FLUXLESS BRAZING AND HEAT TREATMENT OF A PLATE-FIN SANDWICH ACTIVELY COOLED PANEL

Charles S. Beuyukian
Rockwell International, Space Systems Group

INTRODUCTION

Two processes that have a major impact on the quality of brazed plate-fin sandwich structures are the specific brazing process used and post-braze heat treatment.

Fluxless brazing of aluminum generally consists of brazing assemblies without the use of corrosive fluxes. The use of the fluxless brazing process is best suited for assemblies whose in-service inspection is not possible and/or where corrosion could result in catastrophic failure. Meanwhile, it is well known that during brazing with pre-placed alloy, application of mechanical pressure minimizes the possibility of voids in brazed joints. Thus, the application of mechanical pressure during the fluxless brazing process is highly desirable in promoting quality brazed joints.

Heat treatment of plate-fin sandwich structures having little internal support generally requires tooling fixtures to minimize distortion during quenching in water. However, some marking and surface damage to face sheets and slight local crushing of the core often occur. Heat treating without use of fixtures often increases distortion considerably. Straightening the assemblies generally requires considerable effort with resultant possible damage to the panel assembly.

This paper presents the processes and techniques used to fabricate plate-fin sandwich actively cooled panels. The materials were 6061 aluminum alloy and brazing sheet having clad brazing alloy. The panels consisted of small scale specimens, fatigue specimens and a large 0.61 m by 1.22 m (2 by 4 ft) test panel. All panels were fluxless brazed in retorts in heated platen presses while exerting external pressure to assure intimate contact of details. Distortion and damage normally associated with heat treatment were minimized by heat treating without fixtures and solution quenching in an organic polymer solution. The test panel is the largest fluxless brazed and heat treated panel of its configuration known to exist.

SMALL SCALE TEST SPECIMENS

(S.S.T.S.)

Key Elements (figures 1 to 4):

- Fluxless brazed in retort under vacuum.
- Brazed in heated platen press - exerting pressure.
- Heat treated using fixtures.
- Quenched in water.
- Successfully tested to 3.45 MPa (500 psi).
- No braze voids detected by radiographic inspection.

DETAILS FOR SMALL SCALE TEST SPECIMENS (S.S.T.S.)

(Figure 1)

Four panel details being assembled for simultaneous brazing. Cores are of straight-fin and lanced off-set types.

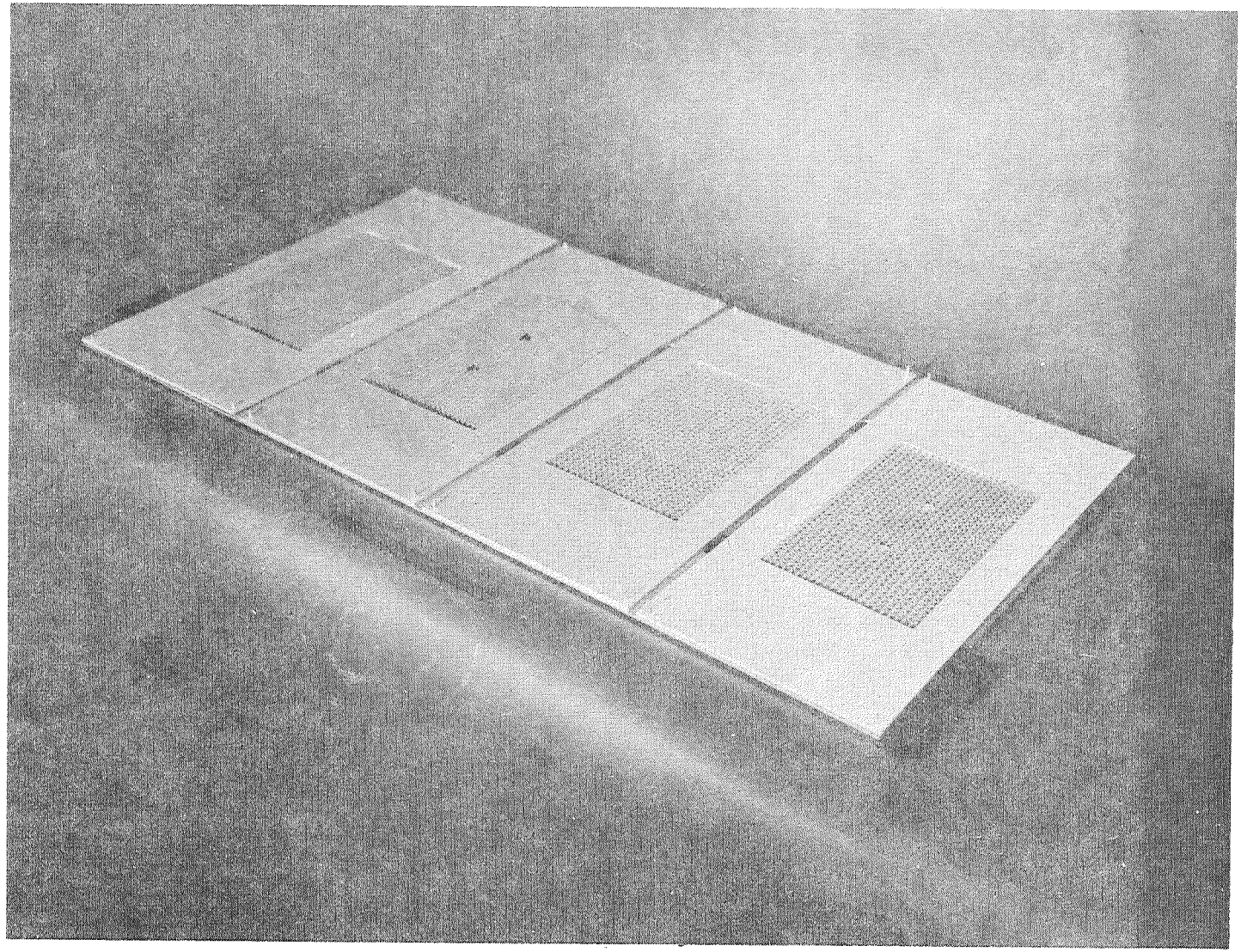

Figure 1.- Details for small scale test specimens (S.S.T.S.).

(S.S.T.S.) SIMULTANEOUSLY BRAZED PANELS

(Figure 2)

Four simultaneously brazed panels prior to removal from brazing retort. Core images are visible on face sheets.

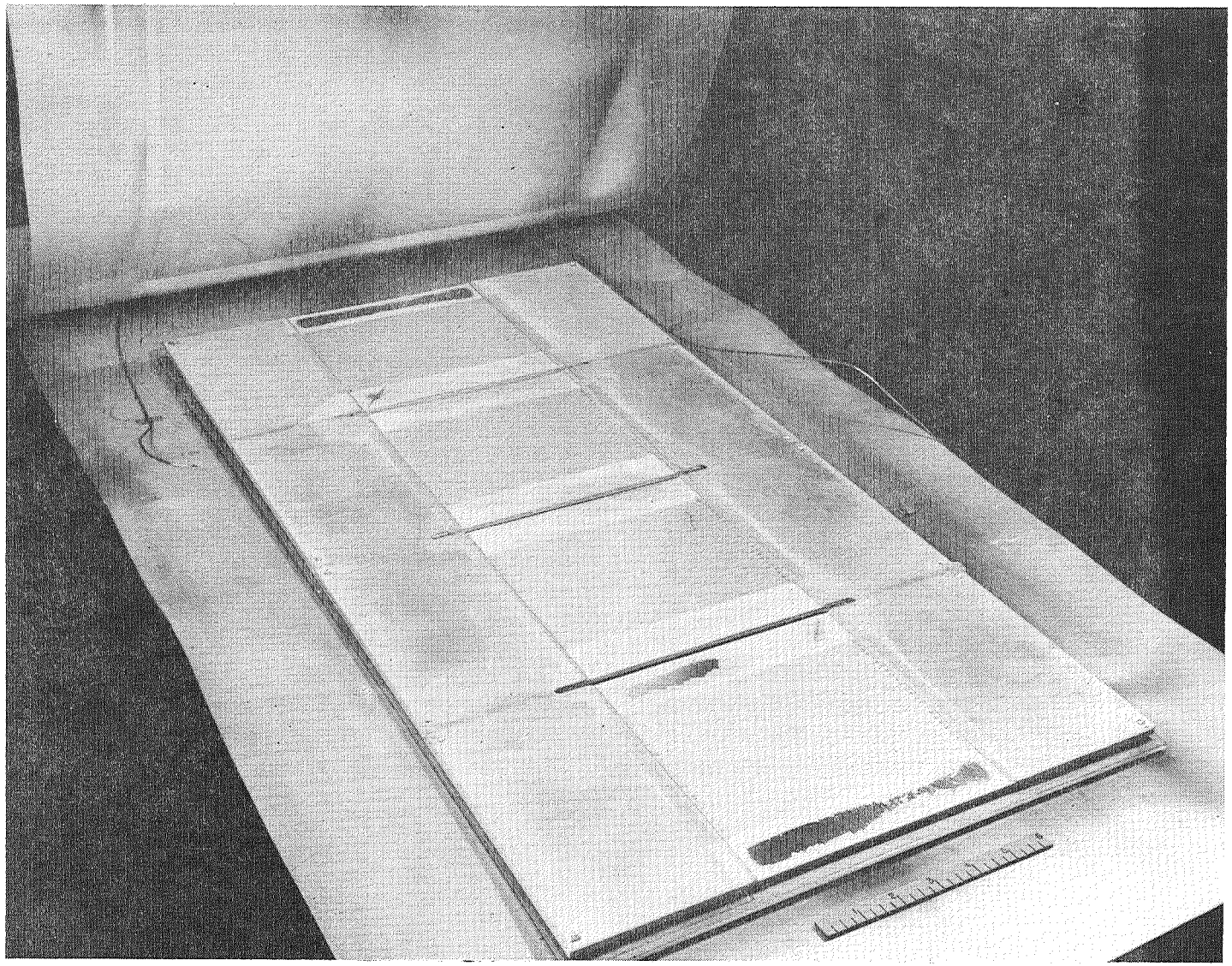

Figure 2.- (S.S.T.S.) simultaneously brazed panels.

(S.S.T.S.) BRAZED PANEL BEING INSTALLED IN HEAT TREAT FIXTURE

(Figure 3)

Brazed small scale test specimen being installed in heat treating fixture. Narrow filler strips and sheets with lightening holes compensate for differing height of panel.

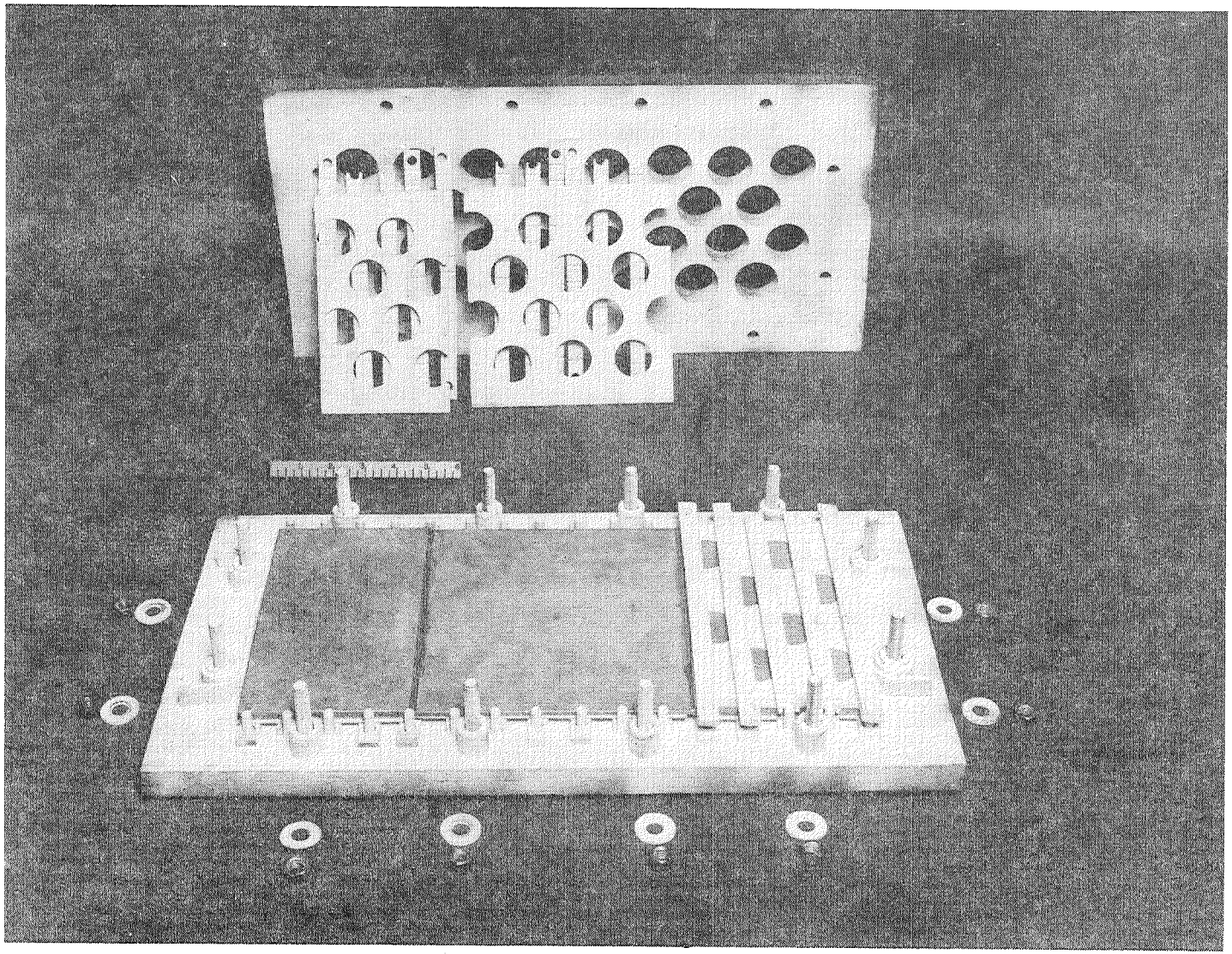

Figure 3.- (S.S.T.S.) brazed panel being installed in heat treat fixture.

(S.S.T.S.) BRAZED PANEL AFTER FINISH MACHINING

(Figure 4)

Brazed small scale test specimen after finish machining.
Tube ports are for manifolding and attachment.

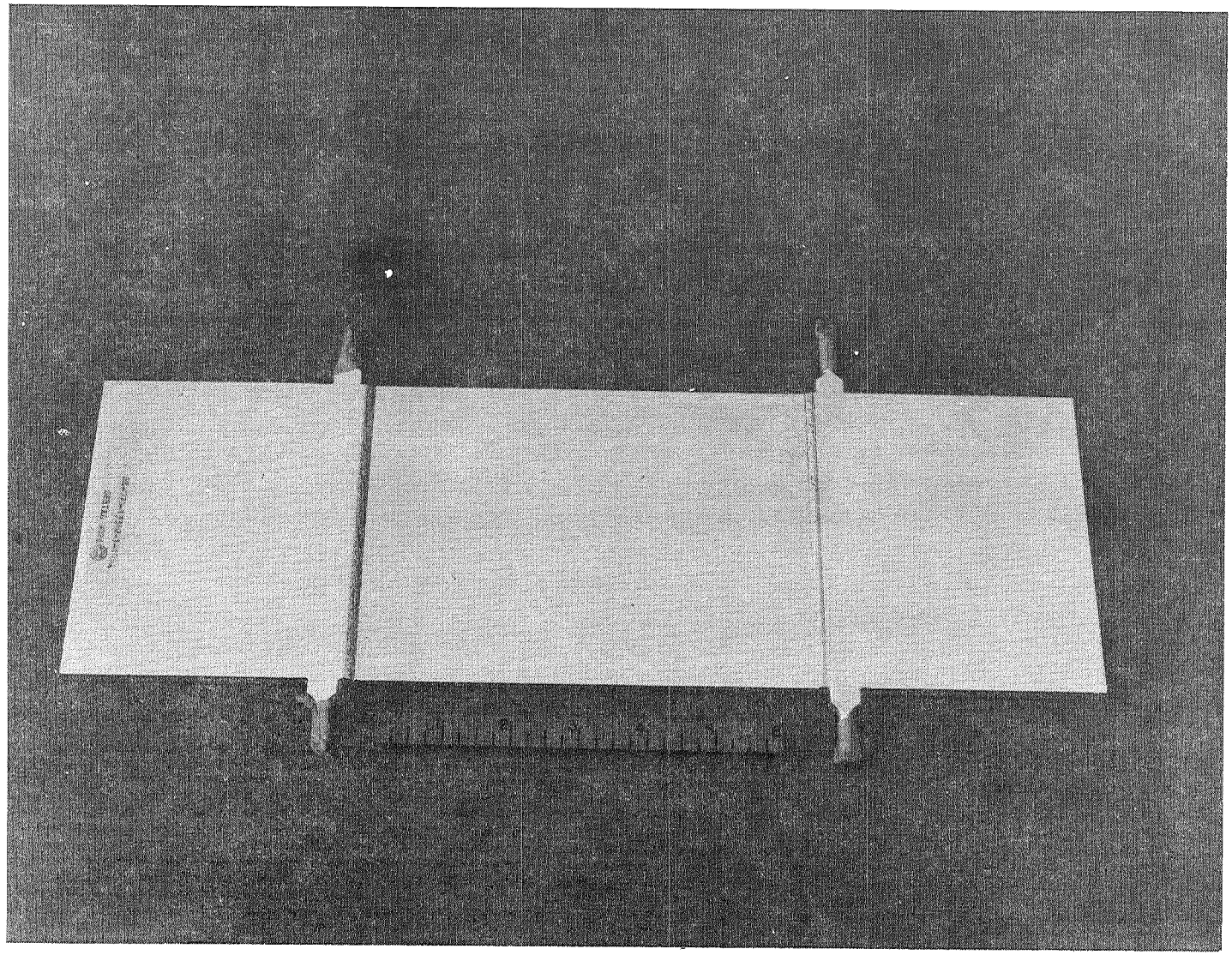

Figure 4.- (S.S.T.S.) brazed panel after finish machining.

SKIN INTERIOR HARDSPOT SPECIMEN

(S.I.H.S.)

First of Three Fatigue Specimens

Key Elements (figures 5 to 8):

- Contained integral manifolding.
- Fluxless brazed in retort under 0.10 MPa (15 psi) argon atmosphere.
- Brazed in heated platen press - exerting pressure.
- Heat treated using fixtures.
- Quenched in water.
- Successfully tested to 1.72 MPa (250 psi).
- No braze voids detected by radiographic inspection.

SKIN INTERIOR HARDSPOT SPECIMEN (S.I.H.S.) DURING ASSEMBLY

(Figure 5)

First of three fatigue specimens. Core sections and hardspot insert are located within the frame prior to brazing.

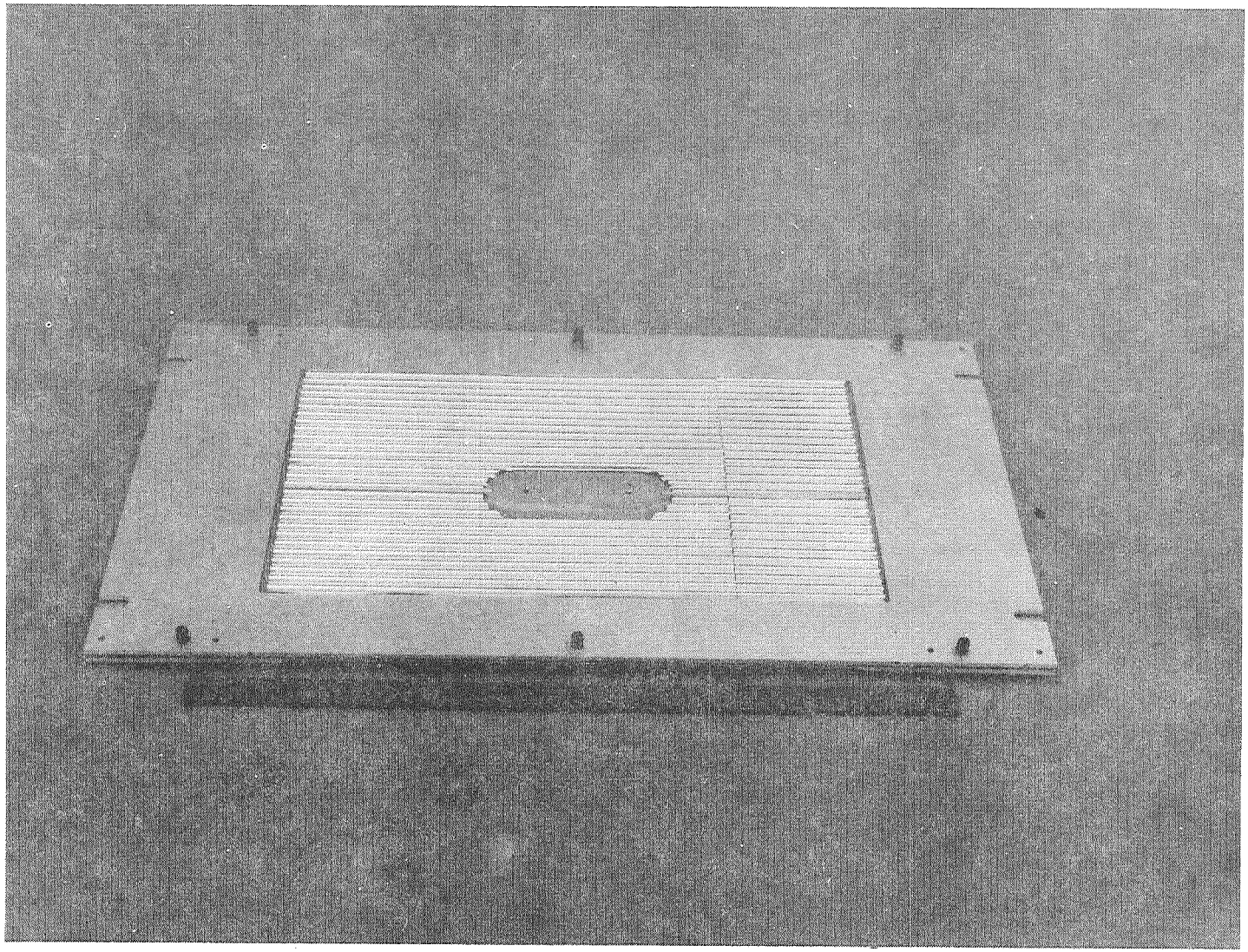

Figure 5.- Skin interior hardspot specimen (S.I.H.S.) during assembly.

(S.I.H.S.) INBOARD SIDE OF PANEL AFTER BRAZING

(Figure 6)

Inboard side of panel after brazing. Images at core convolutions and hardspot insert are visible on face sheet.

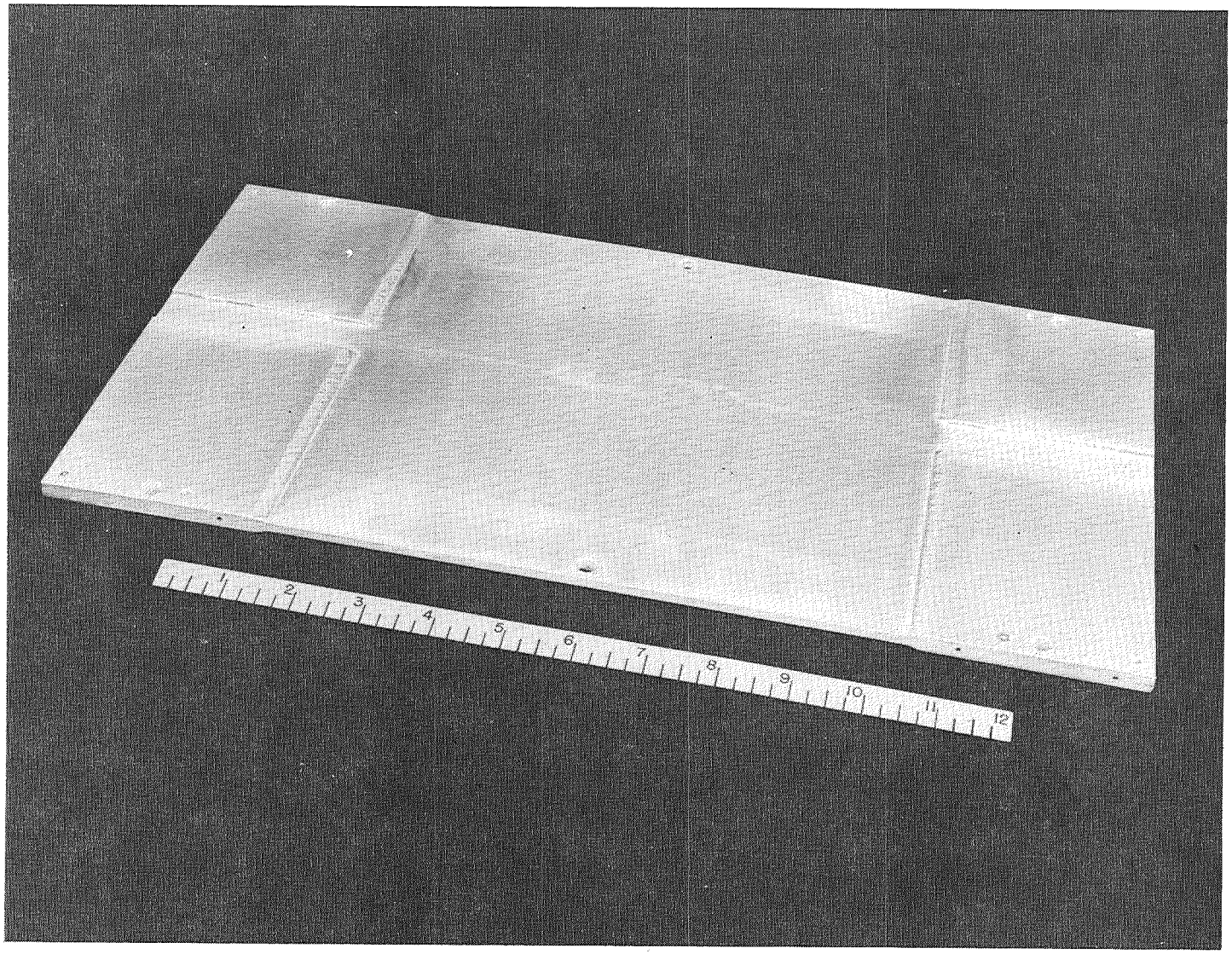

Figure 6.- (S.I.H.S.) inboard side of panel after brazing.

(S.I.H.S.) MOLDLINE SIDE OF BRAZED PANEL WITH LOAD ADAPTORS

(Figure 7)

Moldline side of skin interior hardspot specimen after finish machining. Tubes in edge of panel are for integral manifolds. Load adaptors are bolted to panel for testing.

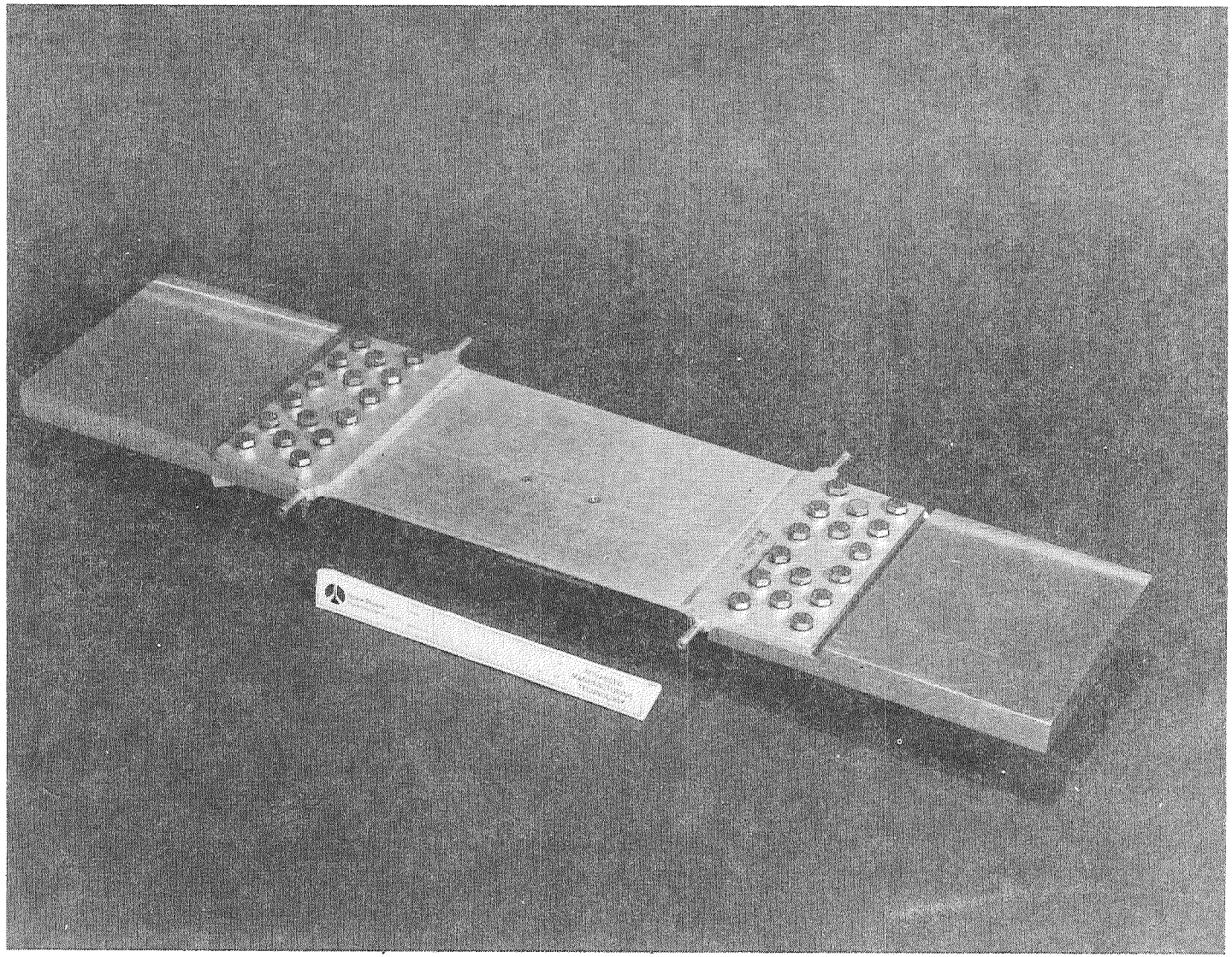

Figure 7.- (S.I.H.S.) moldline side of brazed panel with load adaptors.

(S.I.H.S.) INBOARD SIDE OF COMPLETED SPECIMEN

(Figure 8)

Inboard side of completed panel with center stiffener and end load adapters attached.

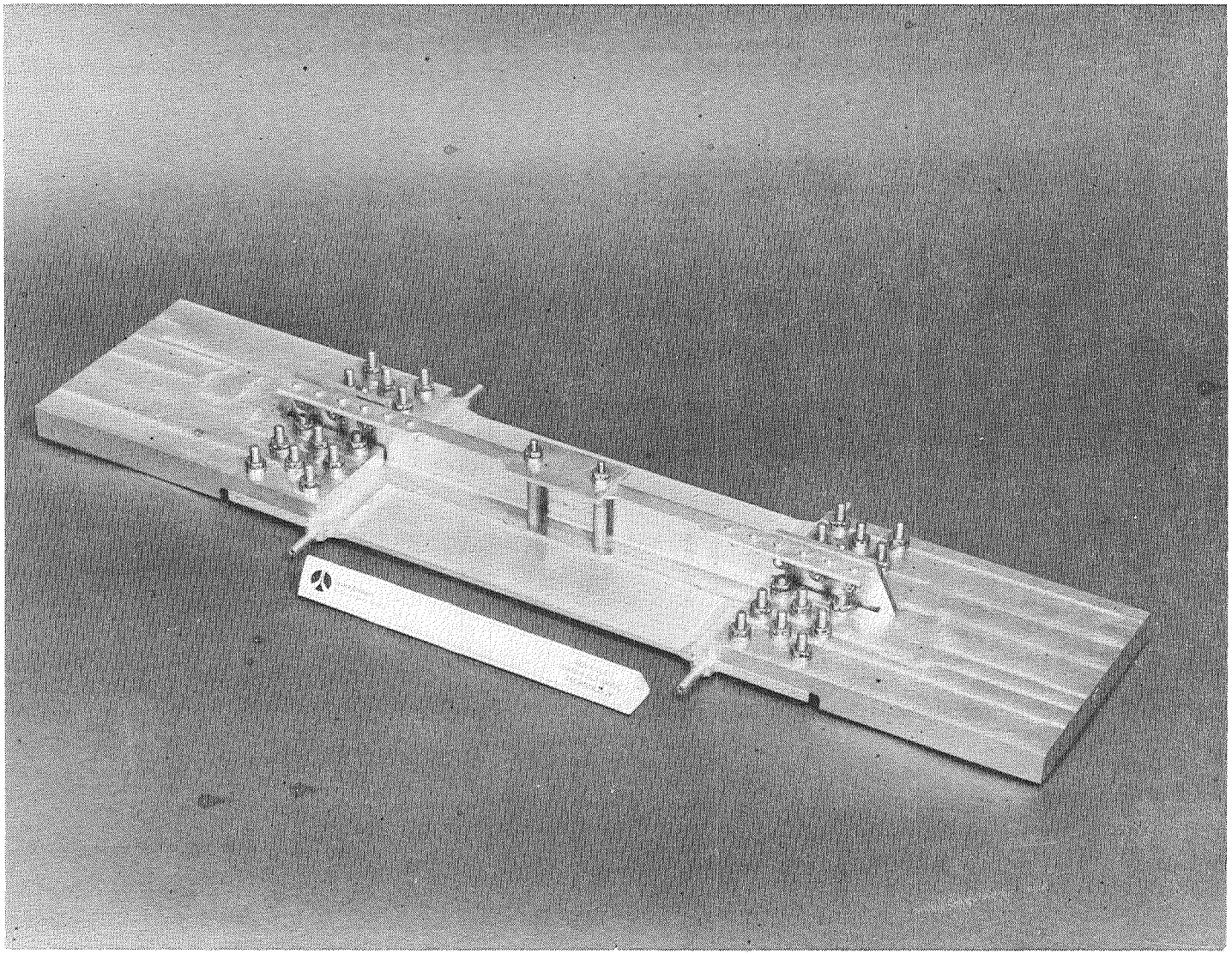

Figure 8.- (S.I.H.S.) inboard side of completed specimen.

PANEL CORNER SPECIMEN

(P.C.S.)

Second of Three Fatigue Specimens

Key Elements (figures 9 to 13):

- Contained external and integral manifolding.
- Fluxless brazed in retort under 0.10 MPa (15 psi) argon atmosphere.
- Brazed in heated platen press - exerting pressure.
- Heat treated without fixtures.
- Quenched in polymer solution.
- Fusion welded after quenching - before aging.
- Successfully tested to 1.72 MPa (250 psi).
- No braze voids detected by radiographic inspection.

PANEL CORNER SPECIMEN (P.C.S.) DETAILS DURING ASSEMBLY

(Figure 9)

Second of three fatigue specimens. Core sections are installed in frame. Channel at edge of frame is for edge cooling. Fingers in frame direct fluid flow from the manifold.

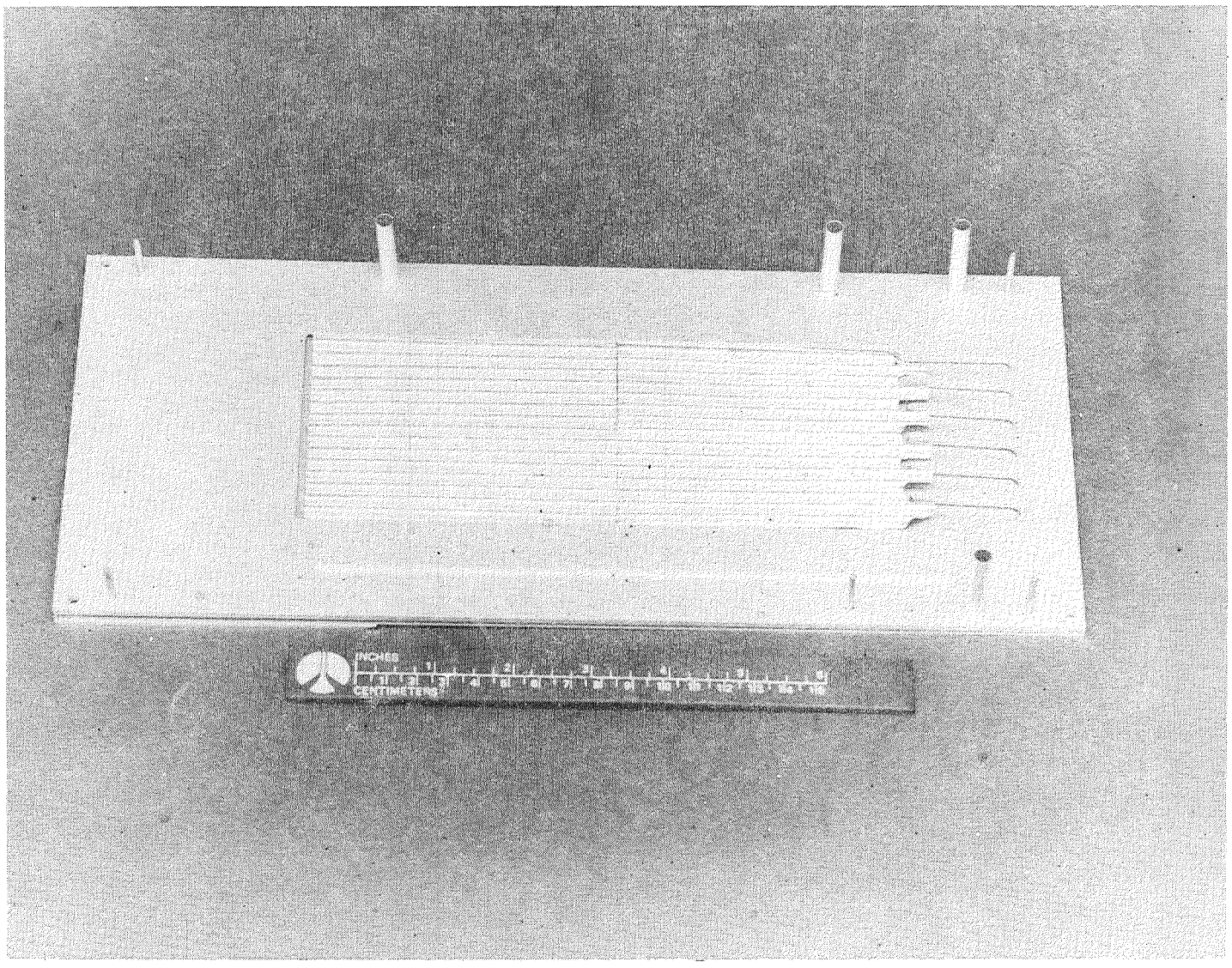

Figure 9.- Panel corner specimen (P.C.S.) details during assembly.

(P.C.S.) BRAZED PANEL AS REMOVED FROM RETORT

(Figure 10)

Brazed panel corner specimen after removal from retort. Note fingers in frame under the manifold prior to welding cap.

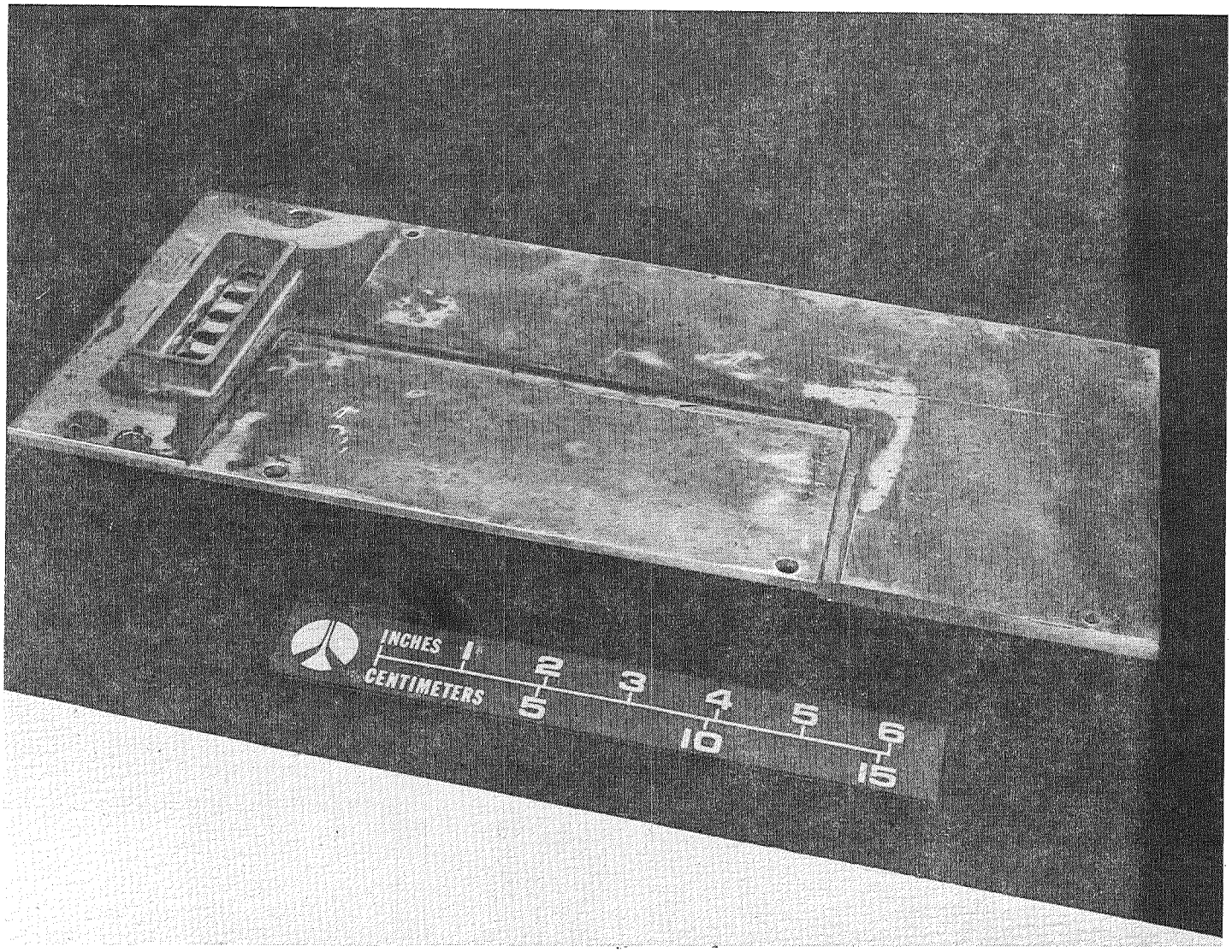

Figure 10.- (P.C.S.) brazed panel as removed from retort.

(P.C.S.) PANELS AFTER FINISH MACHINING

(Figure 11)

Panel corner specimens after heat treating and welding of manifold cap. Tube at edge of panel is for outlet manifolding.

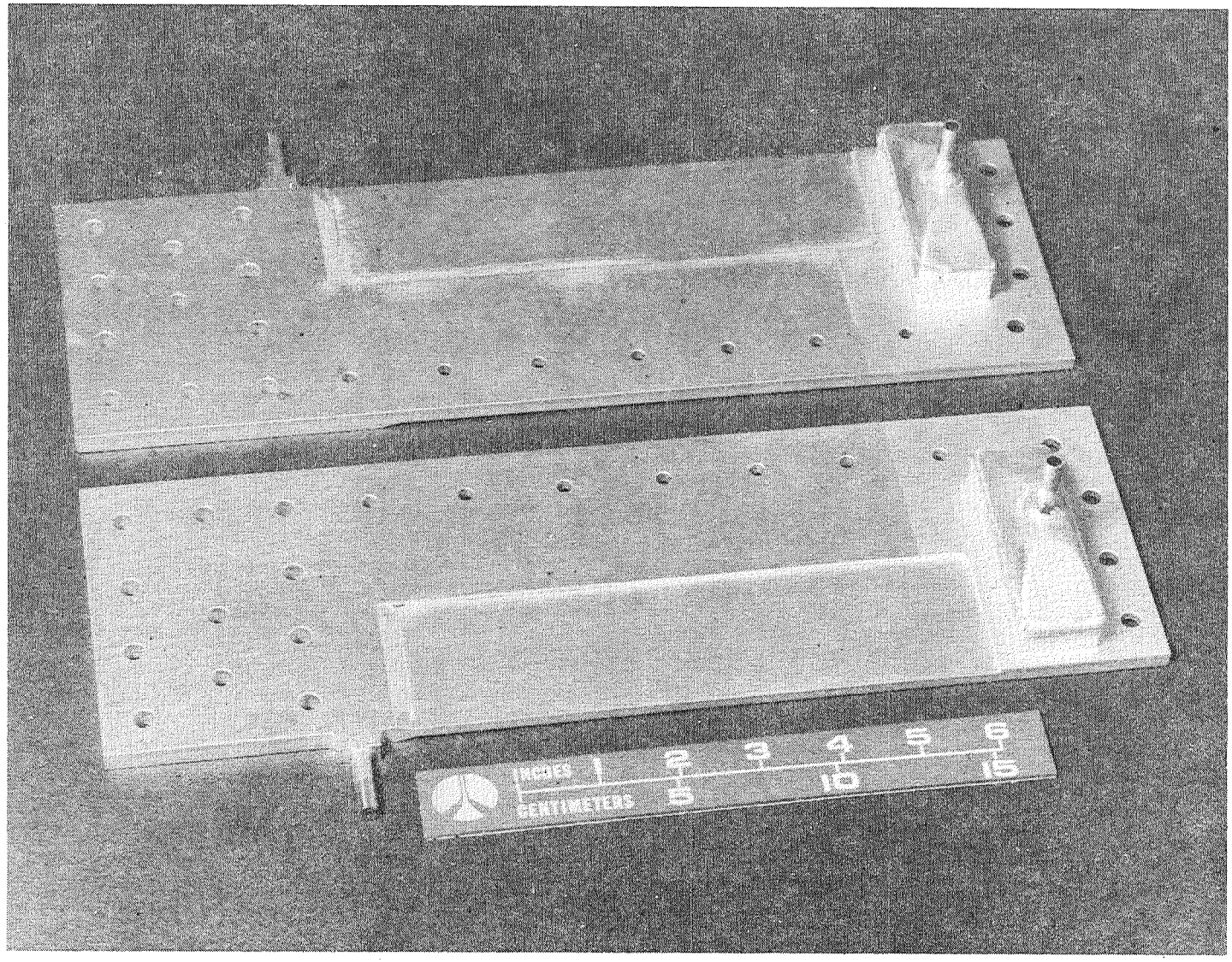

Figure 11.- (P.C.S.) panels after finish machining.

(P.C.S.) MOLDLINE SIDE OF COMPLETED SPECIMEN

(Figure 12)

Moldline side of panel corner specimens attached to end load adapters.

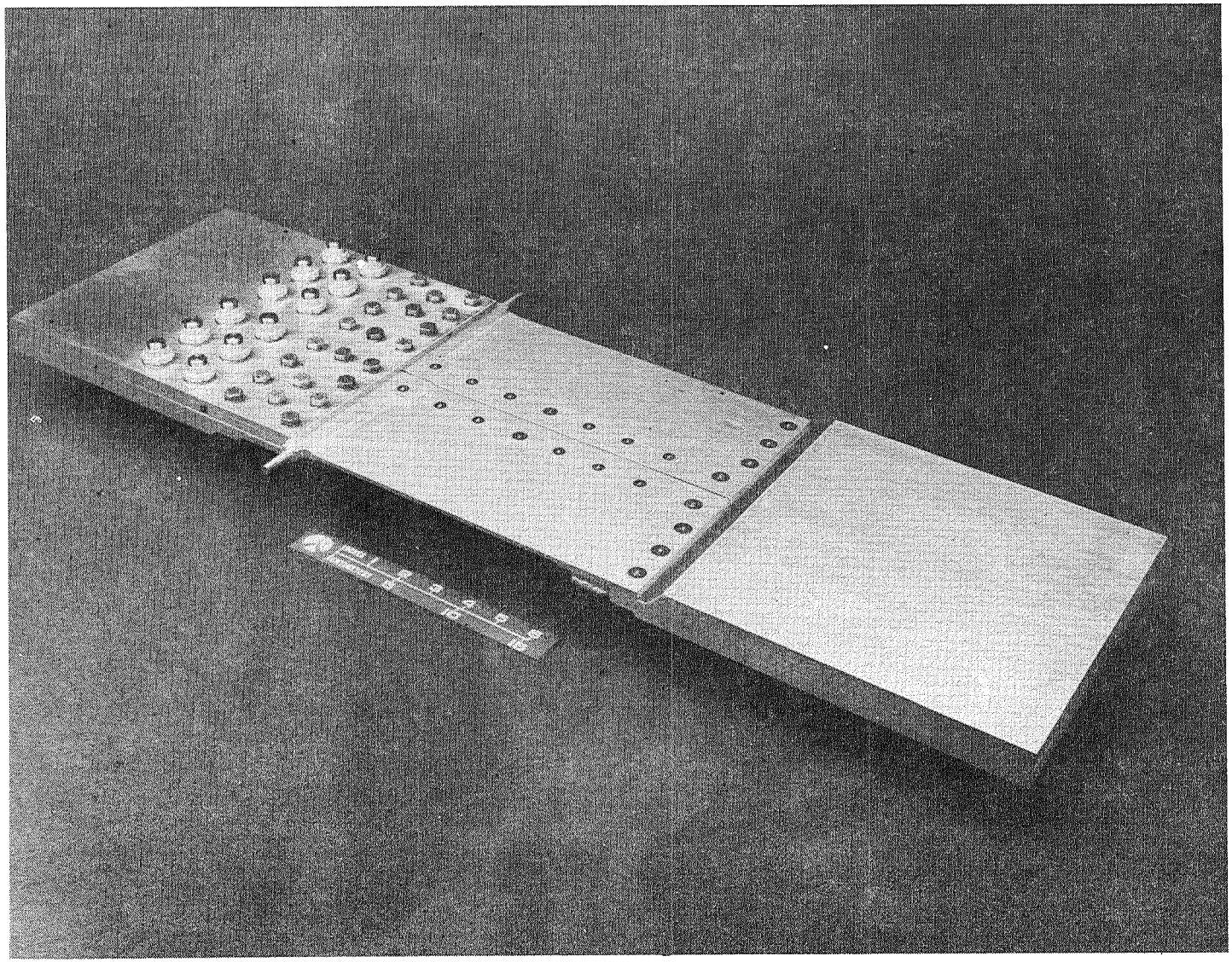

Figure 12.- (P.C.S.) moldline side of completed specimen.

(P.C.S.) INBOARD SIDE OF COMPLETED SPECIMEN

(Figure 13)

Inboard side of panel corner specimen with center stringers and end load adapters attached.

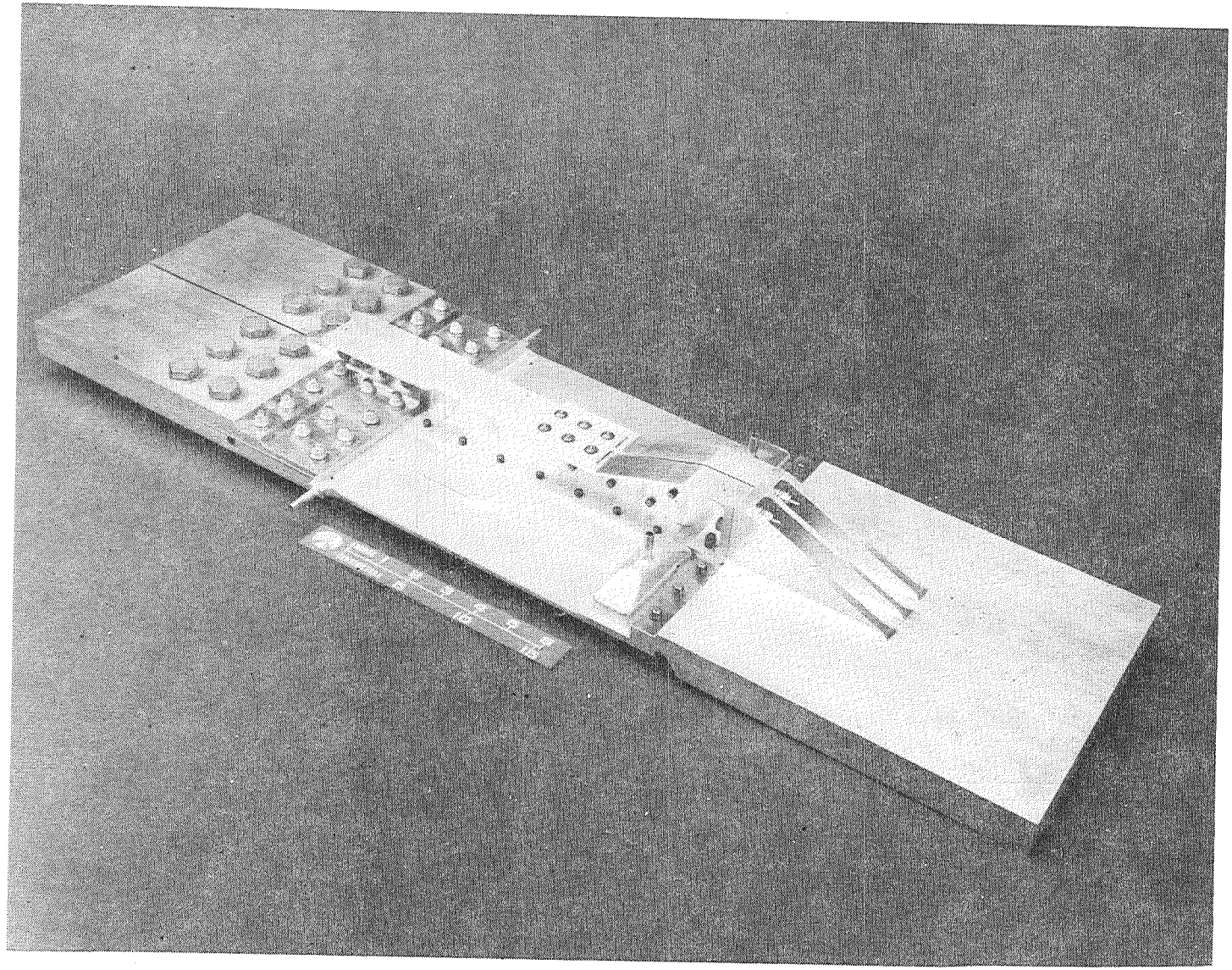

Figure 13.- (P.C.S.) inboard side of completed specimen.

END PANEL INTERIOR STRINGER TERMINATION SPECIMEN

(E.P.I.S.T.S.)

Third of Three Fatigue Specimens

Key Elements (figures 14 to 18):

- Contained external and integral manifolding.
- Fluxless brazed in retort under 0.10 MPa (15 psi) argon atmosphere.
- Brazed in heated platen press - exerting pressure.
- Heat treated without fixtures.
- Quenched in polymer solution.
- Fusion welded after quenching - before aging.
- Successfully tested to 1.72 MPa (250 psi).
- No braze voids detected by radiographic inspection.

END PANEL INTERIOR STRINGER TERMINATION SPECIMEN (E.P.I.S.T.S.) DETAILS DURING ASSEMBLY

(Figure 14)

Last of three fatigue specimens. Core sections located in frame. Note fingers and stringer hardspot machined in frame. Rod is temporarily inserted in holes in frame. Holes will later become integral manifolding ports after machining.

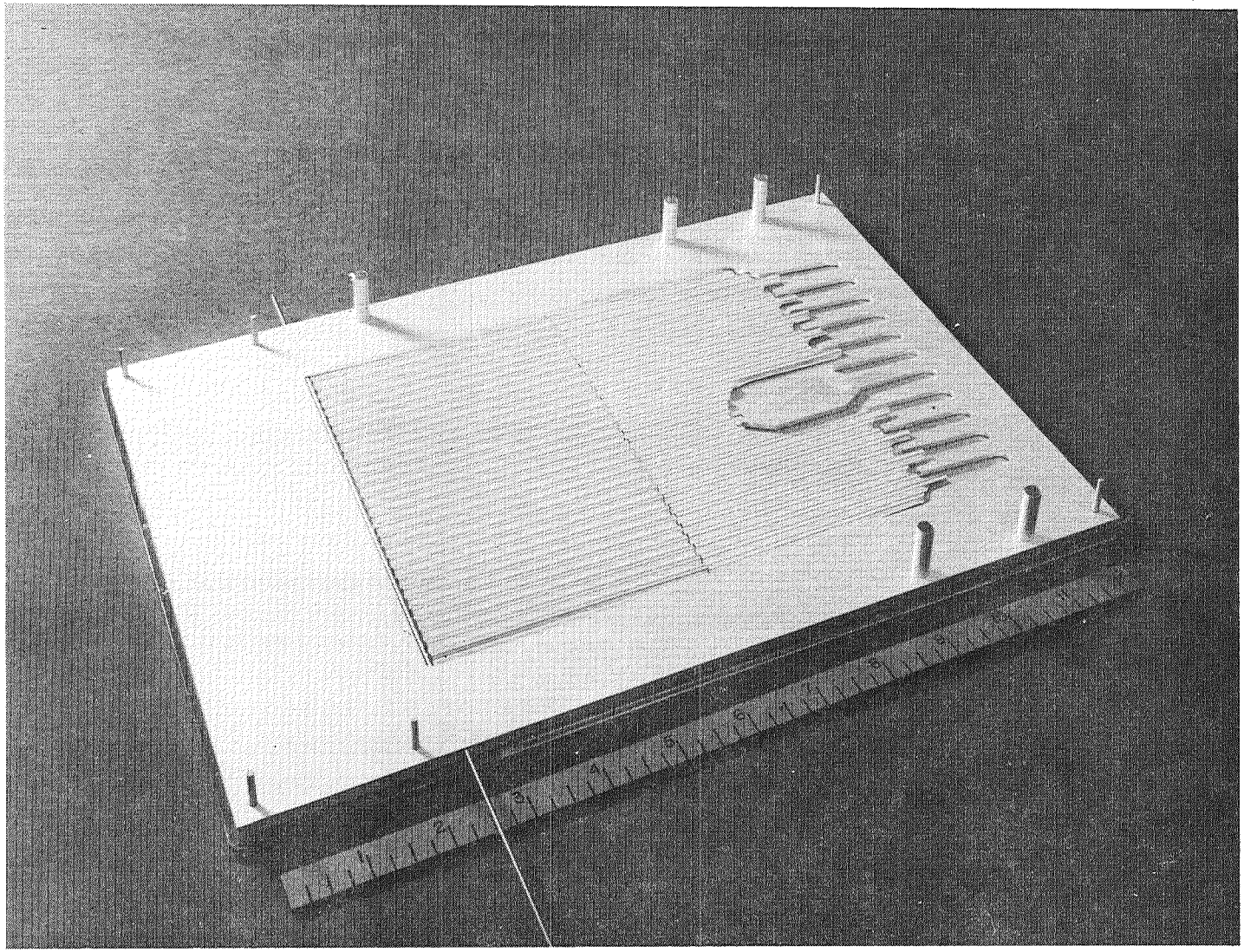

Figure 14.- End panel interior stringer termination specimen (E.P.I.S.T.S.) details during assembly.

(E.P.I.S.T.S.) BRAZED PANEL AFTER REMOVAL FROM RETORT

(Figure 15)

Brazed panel specimen before heat treating, welding, and machining. Note differing heights on surface of panel and within manifold.

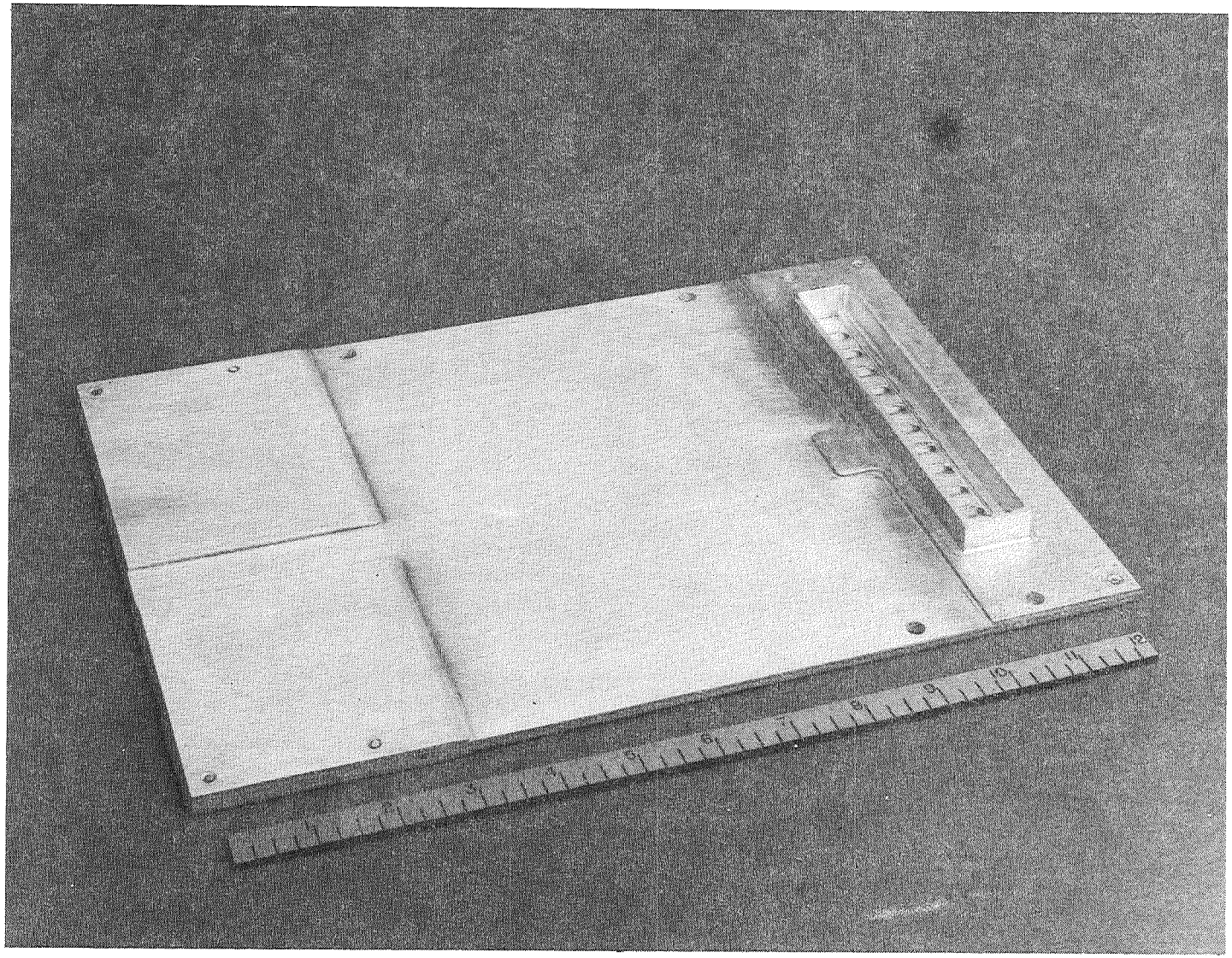

Figure 15.- (E.P.I.S.T.S.) brazed panel after removal from retort.

(E.P.I.S.T.S.) BRAZED PANEL COMPLETED

(Figure 16)

Panel specimen has been heat treated and cap welded to the manifold. Finish machining has left the integral manifolding ports (tubes) on the panel.

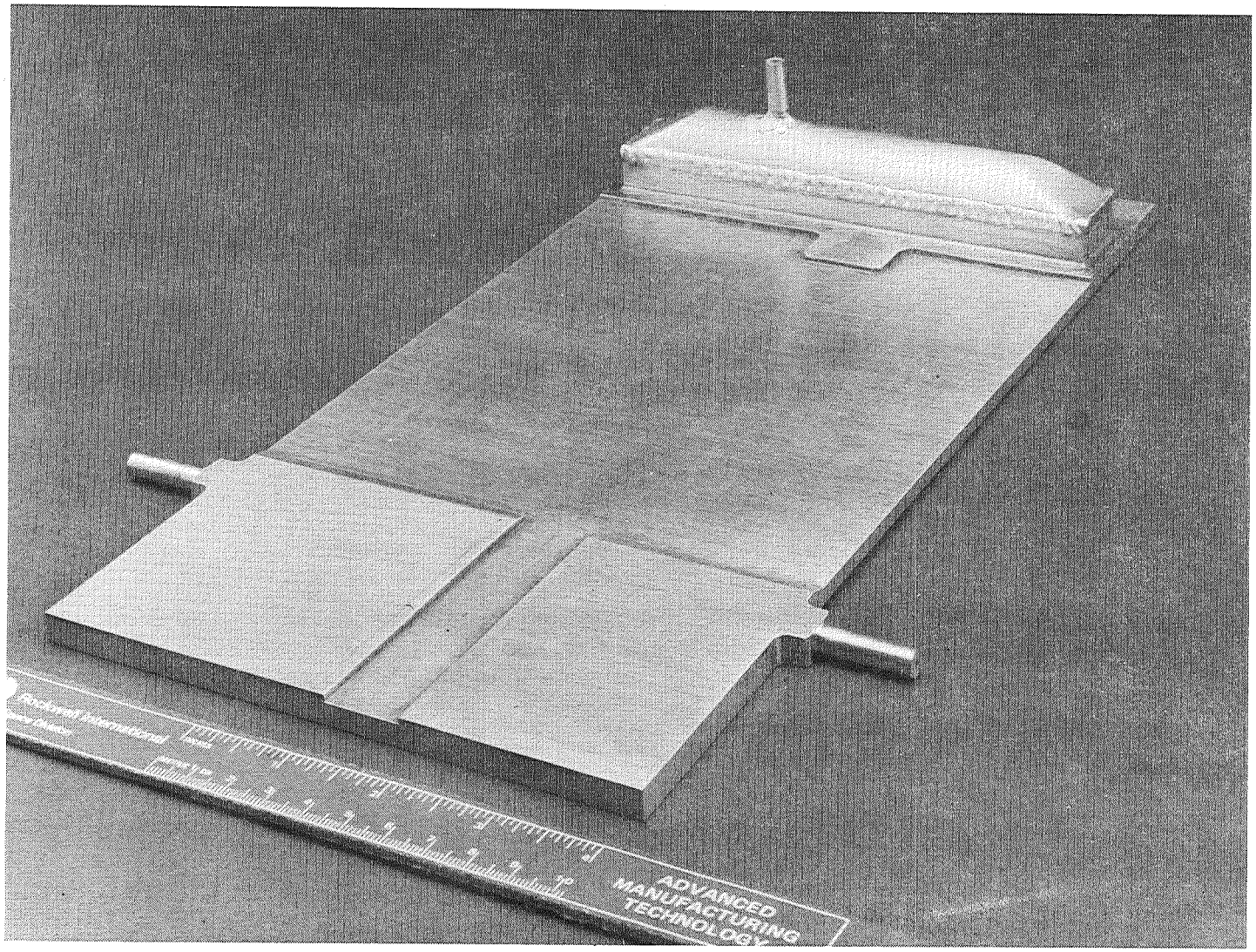

Figure 16.- (E.P.I.S.T.S.) brazed panel completed.

(E.P.I.S.T.S.) INBOARD SIDE OF COMPLETED SPECIMEN

(Figure 17)

Inboard side of completed panel specimen with center stiffener and end load adapters attached. The center stiffener has been adhesive bonded to the panel specimen.

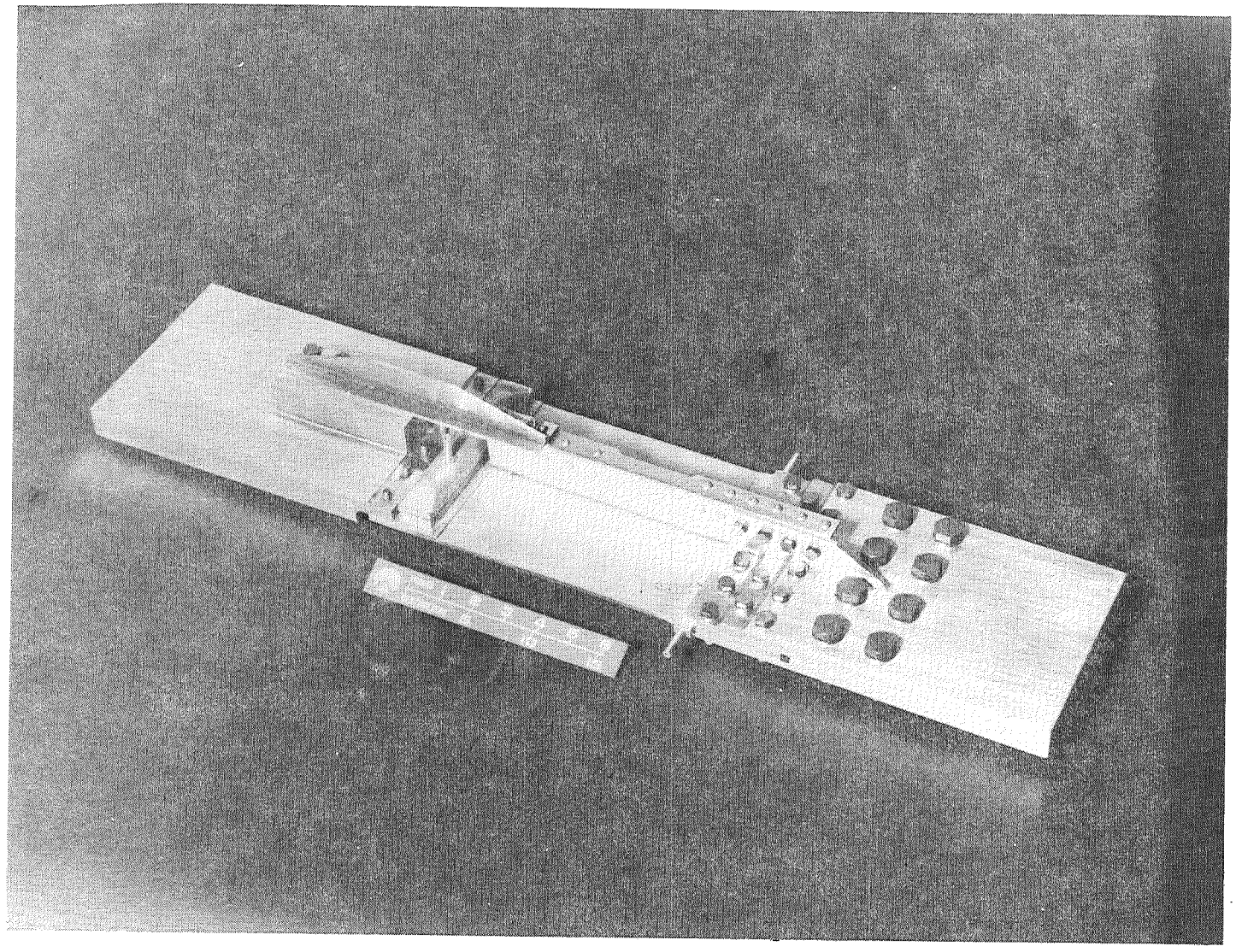

Figure 17.- (E.P.I.S.T.S.) inboard side of completed specimen.

(E.P.I.S.T.S.) MOLDLINE SIDE OF COMPLETED SPECIMEN

(Figure 18)

Moldline side of the completed panel ready for testing.

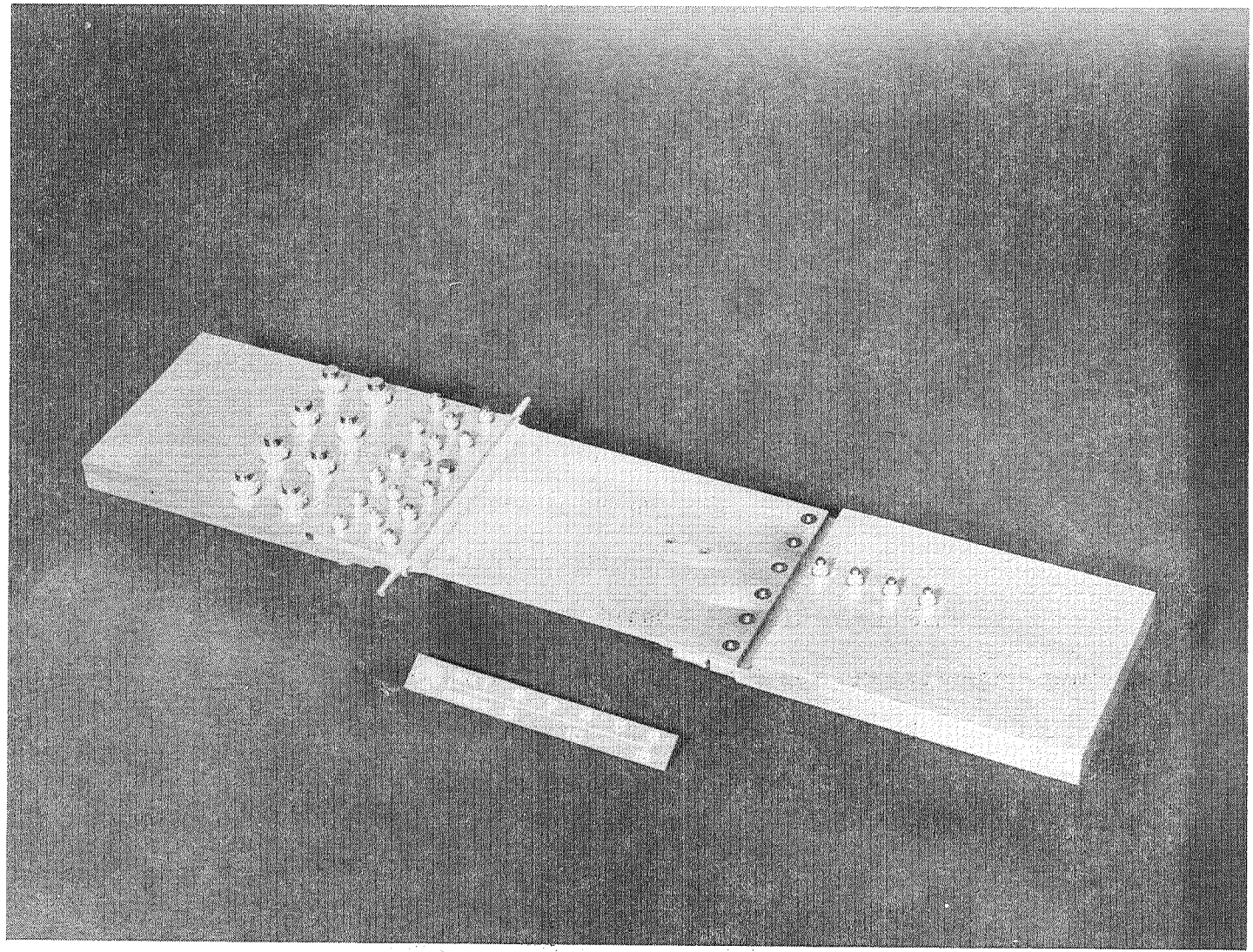

Figure 18.- (E.P.I.S.T.S) moldline side of completed specimen.

ACTIVELY COOLED TEST PANEL

(A.C.T.P.)

0.61 m by 1.22 m (2 by 4 ft)

Key Elements (figures 19 to 36):

- Largest fluxless brazed and heat treated aluminum panel of this configuration known to exist.
- Contained external inlet and outlet manifolding.
- Fluxless brazed in retort under 0.10 MPa (15 psi) argon atmosphere.
- Brazed in heated platen press - exerting pressure.
- Heat treated without fixtures.
- Quenched in polymer solution.
- Flushed with alcohol and freon.
- Fusion welded after quenching - before aging.
- Panel exterior anodized.
- Successfully tested to 1.24 MPa (180 psi).
- No braze voids detected by radiographic inspection.

ACTIVELY COOLED TEST PANEL BRAZE ASSEMBLY COMPONENTS

(Figure 19)

Composite sketch of the lay-up of all components comprising the test panel sandwich structure for brazing.

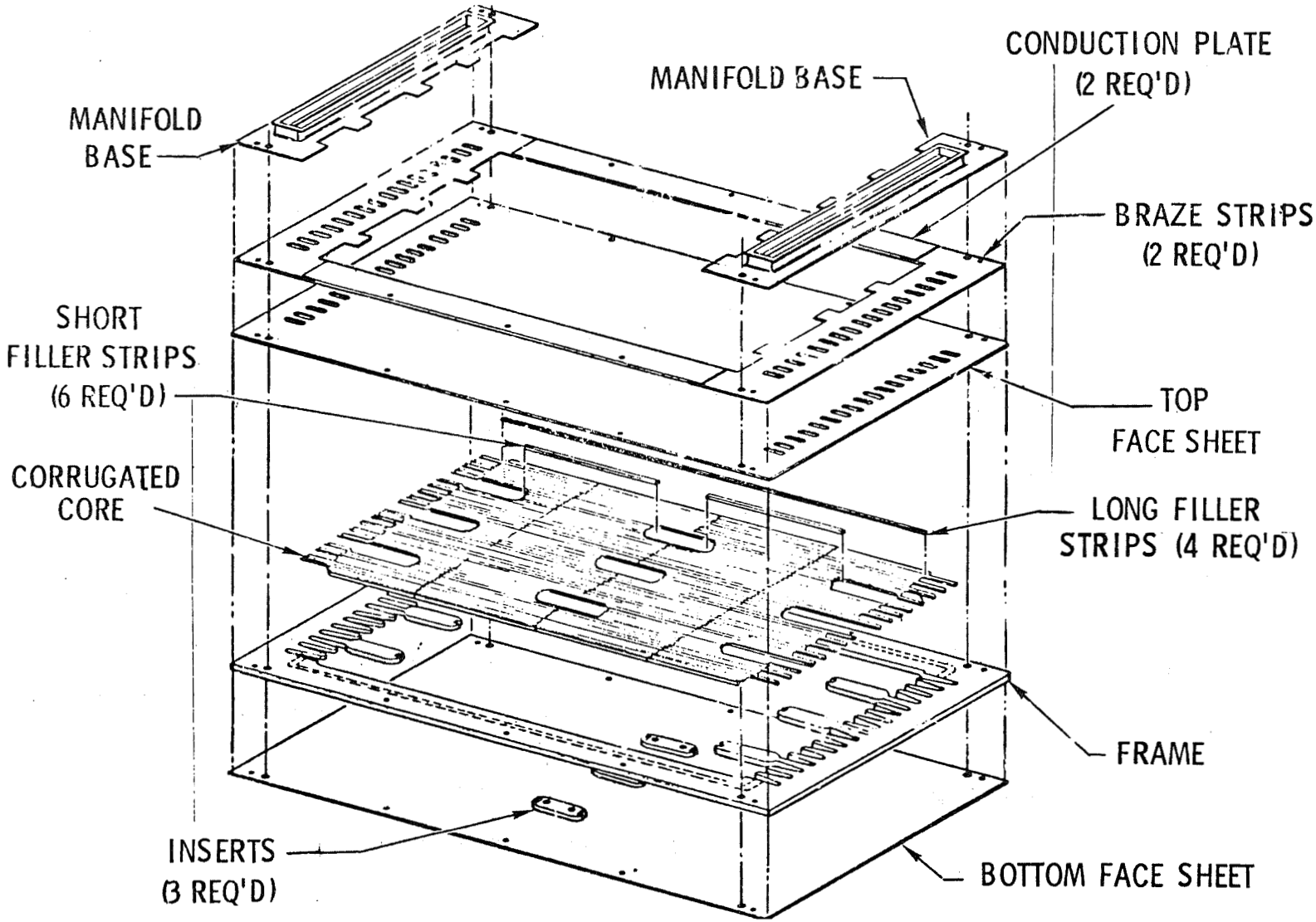

Figure 19.- Actively cooled test panel braze assembly components.

TOOLING LAY-UP SEQUENCE FOR BRAZING ACTIVELY COOLED TEST PANEL

(Figure 20)

Composite sketch of the tooling lay-up and test panel location in preparation to installation in retort prior to fluxless brazing.

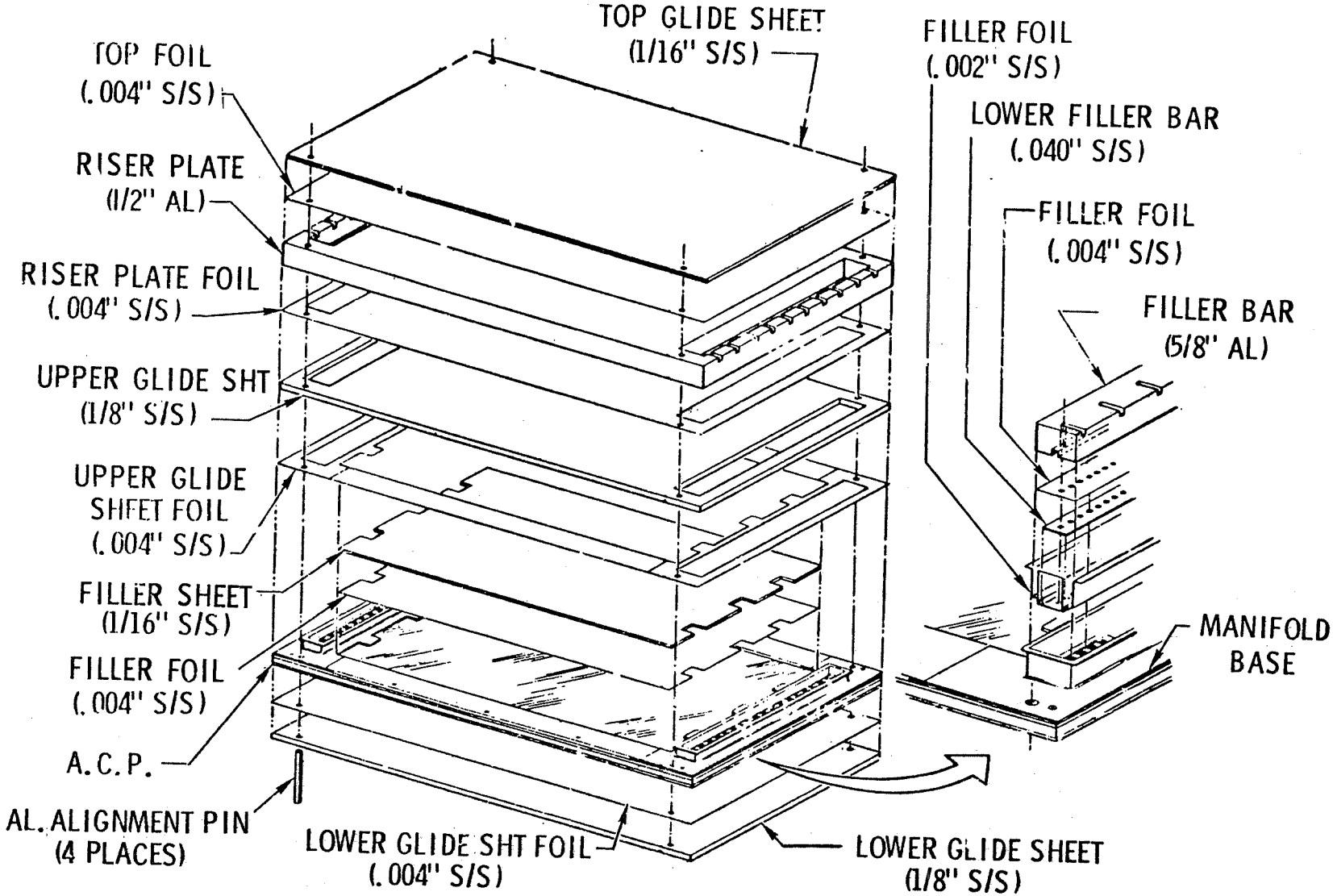

Figure 20.- Lay-up sequence for brazing 0.61 m by 1.22 m (2 by 4 ft) actively cooled panel.

ACTIVELY COOLED TEST PANEL (A.C.T.P.) FRAME

(Figure 21)

The panel frame with the edge fluid channel side exposed. Fusion welds are at the four corners at ends of fingers. Hardspots are part of frame assembly.

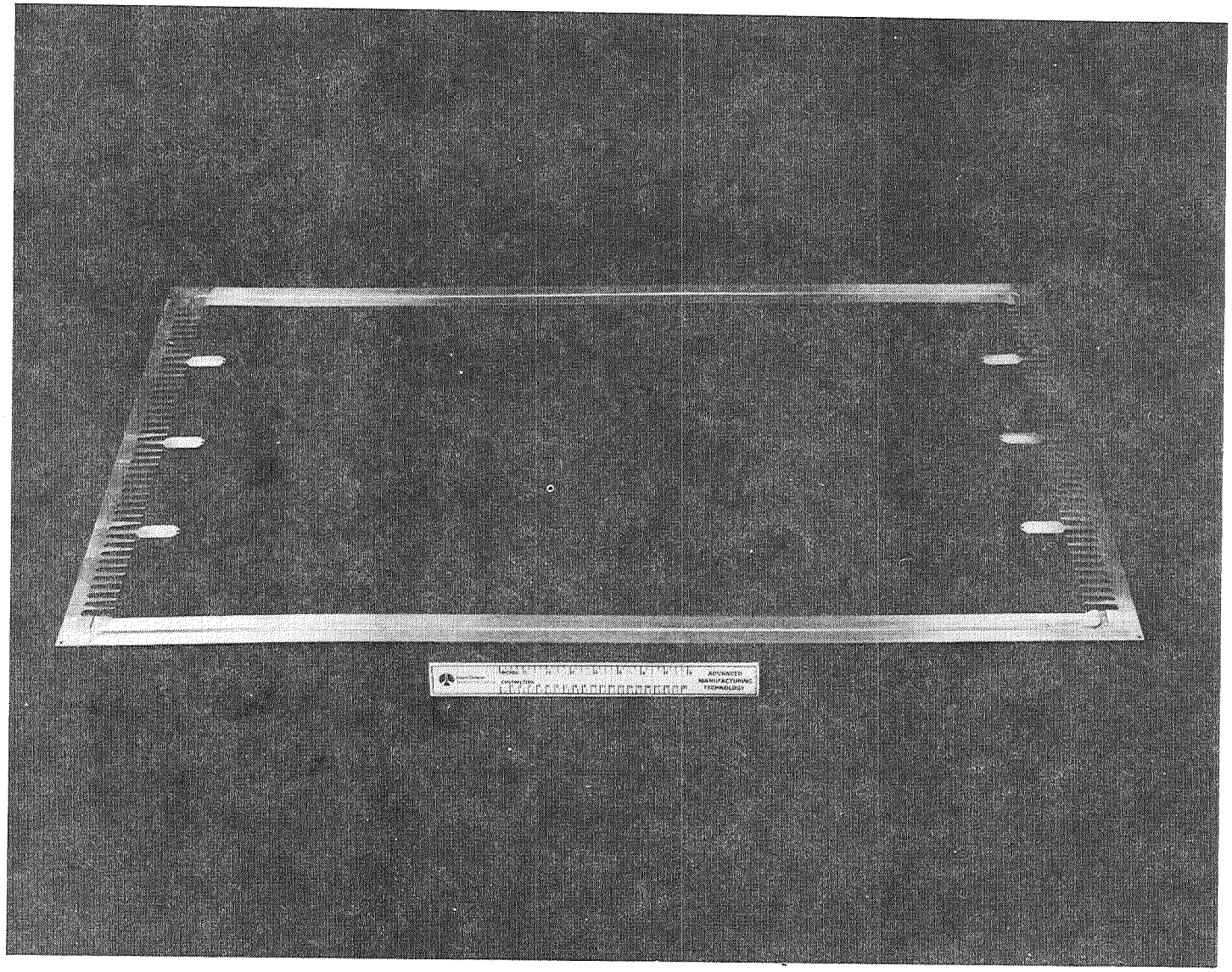

Figure 21.- Actively cooled test panel (A.C.T.P.) frame.

(A.C.T.P.) INTERNAL DETAILS DURING PRE-BRAZE ASSEMBLY

(Figure 22)

Internal details of test panel assembled prior to closure. Corrugated straight-fin core is in four sections. Three center hardspots are riveted to bottom face sheet.

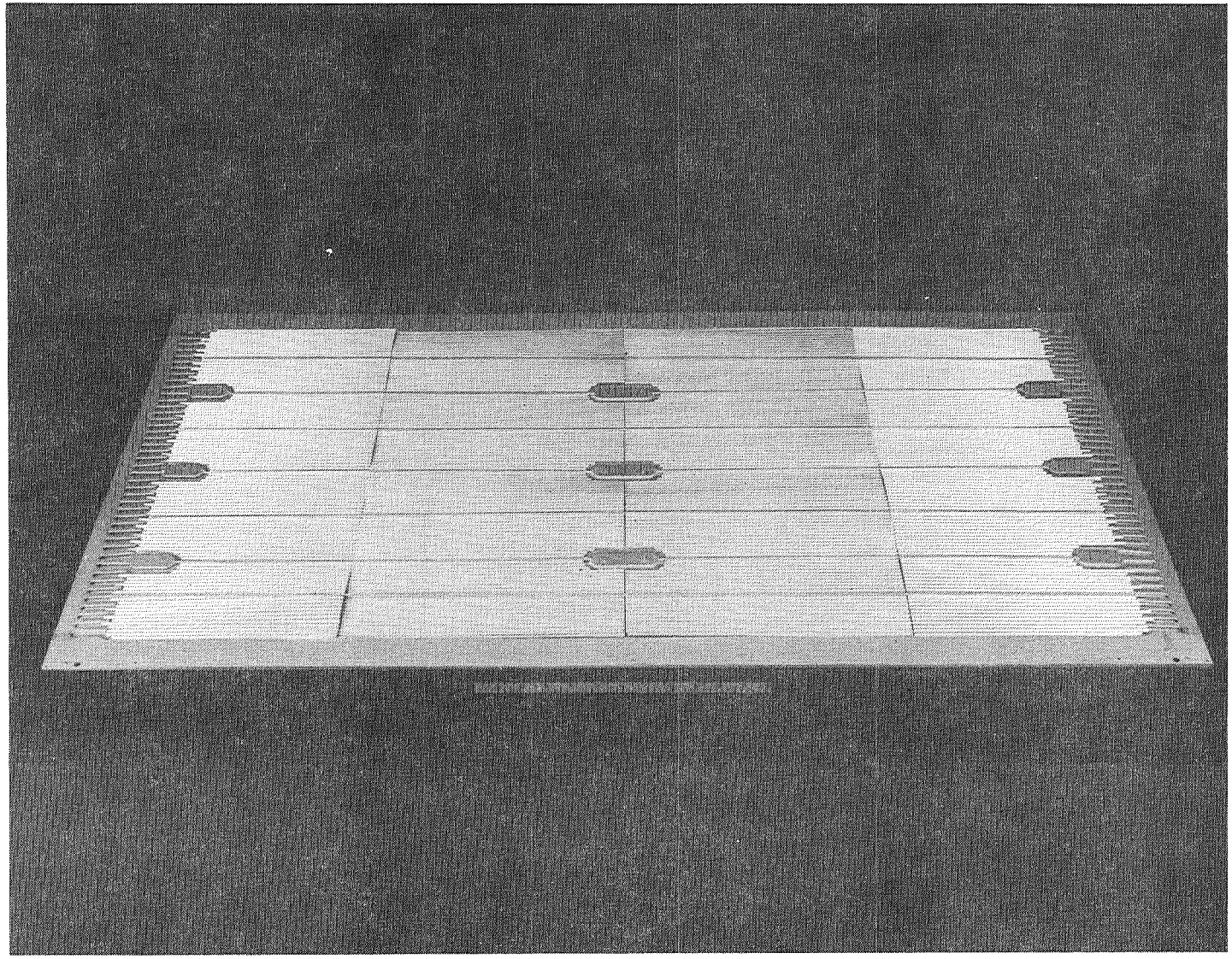

Figure 22.- (A.C.T.P.) internal details during pre-braze assembly.

(A.C.T.P.) PANEL DETAIL STACKED PRIOR TO BRAZING

(Figure 23)

All details of braze panel assembled and pinned together. Braze alloy is clad to inner side of each face sheet and conduction plates. Manifolds are brazed with double-sided braze sheet.

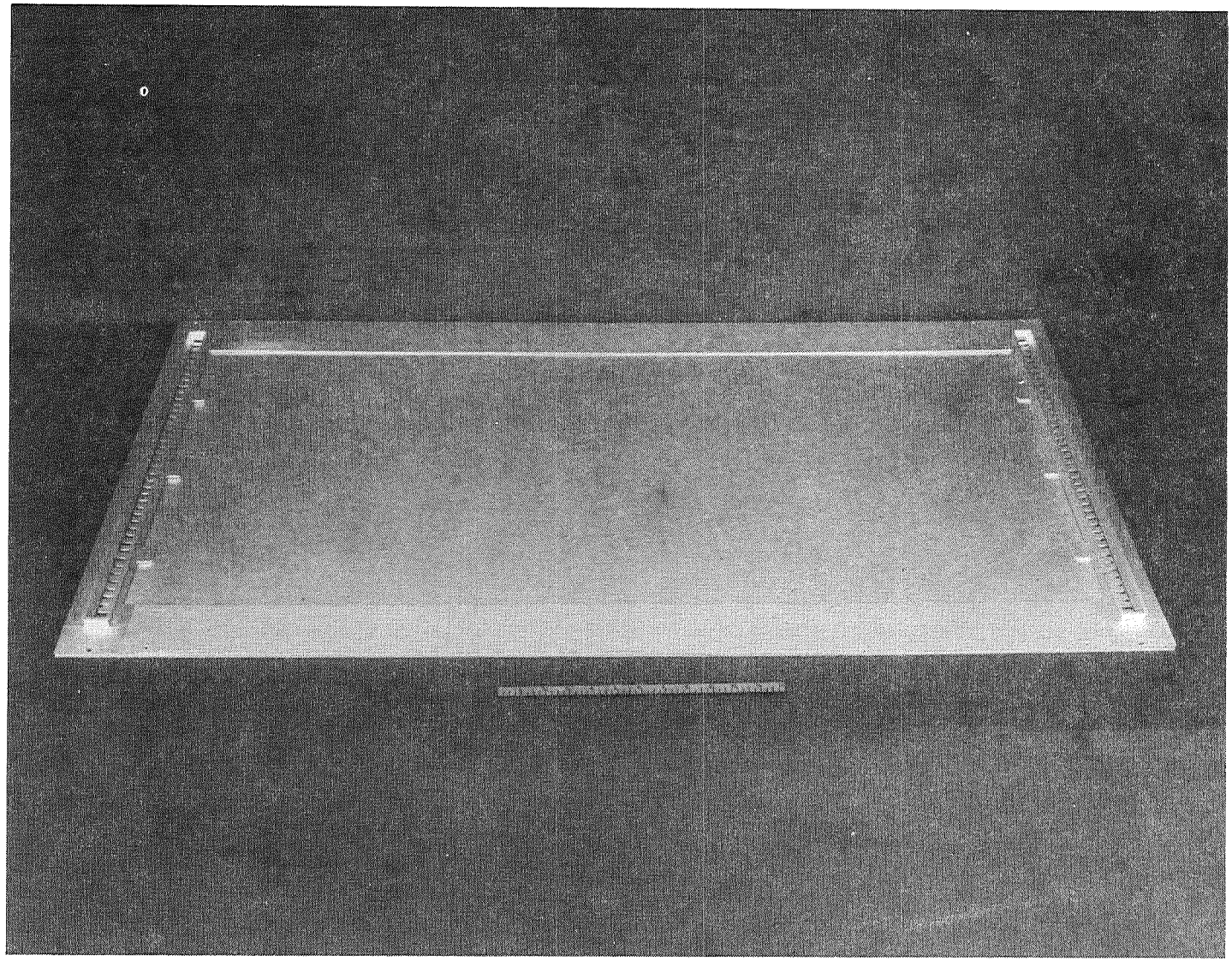

Figure 23.- (A.C.T.P.) panel detail stacked prior to brazing.

(A.C.T.P.) TOOLING RISER PLATE INSTALLED ON DETAILS

(Figure 24)

Tooling riser plate installed to bring pressure areas in one plane. This allows uniform pressure to be exerted across the panel (except in the manifold).

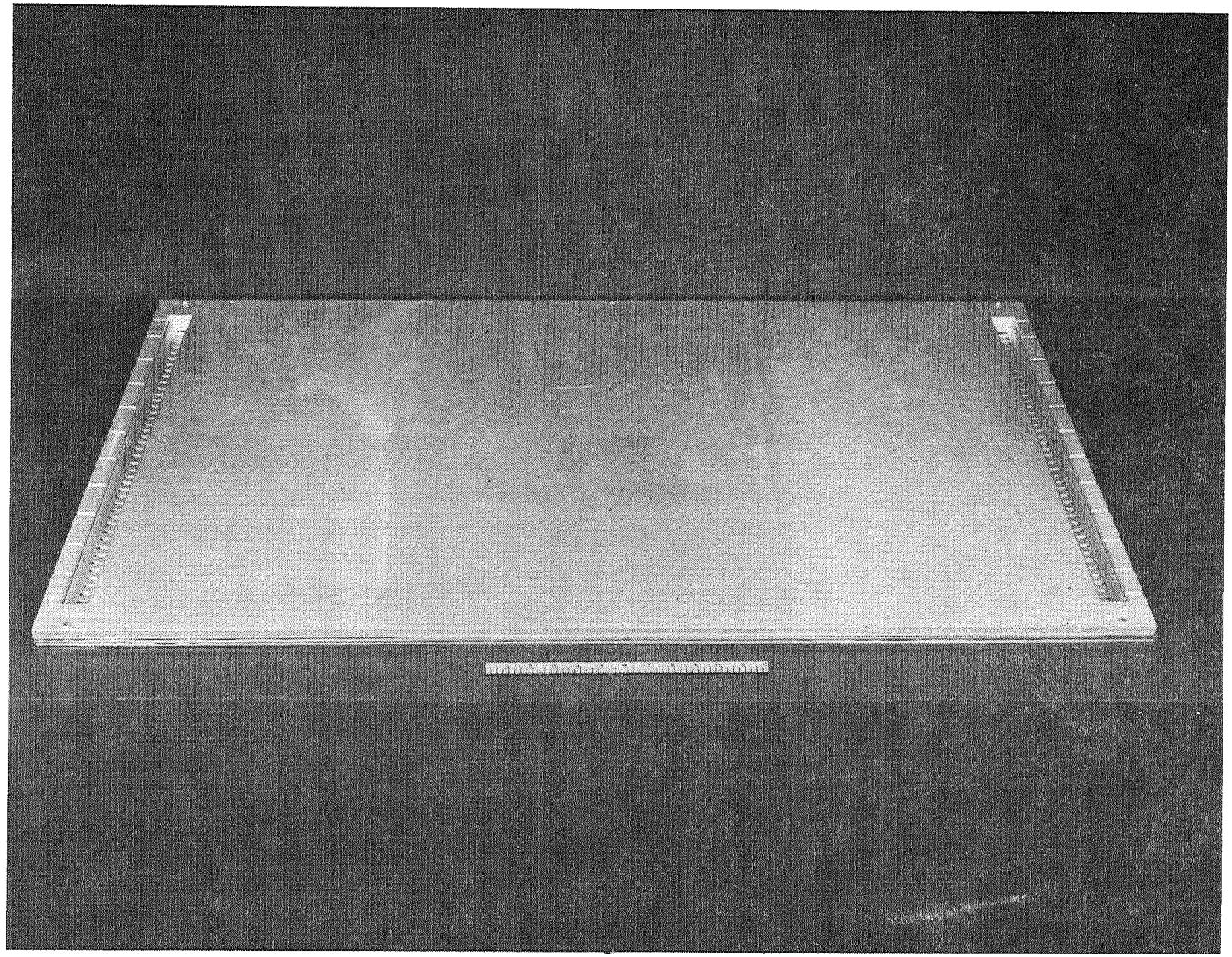

Figure 24.- (A.C.T.P.) tooling riser plate installed on details.

(A.C.T.P.) MANIFOLD FILLER BARS LOCATED OVER FINGERS

(Figure 25)

Manifold filler bars located within the manifold base. These bars permit uniform pressure exertion on the skin-to-frame finger joint areas.

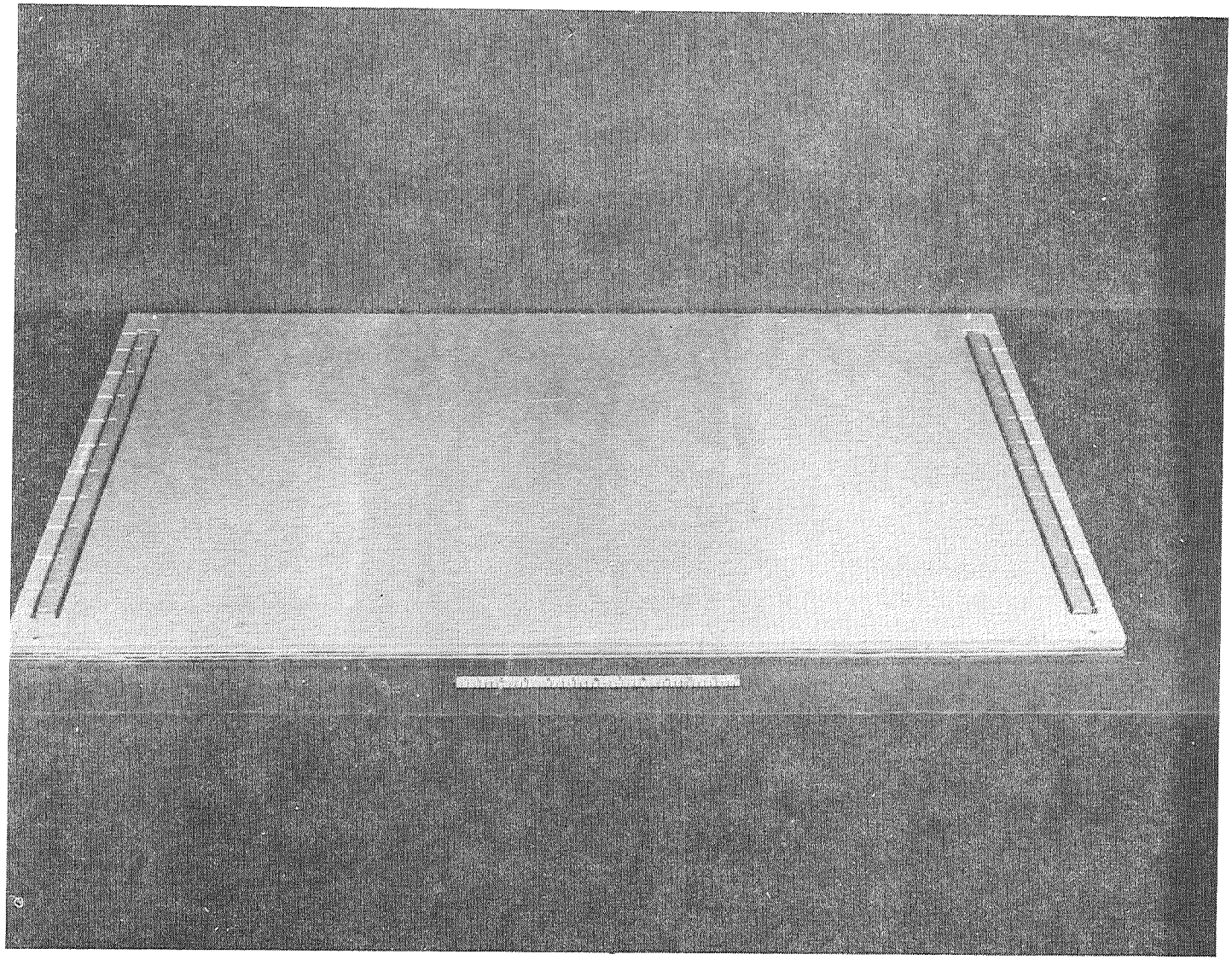

Figure 25.- (A.C.T.P.) manifold filler bars located over fingers.

(A.C.T.P.) DETAILS AND TOOLING IN RETORT BEFORE CLOSURE

(Figure 26)

All actively cooled test panel details and tooling positioned in stainless steel retort prior to closure and sealing. The four thermocouples attached to the A.C.T.P. monitor temperatures during brazing.

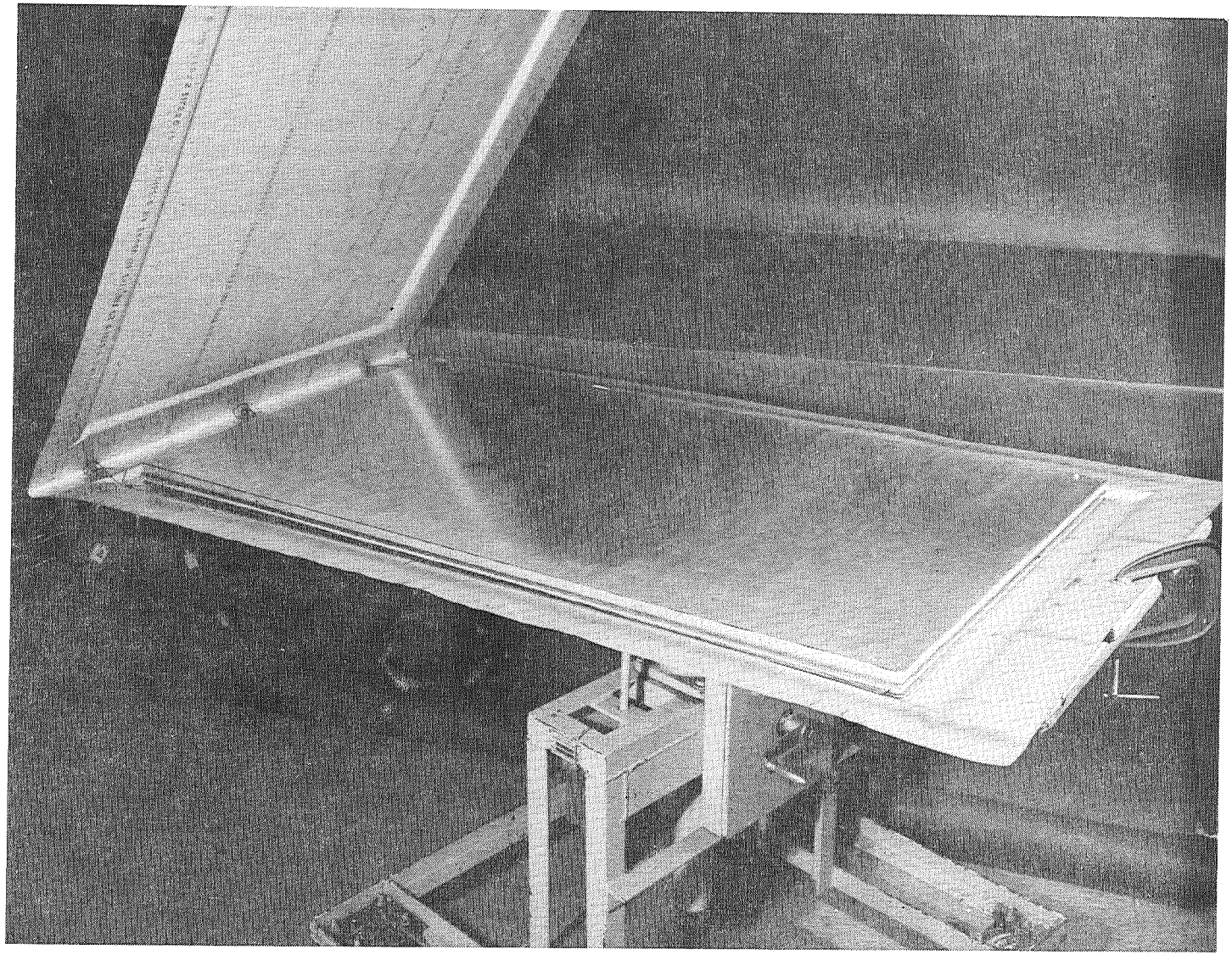

Figure 26.- (A.C.T.P.) details and tooling in retort before closure.

ACTIVELY COOLED PANEL PRESS BRAZE CYCLE

(Figure 27)

Braze cycle used on actively cooled test panel. As shown, panel is subjected to externally applied press pressure and internal argon gas pressure simultaneously during the brazing cycle. External pressure assures joint contact. Internal gas pressure minimizes cavitation.

2 BY 4 FT. ACTIVELY COOLED PANEL PRESS BRAZE CYCLE

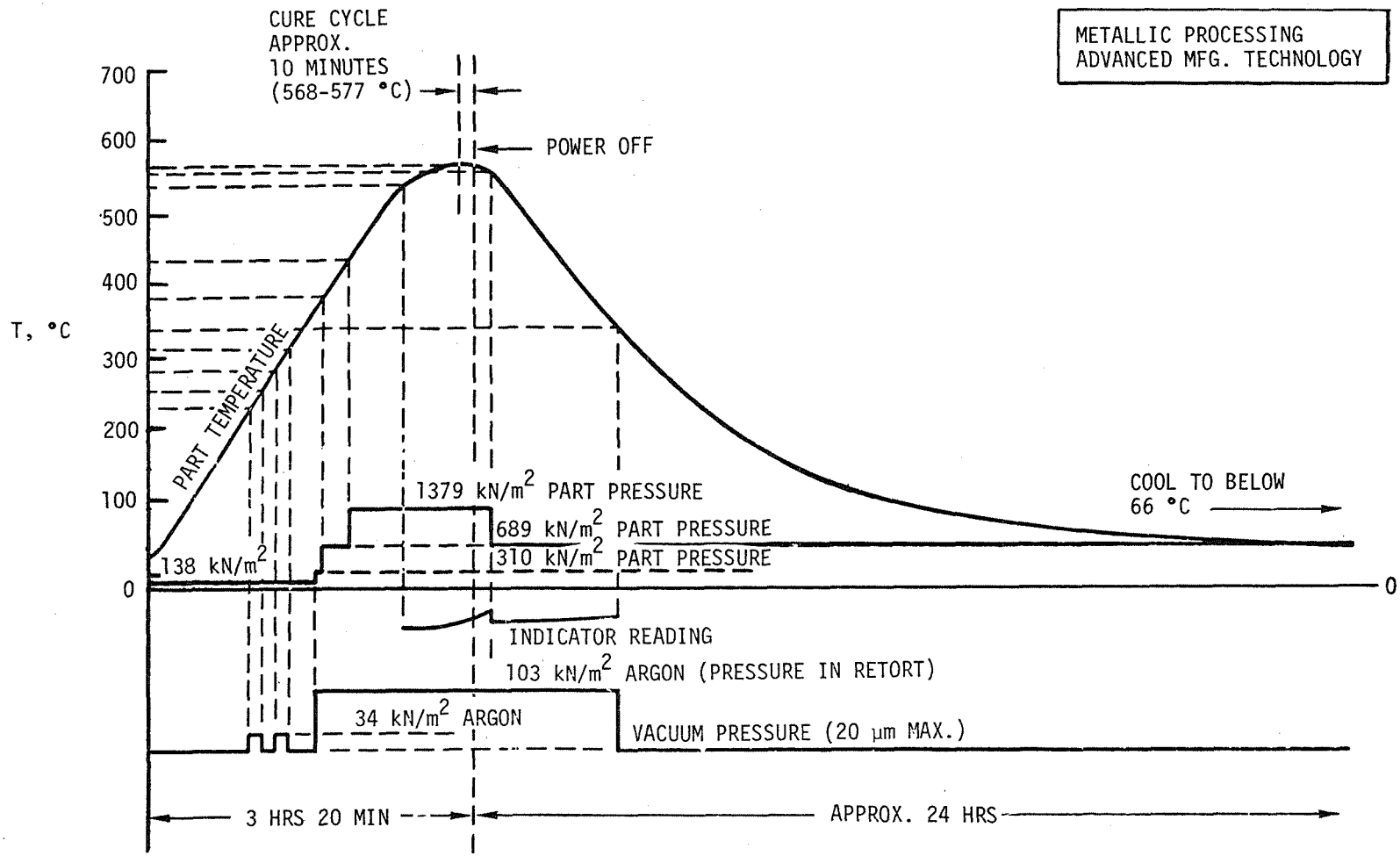

Figure 27

(A.C.T.P.) BRAZED PANEL AFTER REMOVAL FROM RETORT

(Figure 28)

Inboard side of brazed actively cooled test panel after removal from retort. Dark stains are from tooling separator foil. Images from support rods and hardspot inserts are visible due to press pressure applied during brazing cycle.

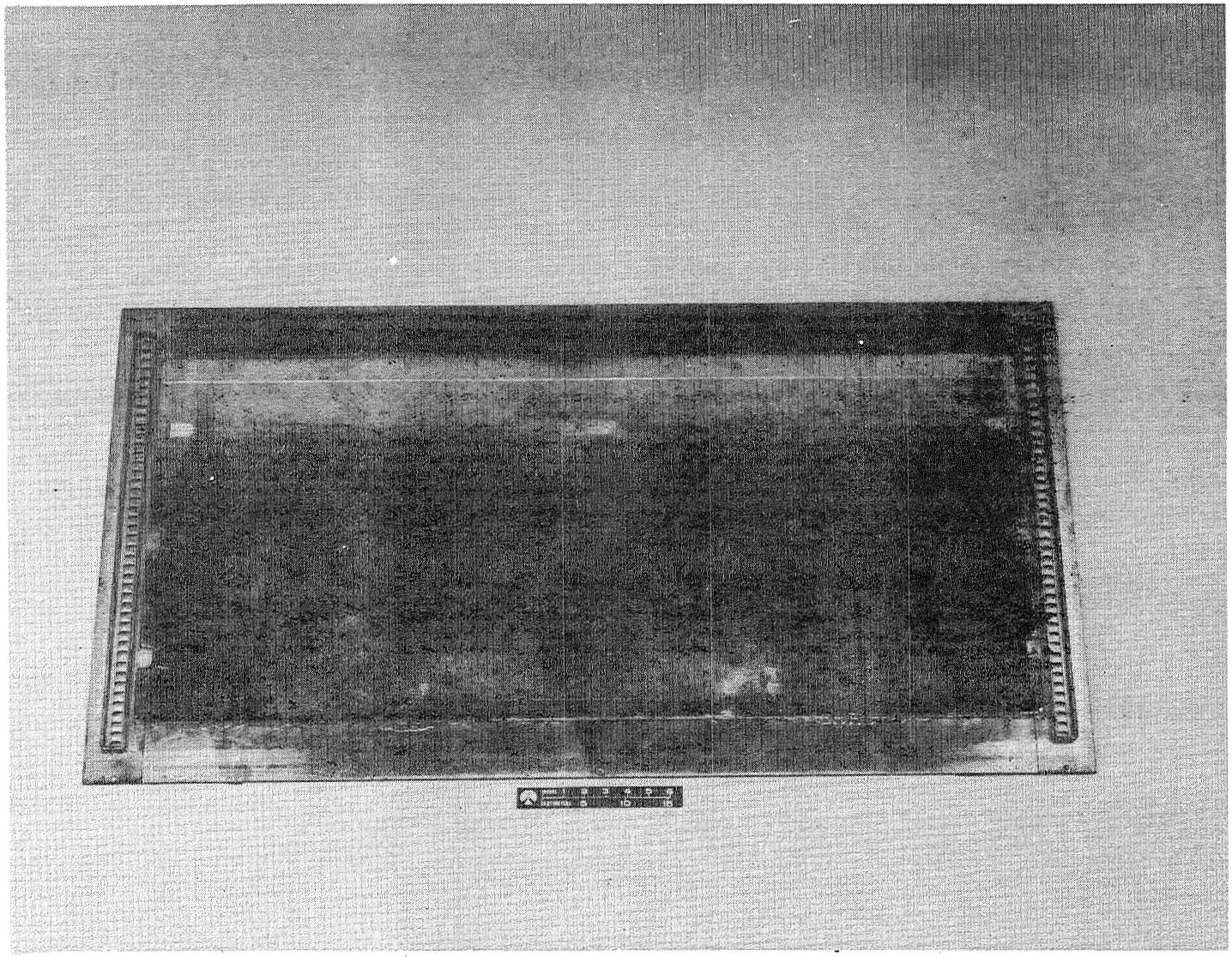

Figure 28.- (A.C.T.P.) brazed panel after removal from retort.

(A.C.T.P.) MOLDLINE SIDE OF TEST PANEL

(Figure 29)

Moldline side of brazed actively cooled test panel. Images of manifold fingers, center hardspot inserts, and support rods are clearly visible.

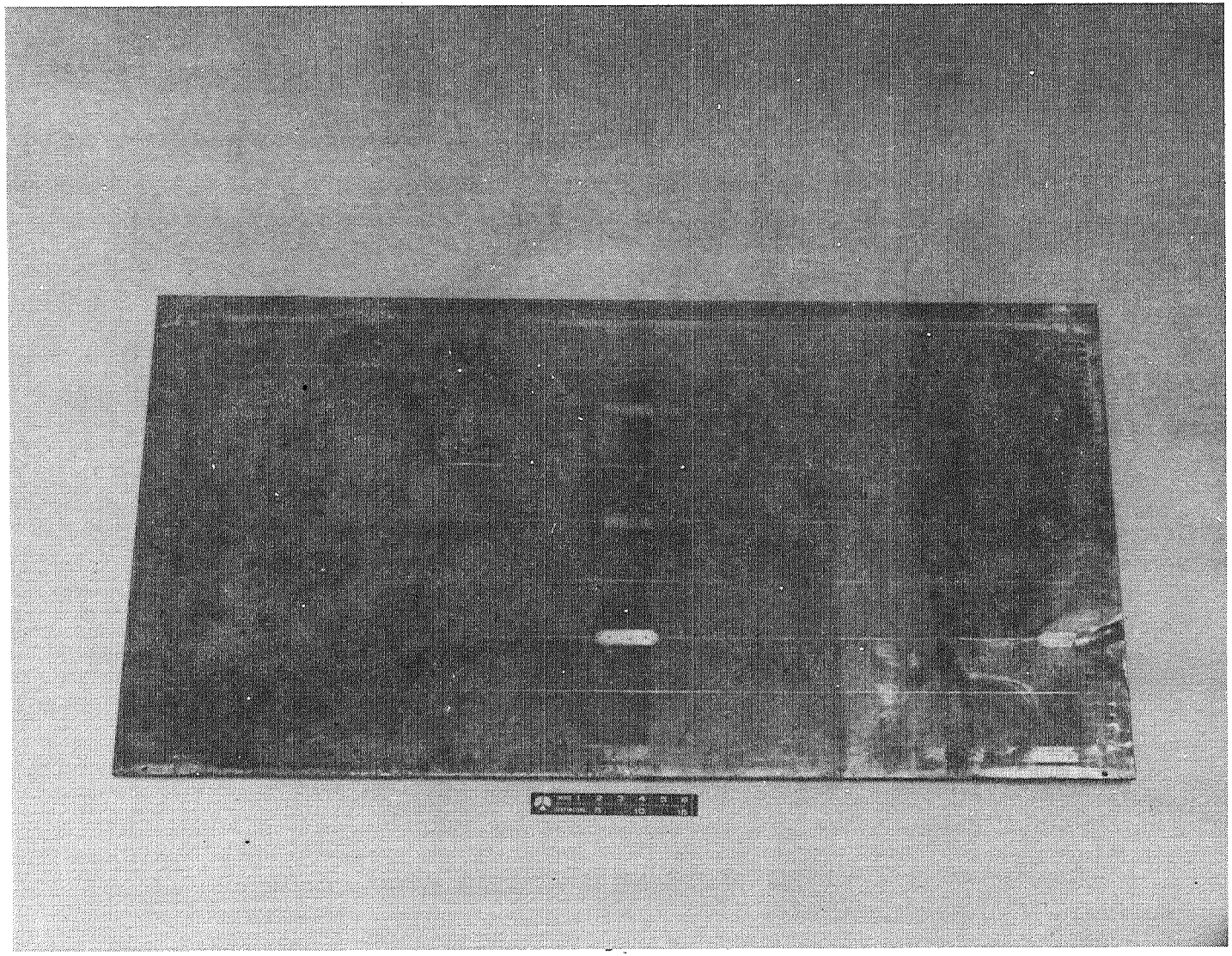

Figure 29.- (A.C.T.P.) moldline side of test panel.

(A.C.T.P.) HELIUM LEAK TESTING OF BRAZED TEST PANEL

(Figure 30)

Brazed actively cooled test panel being helium leak tested before heat treating or welding. Test fixtures clamp over manifold bases for complete sealing during leak and pressure testing.

Figure 30.- (A.C.T.P.) helium leak testing of brazed test panel.

(A.C.T.P.) BRAZED AND WELDED TEST PANEL IN T6-TEMPER

(Figure 31)

Brazed test panel after solution heat treating, welding of manifold caps, and aging to T-6 temper. Fixtures were not used during heat treating. Panel was quenched in organic polymer solution.

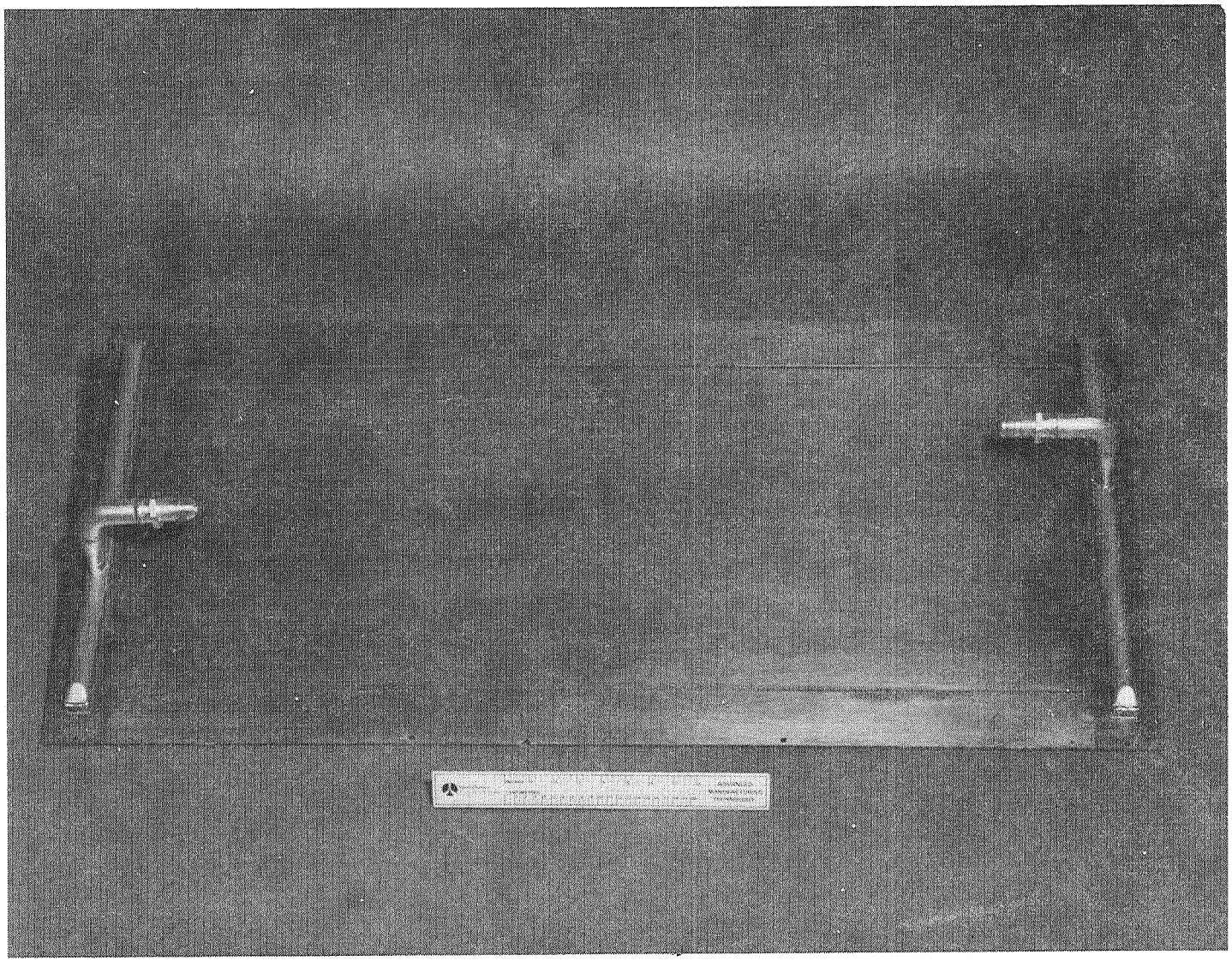

Figure 31.- (A.C.T.P.) brazed and welded test panel in T-6 temper.

(A.C.T.P.) TEST PANEL WITH ADHESIVE BONDED STRINGERS

(Figure 32)

Inboard side of test panel after adhesive bonding three center stringers. Panel had been chromic-acid anodized prior to bonding.

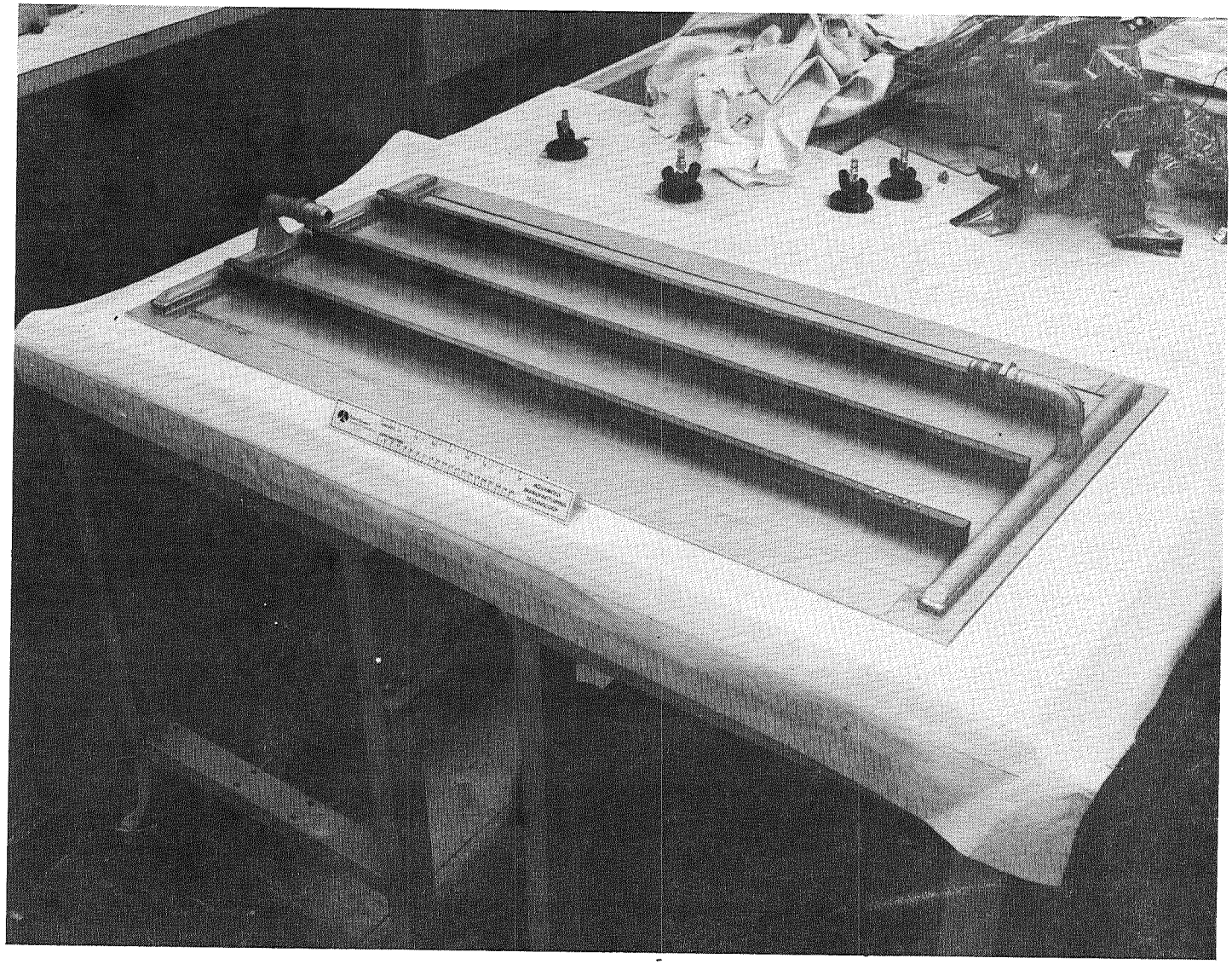

Figure 32.- (A.C.T.P.) test panel with adhesive bonded stringers.

(A.C.T.P.) INBOARD SIDE OF TEST ARTICLE SHOWING ALL MEMBERS

(Figure 33)

Inboard side of test article showing the panel, end load adapters, frame assembly, center structure beam, pillow blocks, manifold plumbing and all fasteners.

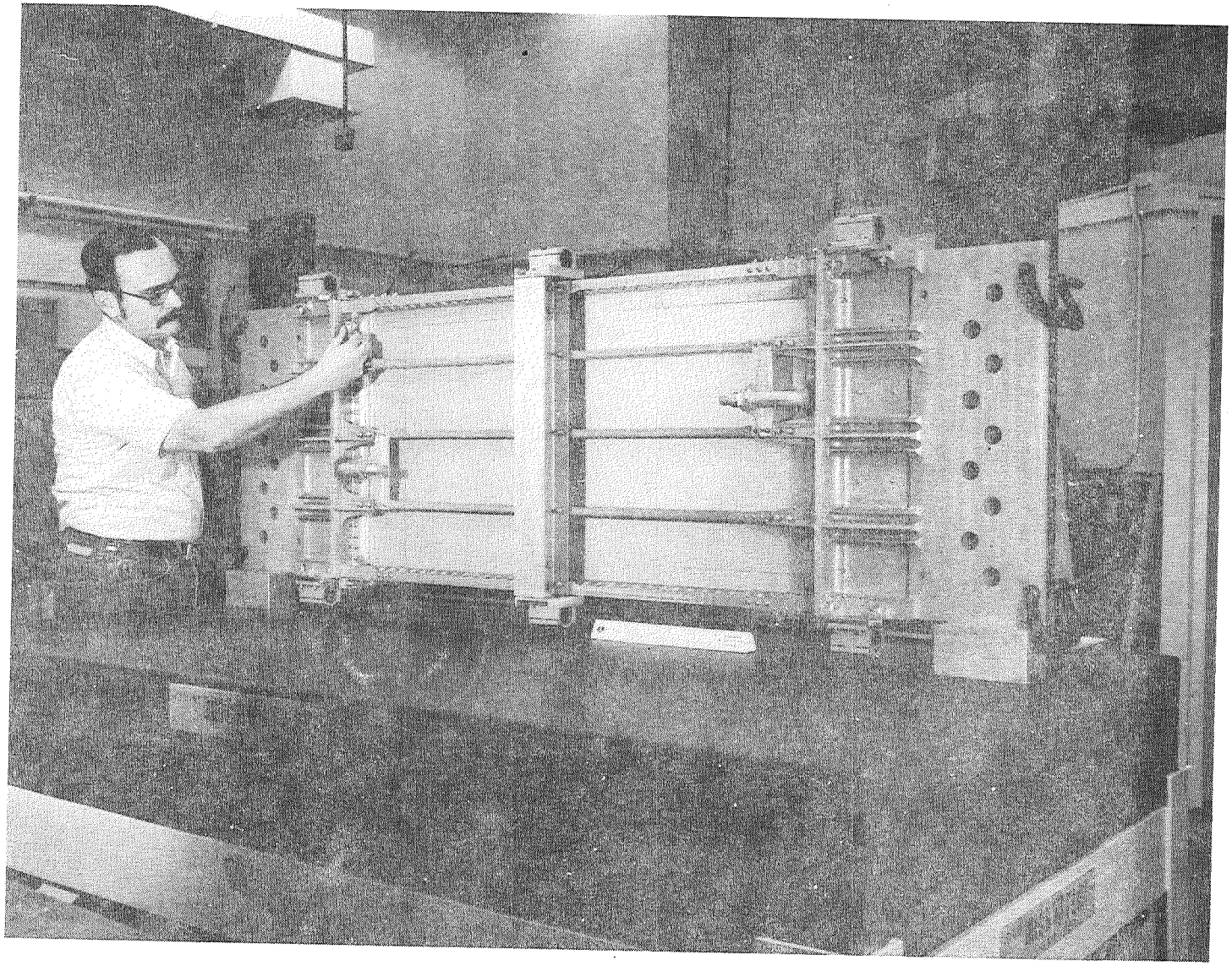

Figure 33.- (A.C.T.P.) inboard side of test article showing all members.

(A.C.T.P.) MOLDLINE SIDE OF TEST ARTICLE

(Figure 34)

Moldline side of test article with heater strips bonded to the end load adaptors.

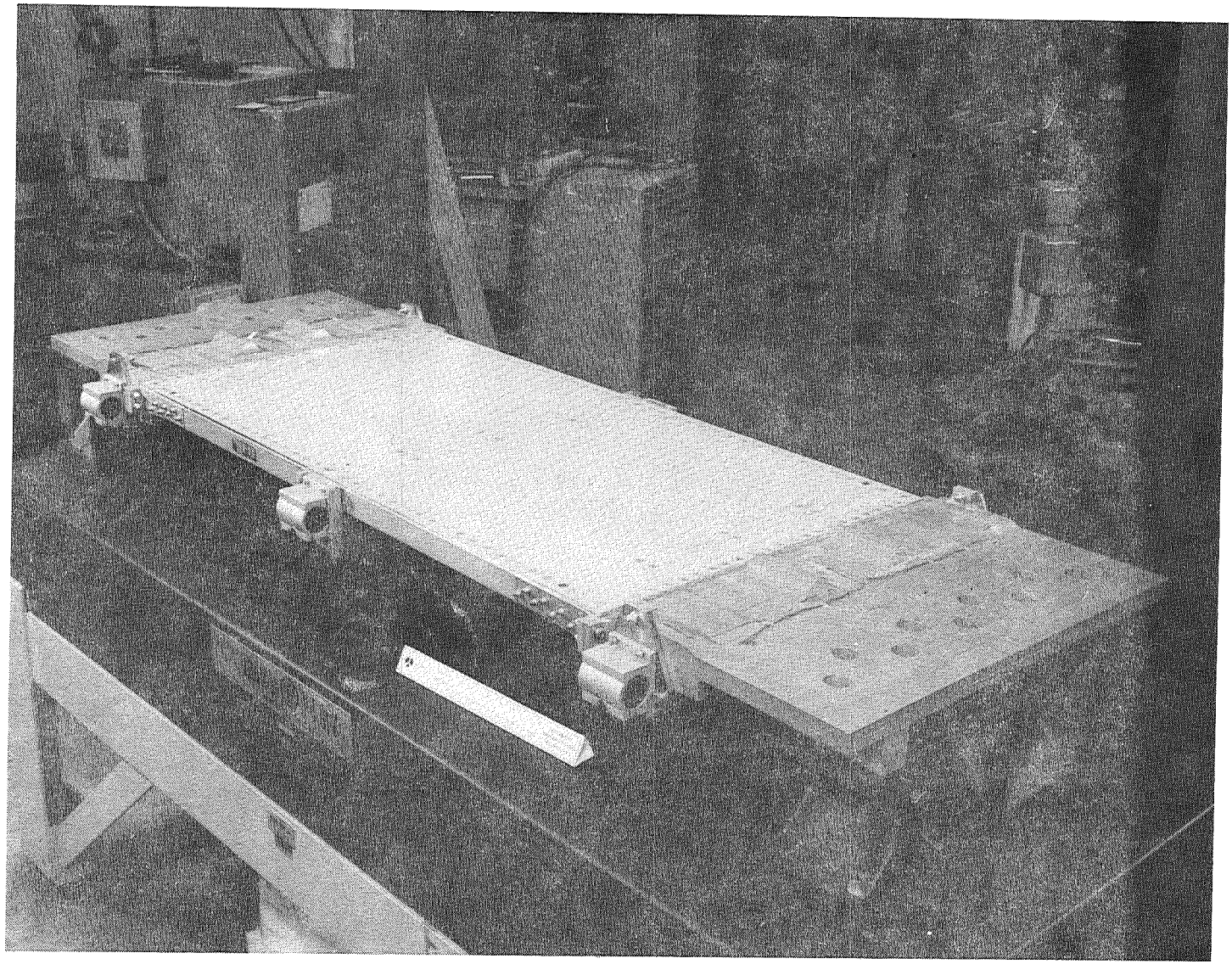

Figure 34.- (A.C.T.P.) moldline side of test article.

(A.C.T.P.) INBOARD SIDE OF COMPLETED TEST ARTICLE

(Figure 35)

Inboard side of completed test article prior to delivery with foam insulation blocks covering end load adapter fins. Aluminum tape covers foam.

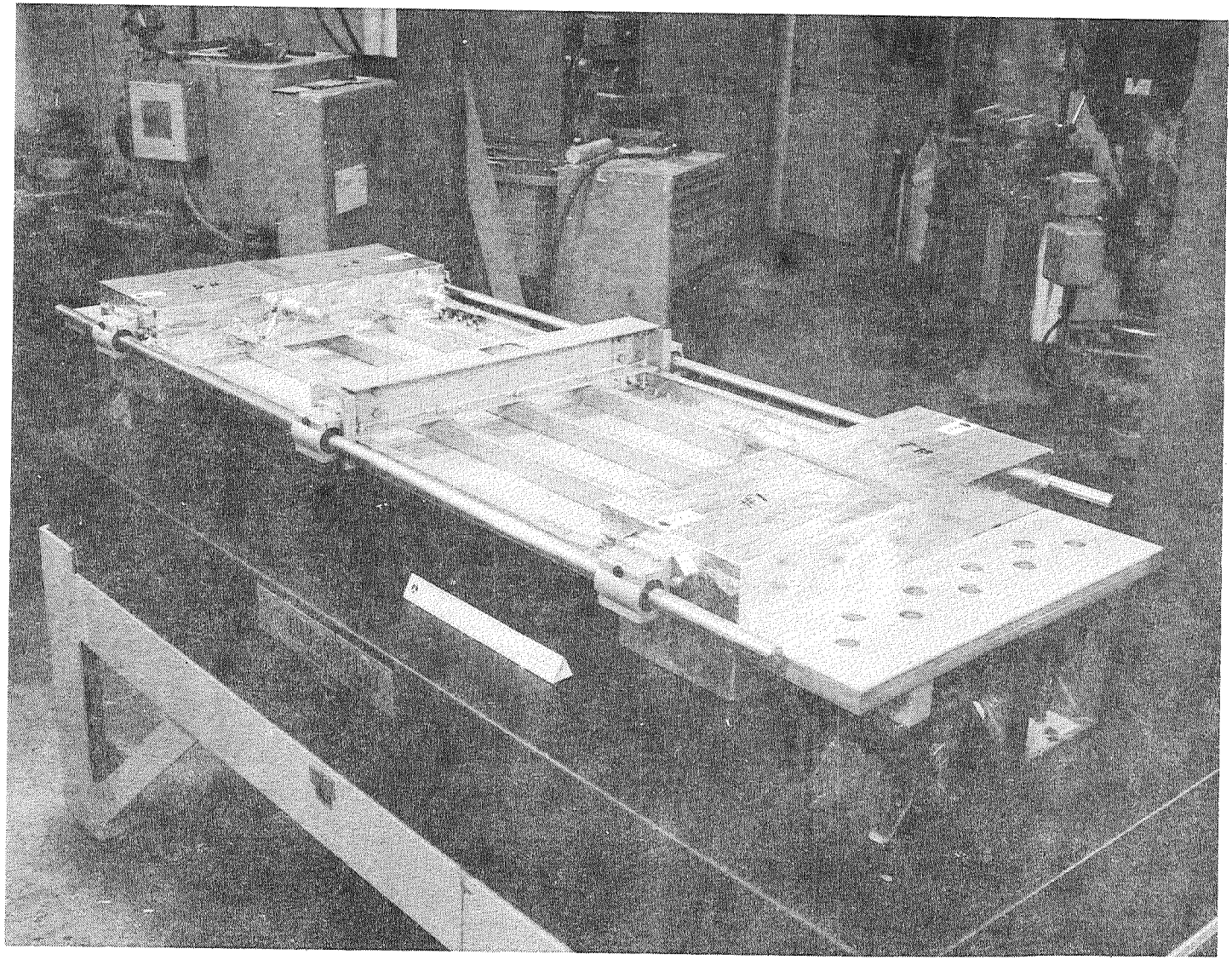

Figure 35.- (A.C.T.P.) inboard side of completed test article.

(A.C.T.P.) MOLDLINE SIDE OF COMPLETED TEST ARTICLE

(Figure 36)

Moldline side of completed test article prior to delivery. Aluminum tape covered foam insulation blocks are located over heater strips.

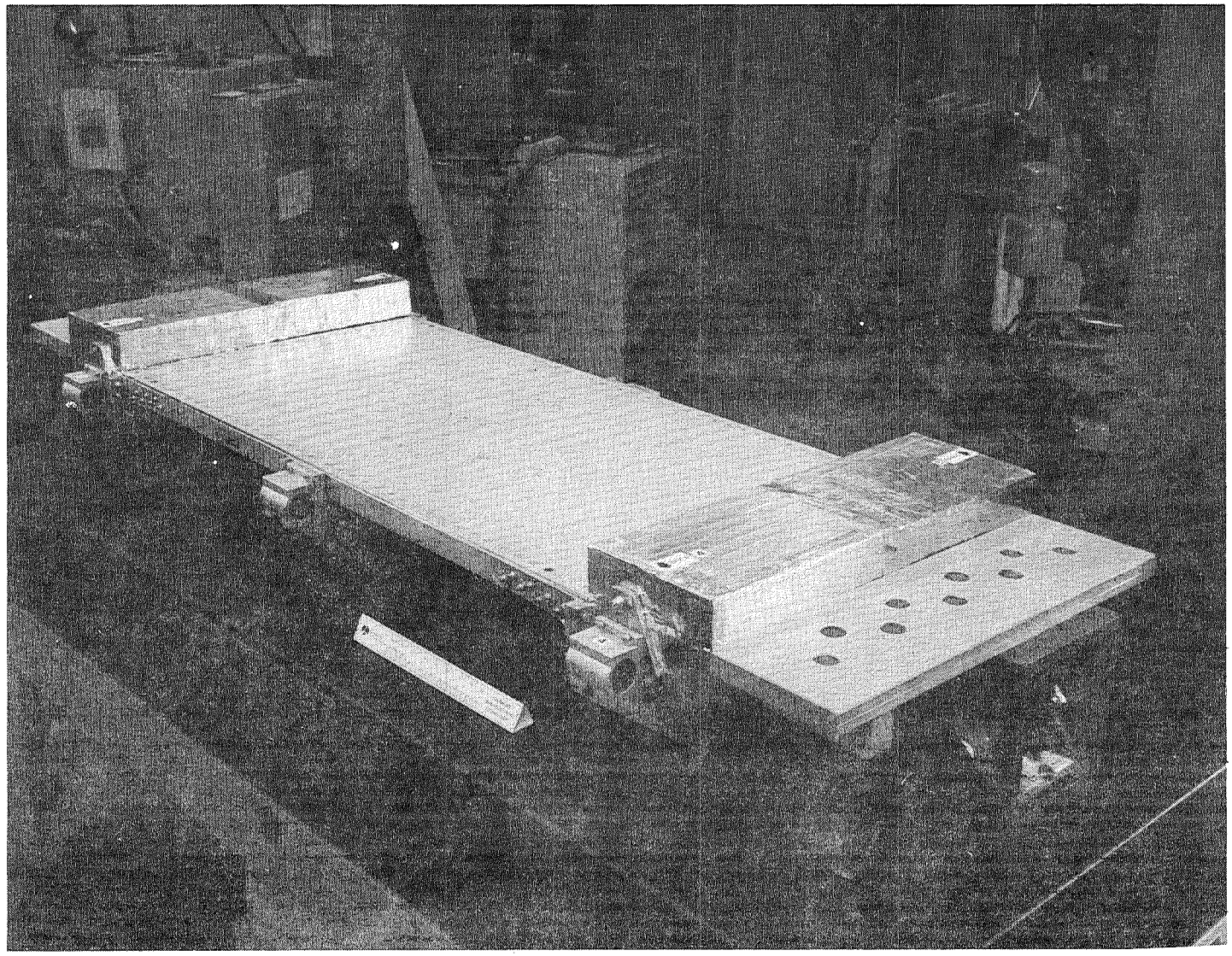

Figure 36.- (A.C.T.P.) moldline side of completed test article.