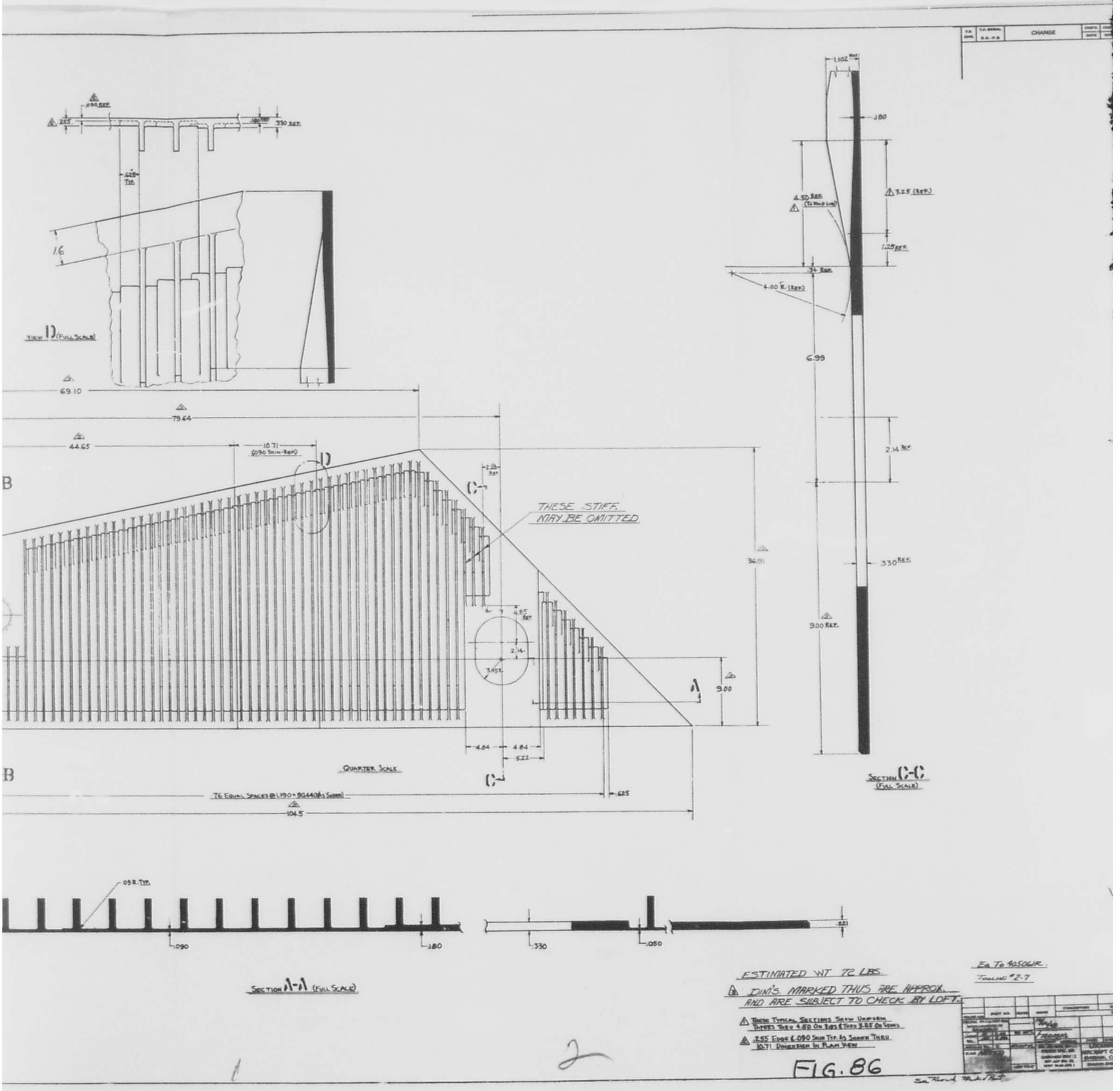
FIG 84



BUMP FORMED SPECIMEN
USED AS PREFORMED
PART IN COMPRESSION
DIE

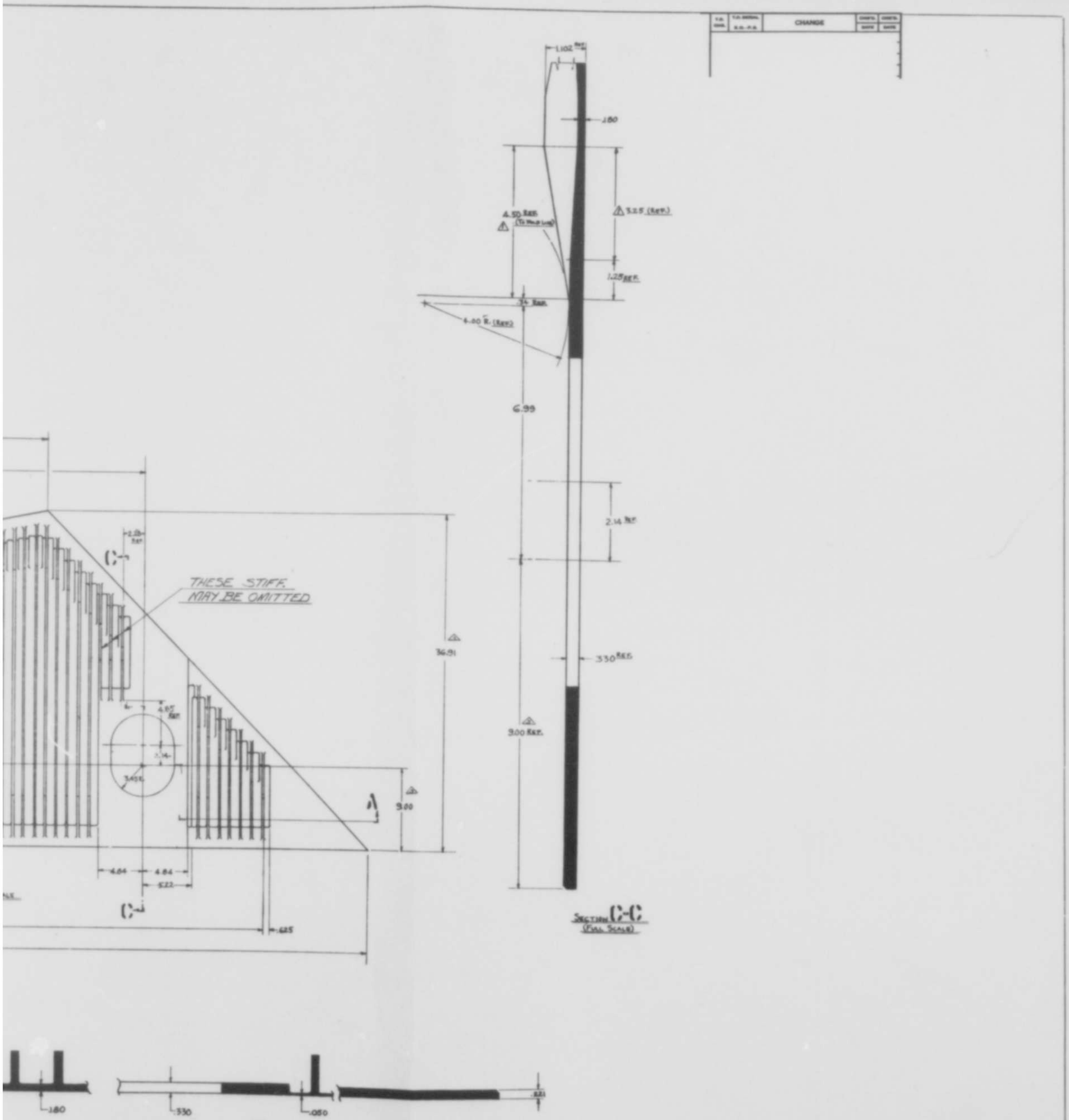
FIG 85


NOTICE
SECTION B-B FULL SCALE
VIEW D (FULL SCALE)
SECTION A-A
SUBJECT TO ENG. APPROVAL
CHAMFER .03 x 45° (TYP) ALL EDGES
76 EQUAL SPACES @ 1.190 = 90.440
69.10
79.64
44.65
12.41
10.71
104.5
22.95
15.12
16.12 REF.
4.50 TYP.
1.25 TYP.
3.88
4.00 R (REF)
4.00 R (TYP)
4.025 DIA.
5.125 DIA.
2.150
.115
.190 TYP.
1.000 TYP.
1.102 TYP.
.050
.090
.221
.102
1.6



VIEW D (FULL SCALE)
69.10
79.64
44.65
10.71
(.090 SKIN-REF)
THESE STIFF. MAY BE OMITTED
36.91
9.00
4.64
5.22
QUARTER SCALE
76 EQUAL SPACES @ 1.190 = 90.440 (AS SHOWN)
104.5
.625
SECTION C-C (FULL SCALE)
1.102 REF.
.180
3.25 (REF.)
4.50 REF.
1.25 REF.
4.00 R. (REF.)
6.99
2.14 REF.
.330 REF.
9.00 REF.
.09 R. TYP.
.090
.180
.330
.050
SECTION A-A (FULL SCALE)
ESTIMATED WT 72 LBS.
DIM'S. MARKED THUS ARE APPROX. AND ARE SUBJECT TO CHECK BY LOFT.
.255 EDGE & .090 SKIN TYP. AS SHOWN THRU 10.71 DIMENSION IN PLAN VIEW
CHANGE

FIG. 86



ESTIMATED WT 72 LBS.

Eq. To 40506 LR.

Tooling #2-7

DIM'S. MARKED THUS ARE APPROX. AND ARE SUBJECT TO CHECK BY LOFT.

Taper Typical Sections Shown Uniform Tapers Thru 4.50 On Ribs & Thru 3.25 On Spars

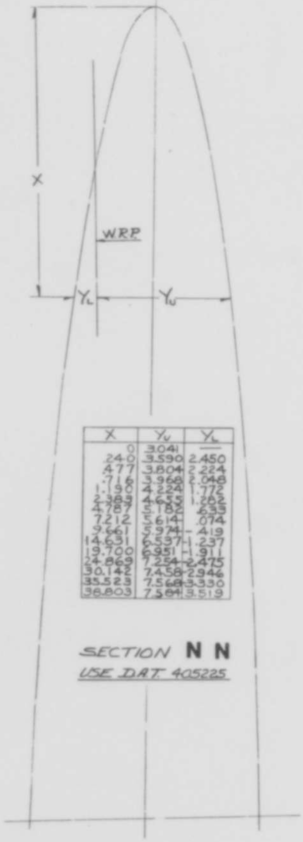
.355 Edge & .080 Skin Tip As Shown Thru 10.71 Dimension In Plan View

LOCKHEED AIRCRAFT CORP. BURBANK, CALIF.

INTEGRAL STIFF'D. PANEL FORMING PROGRAM

PD-115

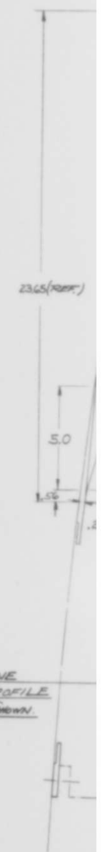
FIG. 86



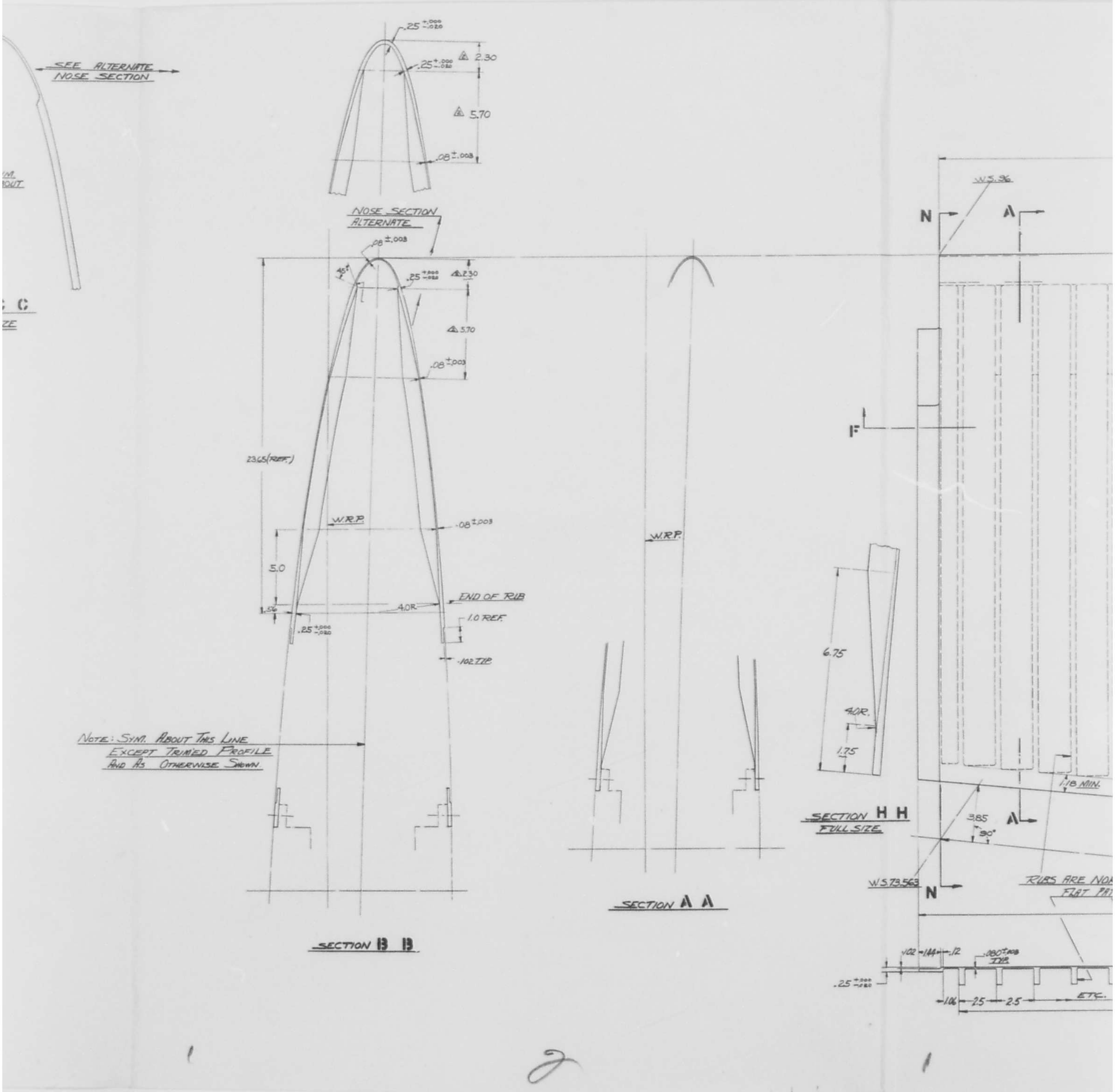
X	Y_U	Y_L
0	3.041	—
.240	3.590	2.450
.477	3.804	2.224
.716	3.968	2.048
1.190	4.224	1.772
2.383	4.655	1.282
4.787	5.182	.633
7.212	5.614	.074
9.661	5.974	-.419
14.631	6.537	-1.237
19.700	6.951	-1.911
24.869	7.254	-2.475
30.142	7.458	-2.946
35.523	7.568	-3.330
38.803	7.584	3.519

SECTION **N N**
USE D.A.T. 405225

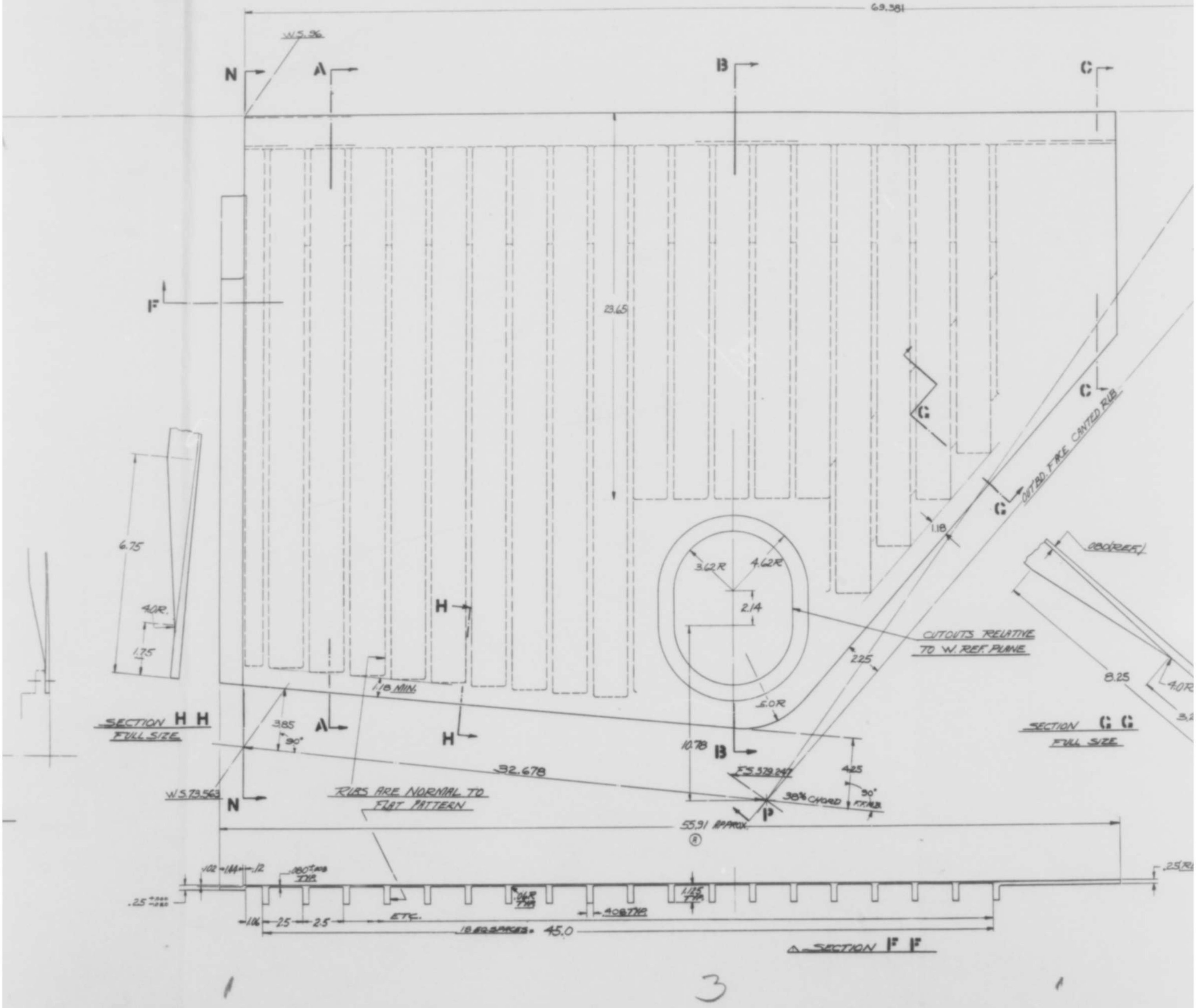
SECTION **C C**
FULL SIZE



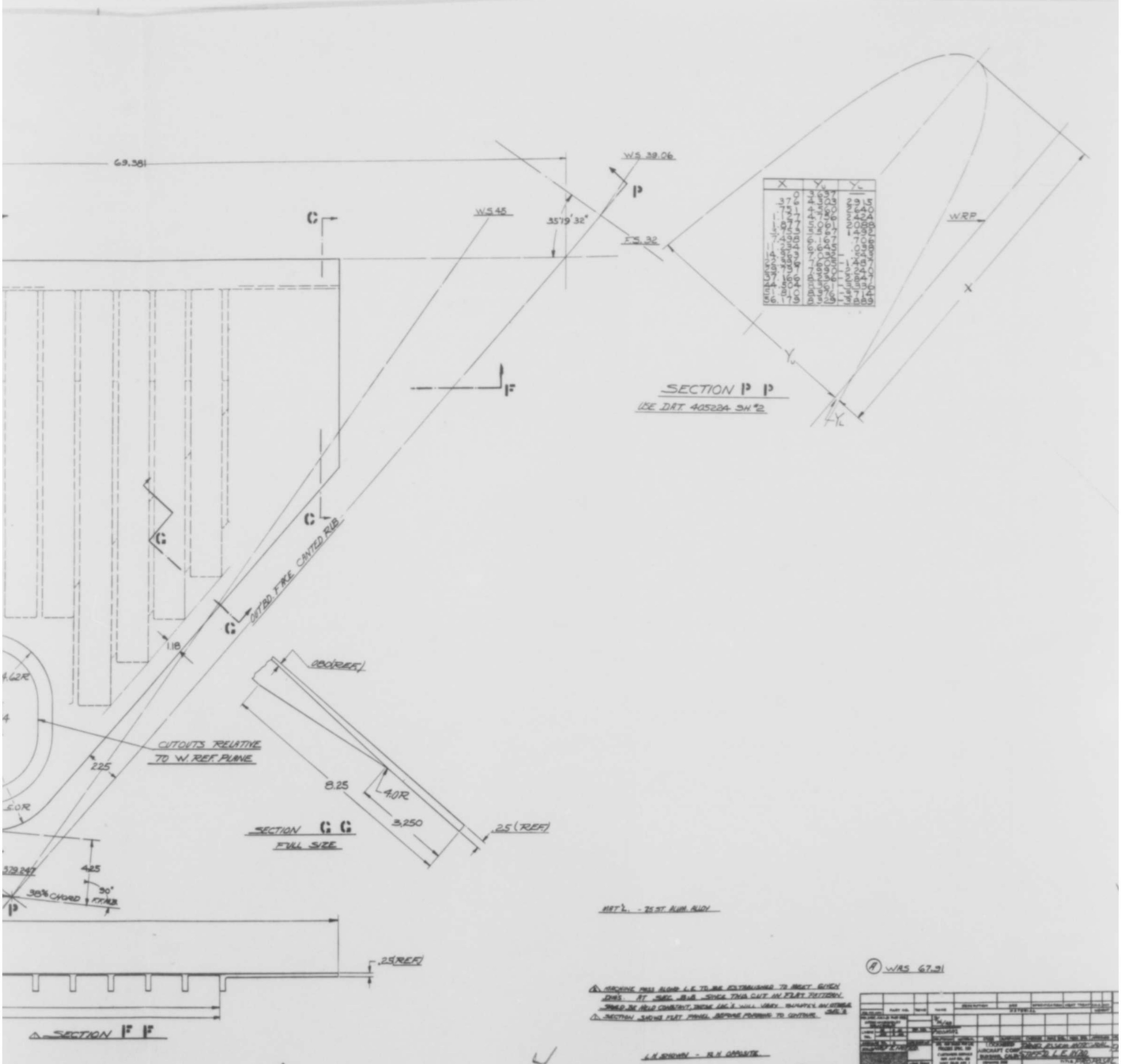
NOTE: SYM. ABOUT THIS LINE EXCEPT TRIMMED PROFILE AND AS OTHERWISE SHOWN



SEE ALTERNATE NOSE SECTION
.25 +.000 -.020
2.30
5.70
.08 ±.003
NOSE SECTION ALTERNATE
.08 ±.003
45°
.25 +.000 -.020
2.30
5.70
.08 ±.003
23.65 (REF.)
W.R.P.
.08 ±.003
5.0
END OF RIB
.56
4.0R.
.25 +.000 -.020
1.0 REF.
.102 TYP.
NOTE: SYM. ABOUT THIS LINE EXCEPT TRIMMED PROFILE AND AS OTHERWISE SHOWN.
SECTION B B
W.R.P.
SECTION A A
6.75
4.0R.
1.75
SECTION H H FULL SIZE
W.S. 96
N
A
F
1.18 MIN.
3.85
90°
A
W.S. 73.563
N
.102
.144
.12
.080 ±.008 TYP.
.25 +.000 -.020
1.06
2.5
2.5
ETC.

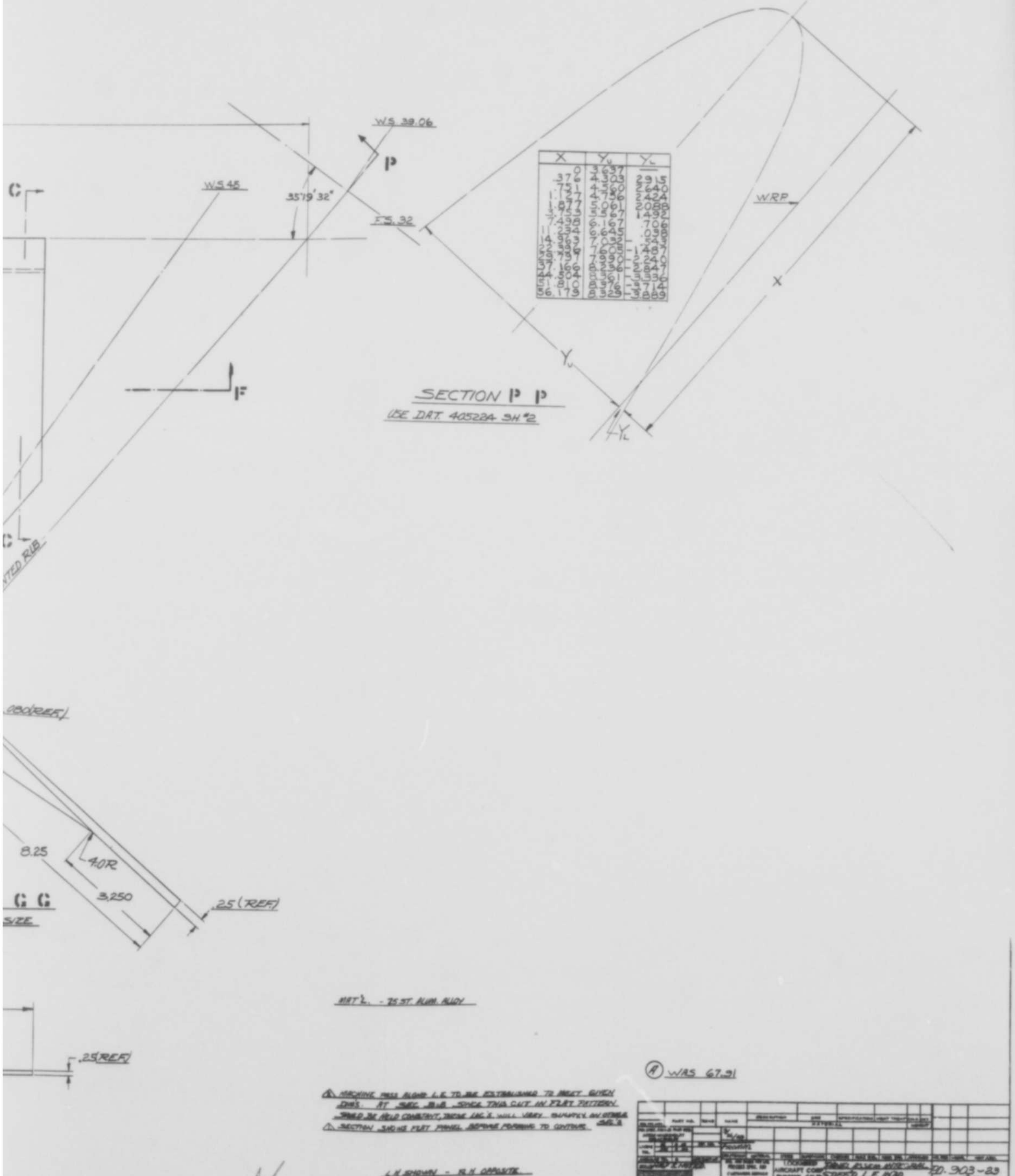


69.381
W.S. 96
N
A
B
C
F
23.65
6.75
4.0R.
1.75
SECTION H H
FULL SIZE
H
3.62R
4.62R
2.14
CUTOUTS RELATIVE
TO W. REF. PLANE
2.25
6.0R
1.18
OUTBD. FIXE. CANTED RIB
.080(REF.)
8.25
SECTION G G
FULL SIZE
1.18 MIN.
3.85
90°
10.78
4.25
32.678
W.S. 73.563
RIBS ARE NORMAL TO
FLAT PATTERN
F.S. 579.247
38% CHORD
P
55.91 APPROX.
ETC.
18 EQ.SPACES = 45.0
SECTION F F
3



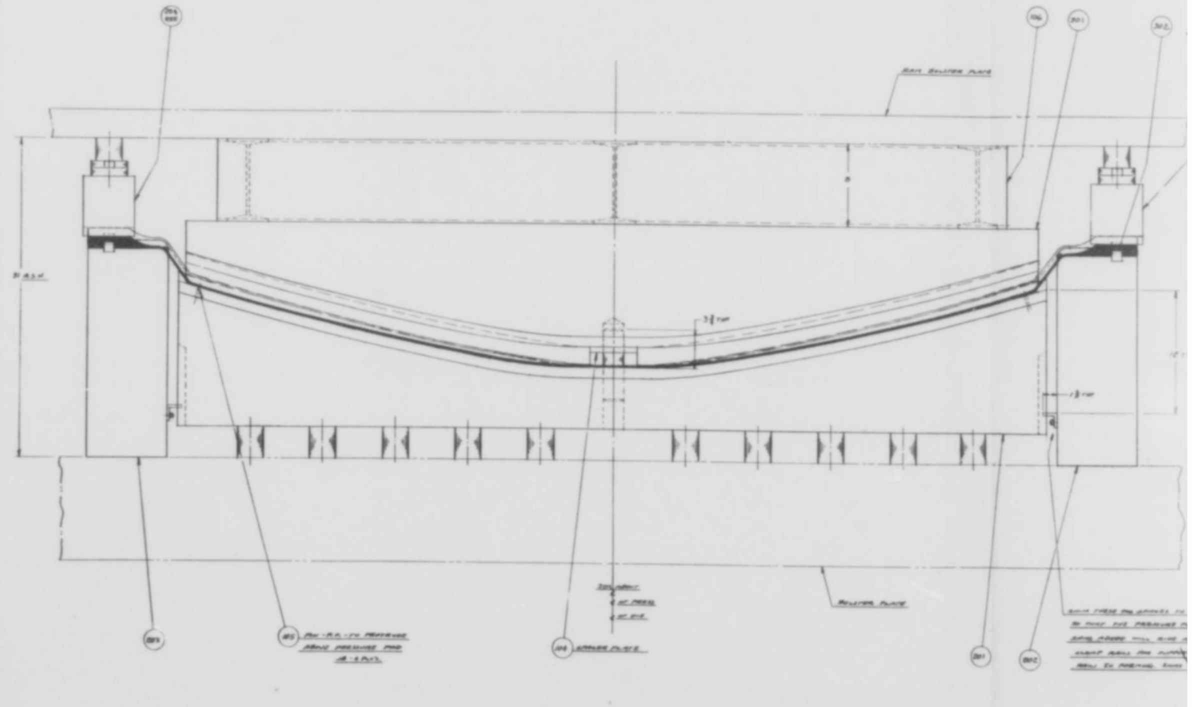
X	Y_U	Y_L
0	3.637	—
.376	4.303	.2915
.751	4.360	.2640
1.127	4.756	[illegible]
1.877	5.061	.2088
[illegible]	5.567	.1492
7.498	6.167	.0706
[illegible]	6.645	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	-.1487
[illegible]	[illegible]	-.2240
37.166	8.236	-.2847
44.504	[illegible]	-.3336
[illegible]	8.976	-.3714
56.179	[illegible]	-.3889

FIG. 87



X	Yu	YL
0	3.637	—
.376	4.303	2.915
.751	4.560	2.640
1.127	4.736	2.424
1.877	5.061	2.088
3.753	5.567	1.492
7.498	6.167	.706
11.234	6.645	.098
14.963	7.032	-.543
22.384	7.605	-1.487
29.737	7.990	-2.240
37.166	8.236	-2.847
44.504	8.361	-3.336
51.810	8.376	-3.714
56.179	8.329	-3.889

FIG. 87


RAM BOLSTER PLATE
106
301
302
BOLSTER PLATE
201
202
ABOVE PRESSURE PAD
SPACER PLATE

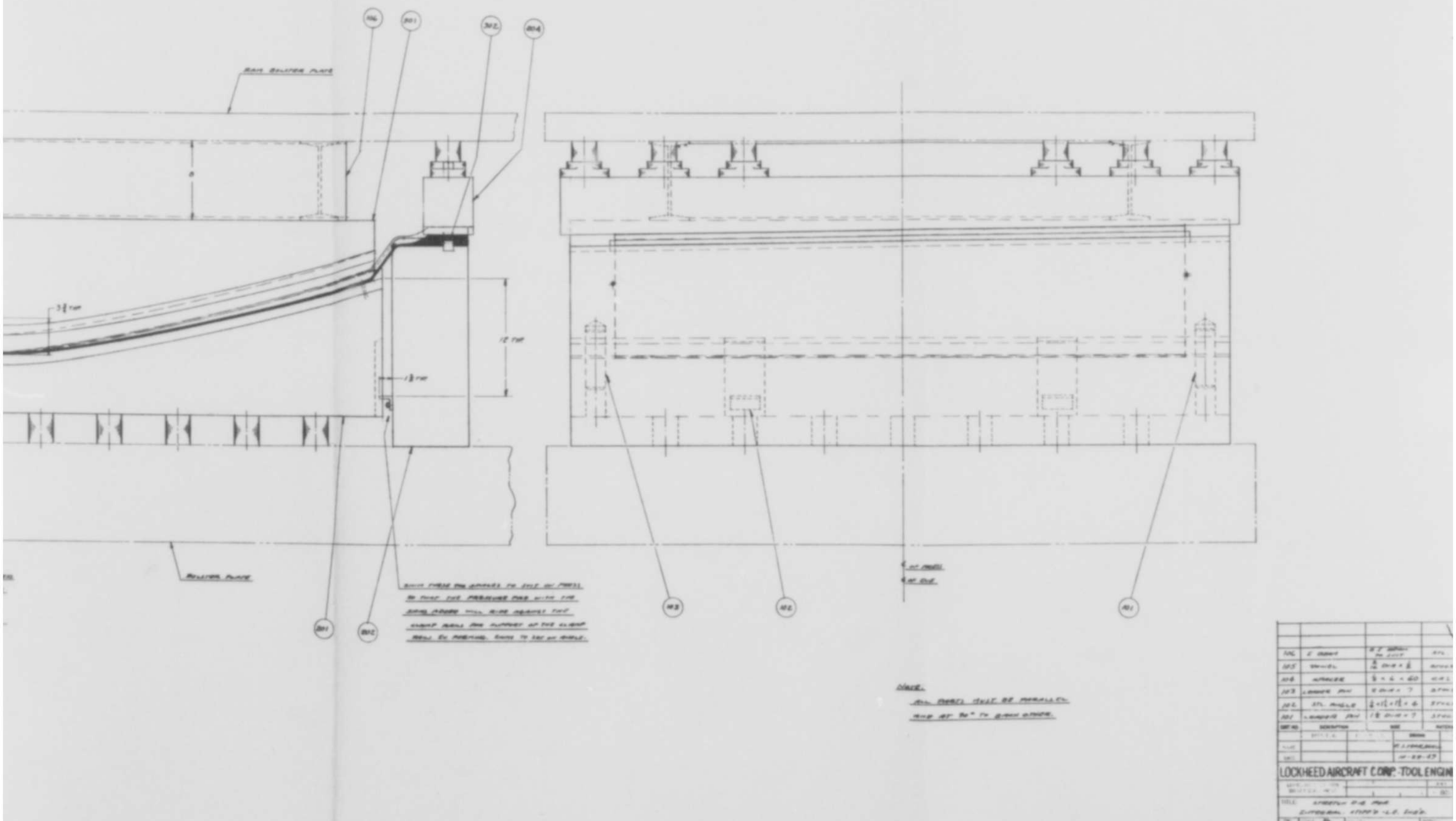


FIG. 88

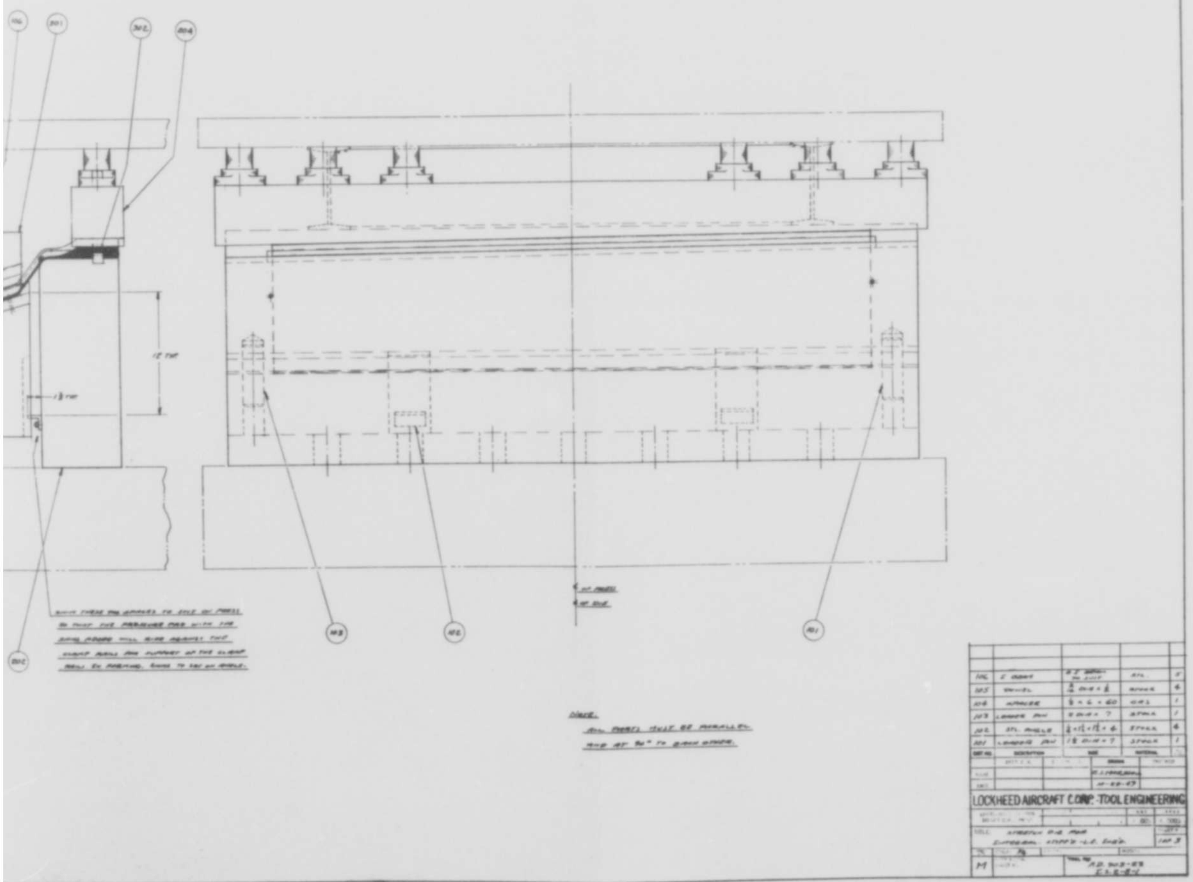
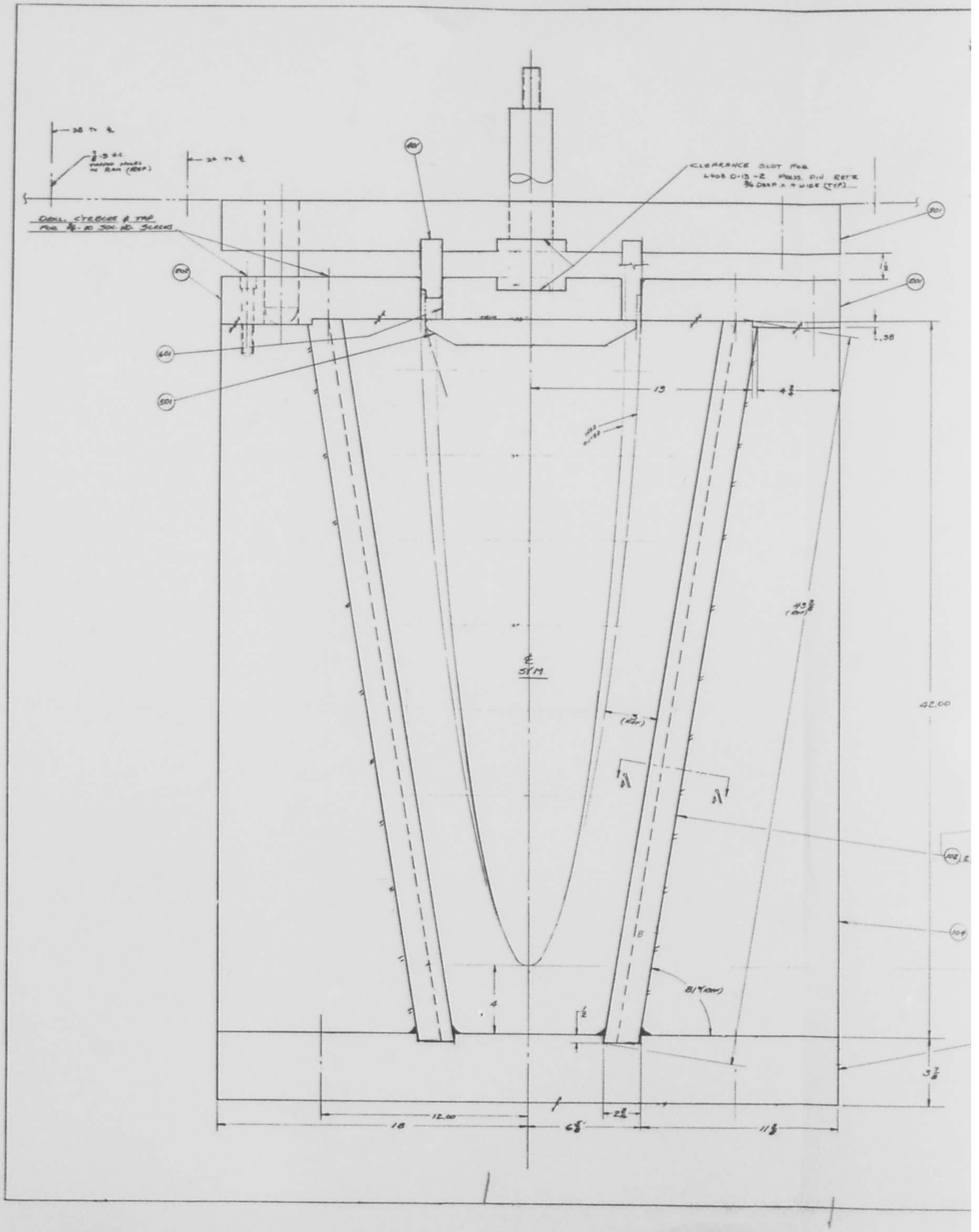
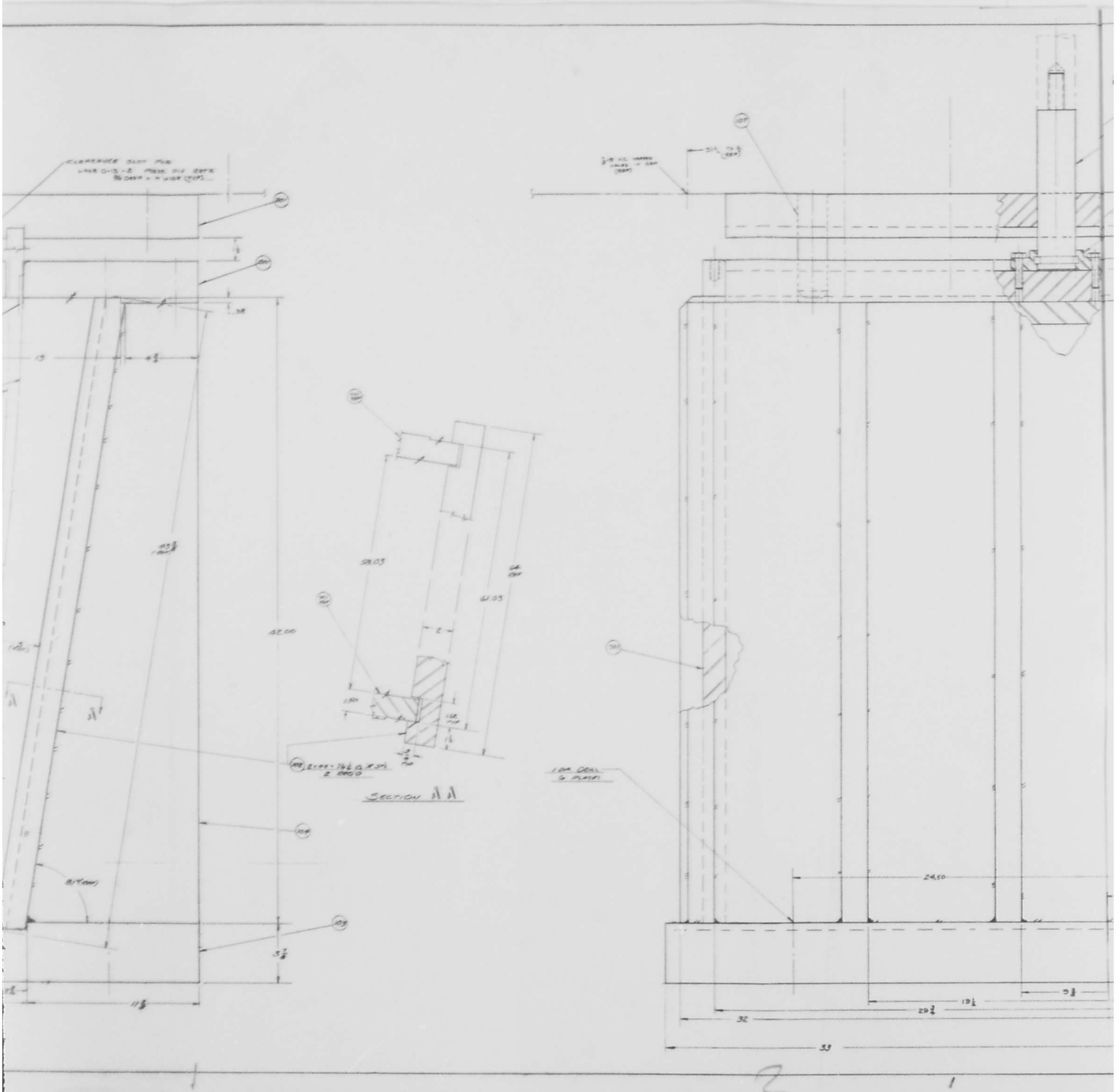
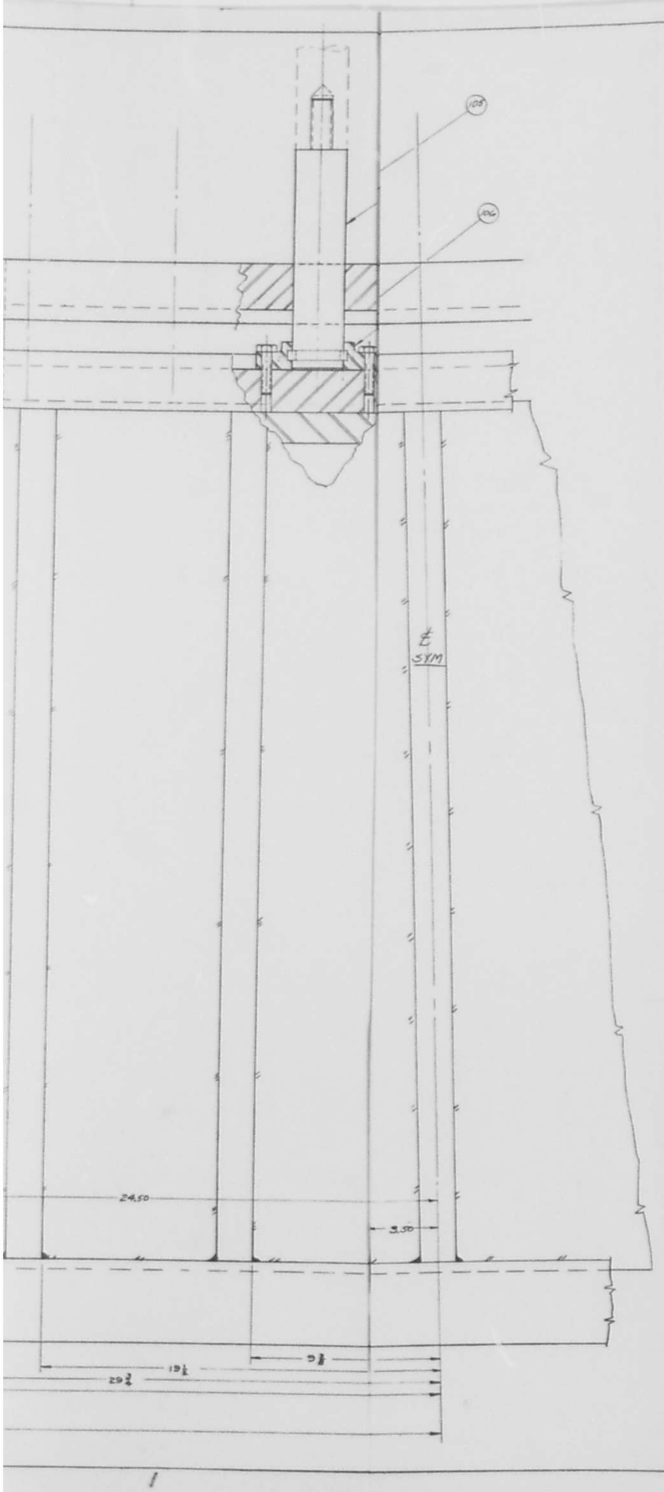


FIG. 88



DRILL, C'BORE & TAP
CLEARANCE SLOT FOR
601
501
.38
13
42.00
SYM
12.00
18


SECTION A A
58.03
61.03
42.00
24.50
1.50
2
11 3/8
5 3/8
19 1/4
29 3/4
32
33
2
1



	CHANGE		
0	DRAWN TO PRE-REL	–	–

NOTE:
1. TO BE USED ON 1500 TON-[illegible] CLEARING PRESS

DET. NO.	DESCRIPTION	SIZE	MATERIAL	REQ.
107	GUIDE POST	2.495 DIA × 7.16	STOCK	8
106	PRESS PIN PLATE	–	L40803-2	6
105	PRESSURE PIN	2½ D × 10.8 LG.	L40810-2	6
104	GUSSET	1½ × 11½ × 42	CLASS-A	14
103	BASE	4 × 36 × 66	CLASS-A	1
102	PLATE	2 × 44 × 64	CLASS A	2
101	WELD ASSEM.	DETS. 102, 103 & 104		1

	SUPV. O.K.	DESIGN O.K.	DRAWN	CHECKED
NAME		[illegible]	[illegible]	[illegible]
DATE		10-2-69	10-11-9	[illegible]

LOCKHEED AIRCRAFT CORP.-TOOL ENGINEERING

TITLE: COMPRESSION FORMING FIXTURE-WING INNER SECT. [illegible]

SHEET NO. 1 OF 7

FIG. 89

ATI— 98 448

Lockheed Aircraft Corp., Burbank, Calif. (Report No. M-100)
FORMING MACHINED INTEGRALLY STIFFENED WING SKIN PANELS - AND APPENDIX - FINAL REPORT - VOLUMES I AND II, by R. B. Scott. 19 June '50, 53 pp. incl. photos, diagrs. UNCLASSIFIED

An investigation with the purpose of developing the production methods and the tooling necessary for forming the contours of machined integrally stiffened wing skin panels applicable to the F-90 fighter is reported. The techniques studied were: stretch forming, compression forming, rubber forming, die forming, roll forming,
(over)

DIVISION: Production (36)
SECTION: Fabrication Processes and Methods (8)
DISTRIBUTION: Copies obtainable from CADO.

1. Production methods
2. Wings
I. Scott, R. B.
II. USAF Contr. No. AF33-038-1178

CENTRAL AIR DOCUMENTS OFFIC[E]

and bumping. It was found that upper and lower integrally stiffened panels could be formed to precision contours by means of stretch forming. Leading edge integrally stiffened panels were contoured by combination stretch and compression forming. The success of either method is dependent upon the development of specialized tooling and techniques.

ATI– 98 448