(NASA-CR-161693) SPACE FABRICATION DEMONSTRATION SYSTEM Quarterly Progress Report, 27 Aug. - 15 Nov. 1977 (Grumman Aerospace Corp.) 194 p HC A09/MF A01 CSCL 22A G3/12

N81-21090

Unclas 20656

GRUMMAN

SPACE FABRICATION DEMONSTRATION SYSTEM

QUARTERLY PROGRESS REPORT NO. 3

August 27, 1977 - November 15, 1977

NASA-MSFC Contract NAS8-32472

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK 11714

NSS-SFDS-LR022
Contract NAS8-32472
November 30, 1977

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: Erich E. Engler, COR
Code EP-13 Bldg. 4610

Subject: SPACE FABRICATION DEMONSTRATION SYSTEM - Quarterly Progress Report No. 3 August 27, 1977 - November 15, 1977

Enclosures:
(1) SFDS Program Review Vu-graph Presentation Copy - 25 October 1977
(2) TASK 1.2.2 Fabrication Facility Design

References:
(a) SFDS - Monthly Progress Letter No. 5, September 30, 1977
(b) SFDS - Monthly Progress Letter No. 6, October 30, 1977

SUMMARY

The Space Fabrication Demonstration System (SFDS) program concluded three milestones during this third quarter year. Two were the successful completions of Incremental Critical Design Reviews (ICDRs) held on September 29, 1977 and October 26, 1977 and the third was a program review held on October 25, 1977, see enclosure (1). This report, supplemented by our previous monthly progress letters, references (a) and (b), constitutes our third quarterly report.

At the conclusion of the above ICDRs we had received concurrance to proceed with the fabrication of the following SFDS subsystems:

- September 29, 1977 - Fabrication facility support structure
  - Control
- October 26, 1977 - Clamp/weld block and welding
  - Truss cut-off

During the next monthly reporting period, we anticipate successful completion of the third and last ICDR for the cross brace magazine/dispenser subsystem and the rolling mill supply reel, guide and drive. Currently, this is scheduled to be held on December 14, 1977 with the location still to be determined.

The weekly telcon review continues to provide an excellent information base for problem resolution as they occur. These and the periodic meetings of NASA-MSFC and Grumman program personnel have assisted in keeping the program progressing smoothly.

No major problems are anticipated at this time which would prevent us from meeting our next major milestone, assembly of the SFDS by the end of February, 1978.

DISCUSSION

WBS 1.1 PROGRAM MANAGEMENT

Continued detailed review of tasks committed versus task completion has kept the SFDS program essentially on schedule. Our progress, in percent completion, where applicable, is shown in Figure 1 SFDS Master Program Schedule.

WBS 1.2 DESIGN and DEVELOPMENT

1.2.1 Structural Member Development

No further analysis effort is being conducted in this area at present. The test of the structural test truss has been delayed by the late receipt of the rolling mills and is being rescheduled for early next year. This delay will not impact our next major milestone, assembly of the fabrication facility.

1.2.2 Fabrication Facility Design

Enclosure (2) provides data associated with the status of the design of the beam builder (fabrication facility). Our effort during the next reporting period is directed toward completing the detail design for the cross brace magazine and dispensing subsystem and the rolling mill reel, feed and drive mechanisms.

WBS 1.3 FABRICATION and ASSEMBLY

1.3.1 Detailed Parts

The difficulties associated with the roll forming tooling report in reference (b) has been partially resolved at this time. It is anticipated that full resolution will be completed within the next reporting period. The delay in the delivery of the rolling mills while impacting our schedule will not prevent us from meeting the next major milestone, completion of the assembly of the beam builder by the end of February, 1978.

Detailed parts fabrication for other long lead purchased parts continues at various vendors. No problems have been encountered that will effect on-time delivery of components needed to complete the various beam builder subsystems.

Fabrication of detailed parts at Grumman is discussed in enclosure (2).

1.3.2 Assembly

Assembly of the beam builder has been waiting for the delivery and assembly of detailed parts and components into the various subsystems. It is anticipated that assembly will be initiated during the next reporting period.

WBS 1.4 TEST

Acceptance testing of the Yoder rolling mills will take place during the next reporting period.

The revised magazine/dispensing subsystem mock-up was completed and operationally tested during this reporting period. It has now become the design to be incorporated in the beam builder. See enclosure (2) for more detailed information.

No other development tests were conducted during this reporting period.

WBS 1.5 FLIGHT DEMONSTRATION PLAN

We have initiated a comparison of the final design of the ground demonstration beam builder with that of the preliminary design configuration utilized in the preliminary Flight Demonstration Program Plan to better define space flight capability of each subsystem incorporated in the machine. We do anticipate receiving shortly NASA's questions and comments to this plan, cost and schedule which we submitted to them this past July.

CONCLUSION

The SFDS program has progressed satisfactorily during this third quarter reporting period including successful conclusion of the two ICDRs scheduled.

RECOMMENDATION

Continued close management surveillance of all SFDS program elements by NASA/MSFC and Grumman program management personnel with continued telcon and face-to-face information interchange and program discussions.

Should you have any questions or comments with regard to the above, the program in general or the enclosed, please contact us.

Very truly yours,

GRUMMAN AEROSPACE CORPORATION

Walter K. Muench

Walter K. Muench
SFDS Program Manager

WKM/ys
cc: Distribution: NASA/MSFC
Grumman

DISTRIBUTION: NASA-MSFC

CODE	COPIES	ATTENTION	BLDG.
EH 44	1	James H. Ehl	4711
EP 12	1	W. Prasthofer	4610
EP 13	13	Erich E. Engler	4610
EM 34-13	1		
AS21D	5		
AP 12	1		
AT 01	1		
NAVPRO KK 105	1	B. Miller, Navy Contracts	Grumman, Plt. 30

DISTRIBUTION: GRUMMAN		MAIL STOP
R. S. Mickey	1	C03-05
D. A. Imgram	1	A13-25
R. W. Johnson	1	A13-25
A. Alberi	1	A09-25
J. Huber	2	A04-12
P. Jacknis	1	A15-25
L. Junen	1	-
E. Mastik	1	A01-10
H. Morfin	1	A09-25
W. Muench	4	A09-25
L. Rooney	1	A02-25

SFDS MASTER PROGRAM SCHEDULE

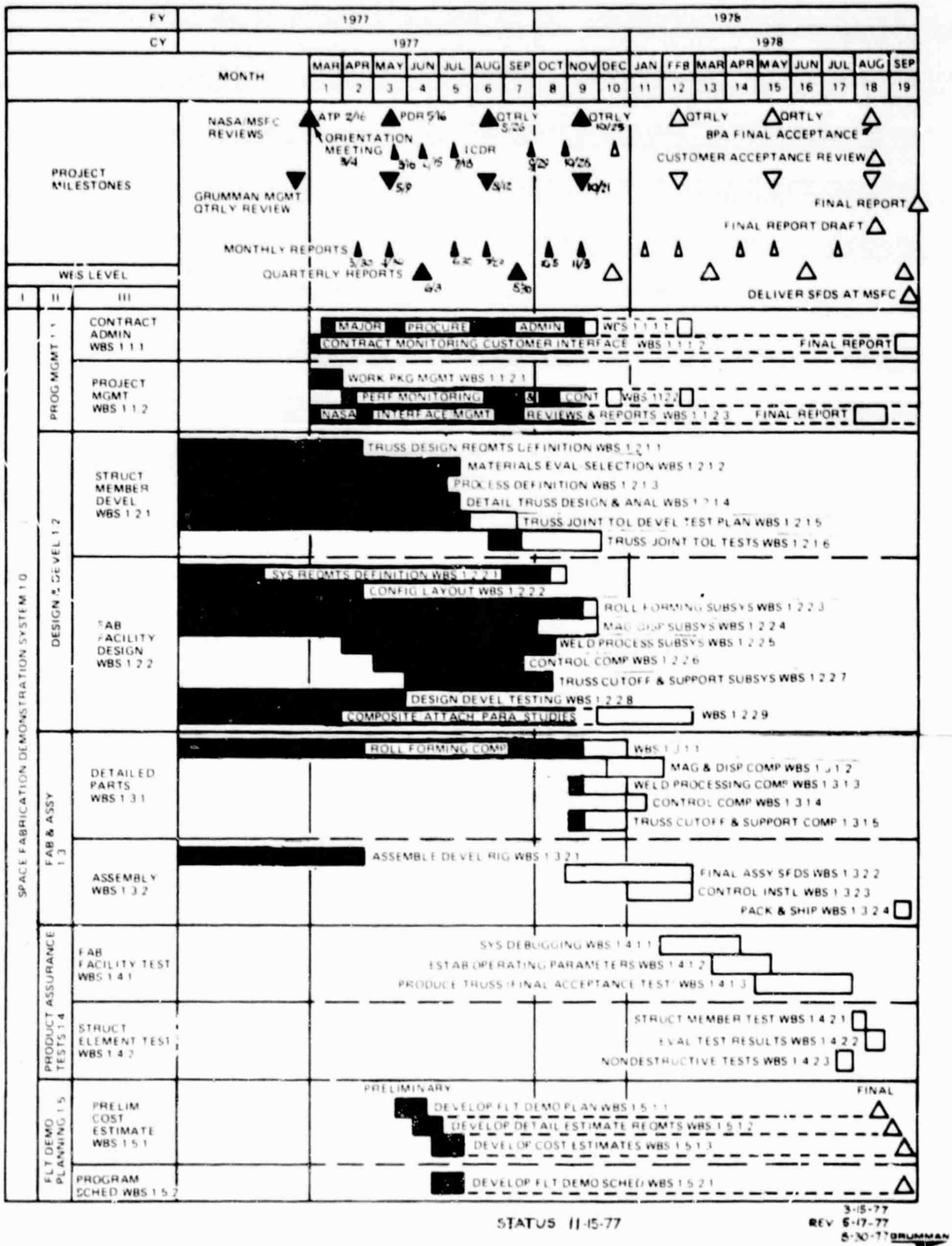


FIGURE 1

ENCLOSURE (1)

SFDS PROGRAM REVIEW

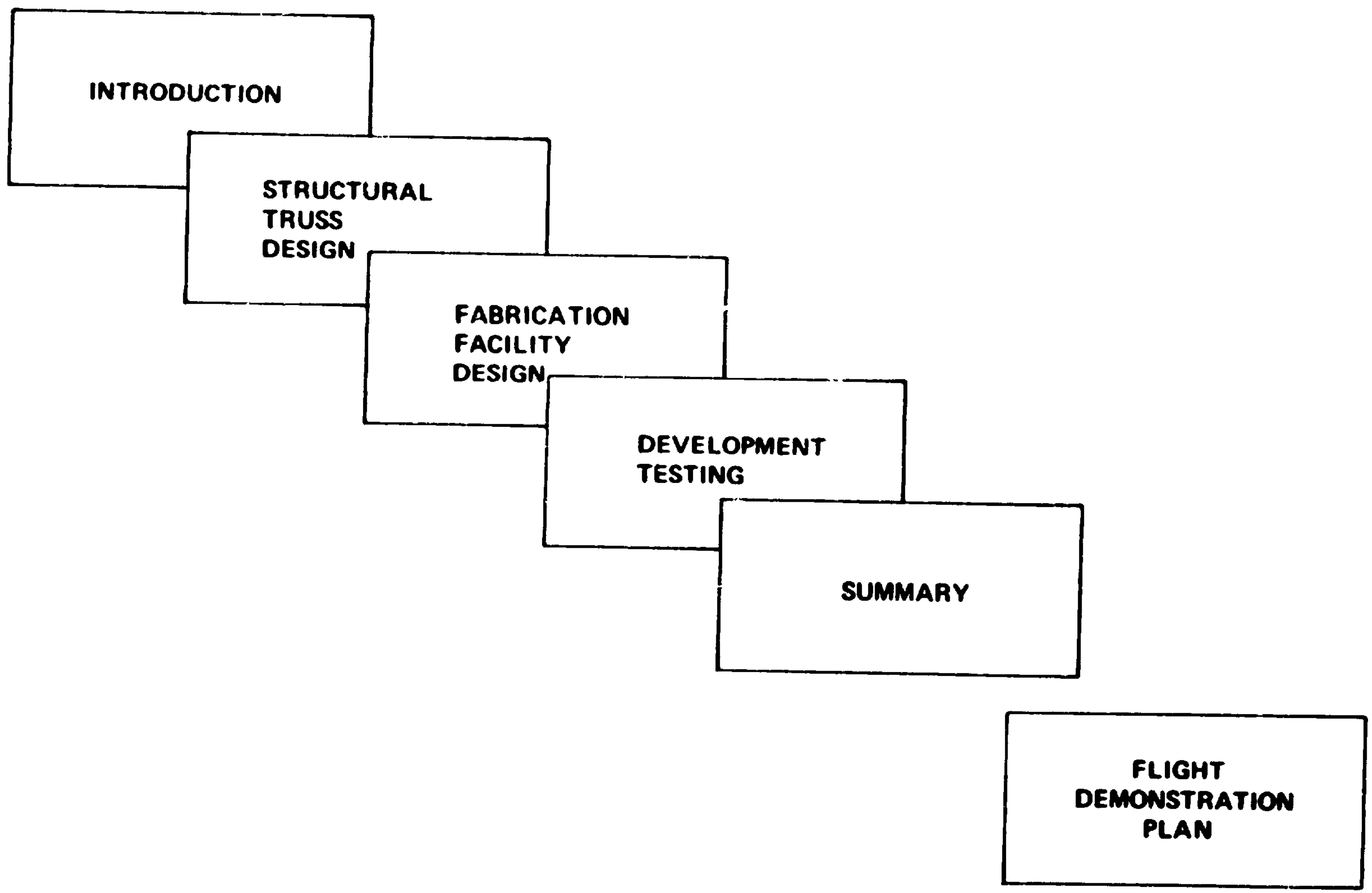
SPACE FABRICATION DEMONSTRATION SYSTEM PROGRAM REVIEW

PRESENTED

25 OCTOBER 1977

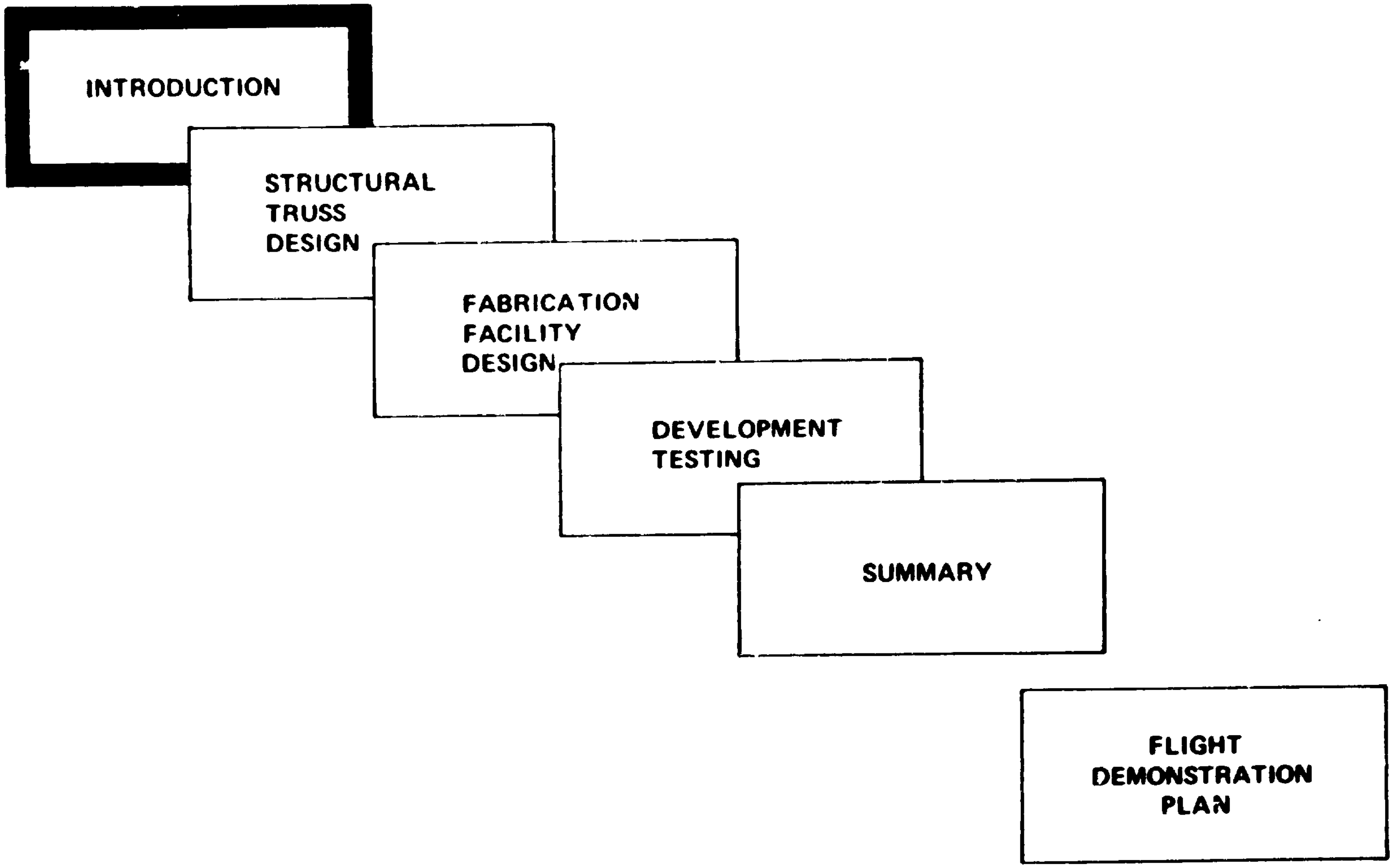
2420-140W
WM-1T

SPACE FAB DEMO SYSTEM



2420-231W
WM-76

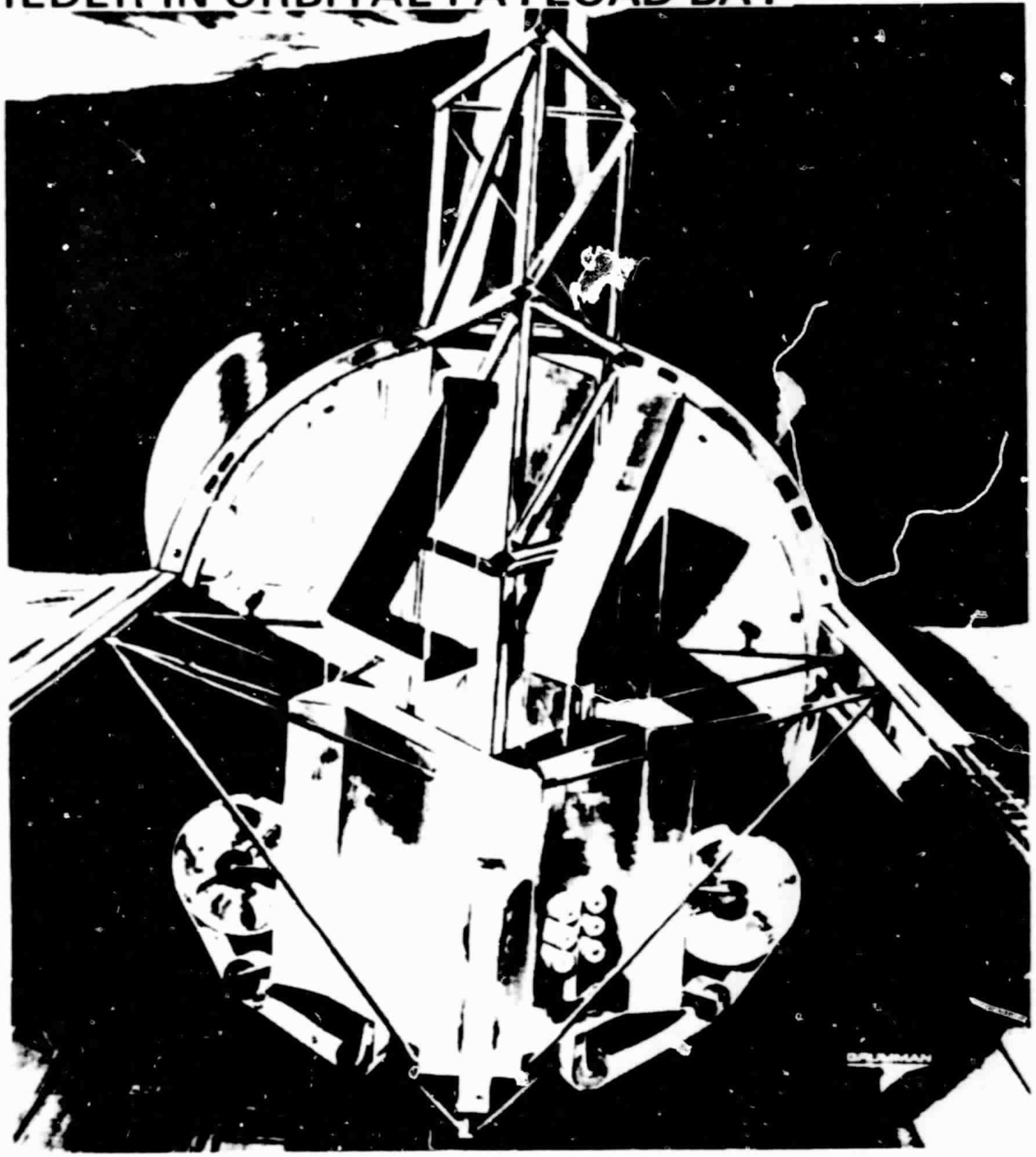
SPACE FAB DEMO SYSTEM



242C-237W
WM-82

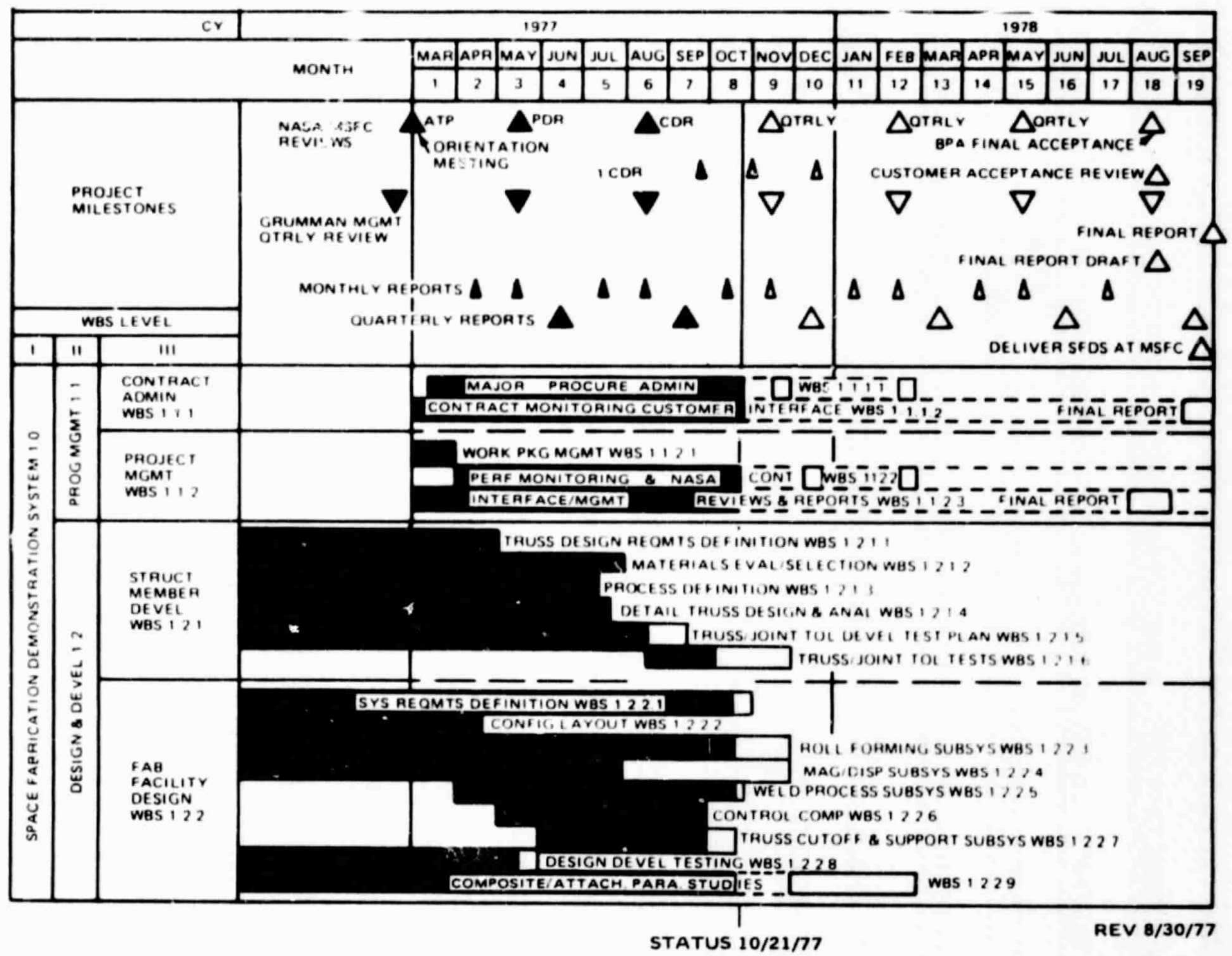
SPACE FAB DEMO SYSTEM

BEAM BUILDER IN ORBITAL PAYLOAD BAY



2420-289W
WM-75

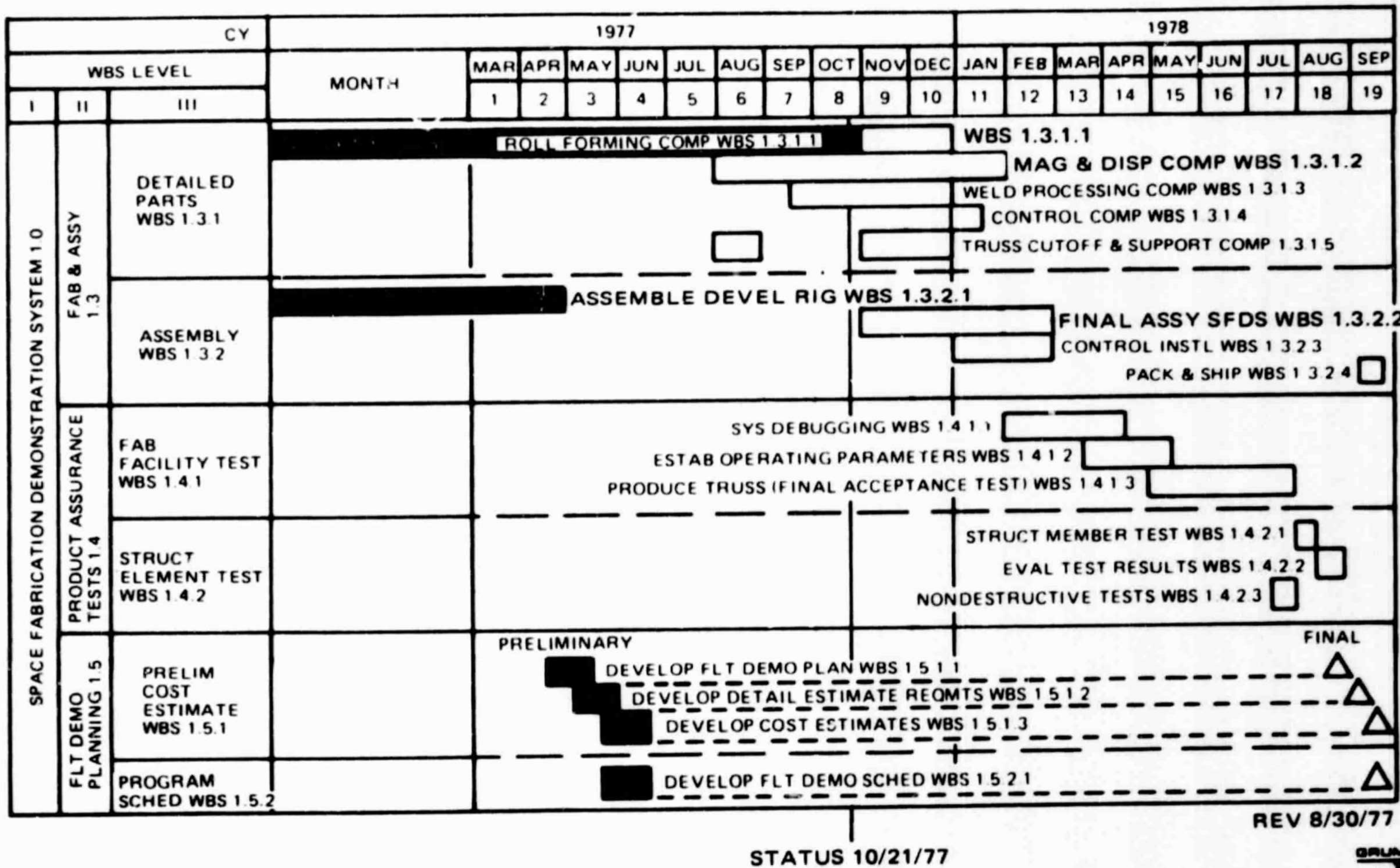
SFDS MASTER PROGRAM SCHEDULE



GRUMMAN

2420-203W
WM-5TA

SFDS MASTER PROGRAM SCHEDULE (CONT)



GRUMMAN

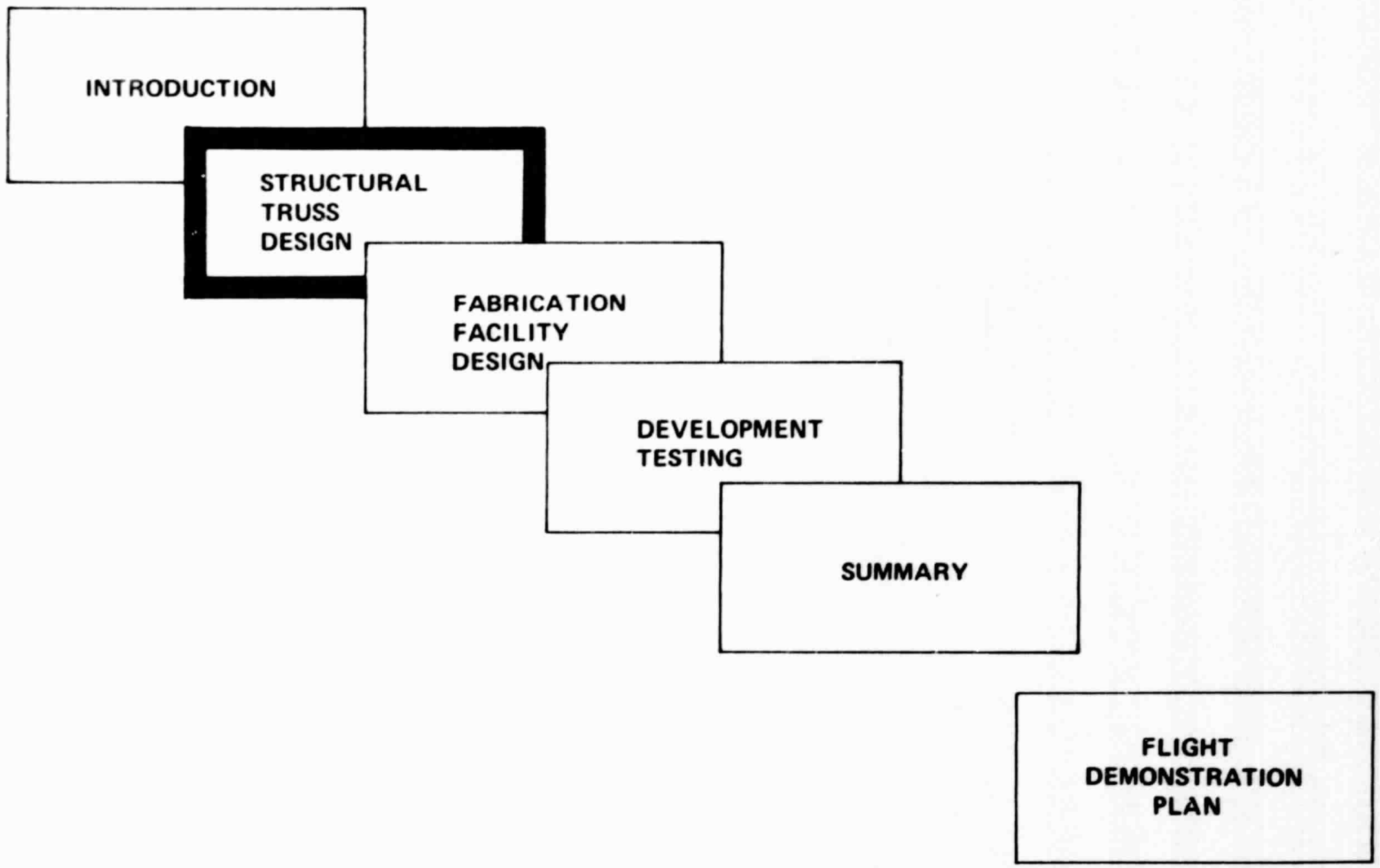
2420-204W
WM-5TB

ICDR SCHEDULE/SUBSYSTEM

SEPT 29, 1977	–	SUPPORT STRUCTURE & CONTROLS
OCT 31, 1977	–	CLAMP/WELD BLOCK & CUTOFF
DEC 14, 1977	–	MAGAZINE/DISPENSER & ROLLING MILL AUXILIARY EQUIPMENT

2420-143W
WM-7T

SPACE FAB DEMO SYSTEM – WSB 1.2.2



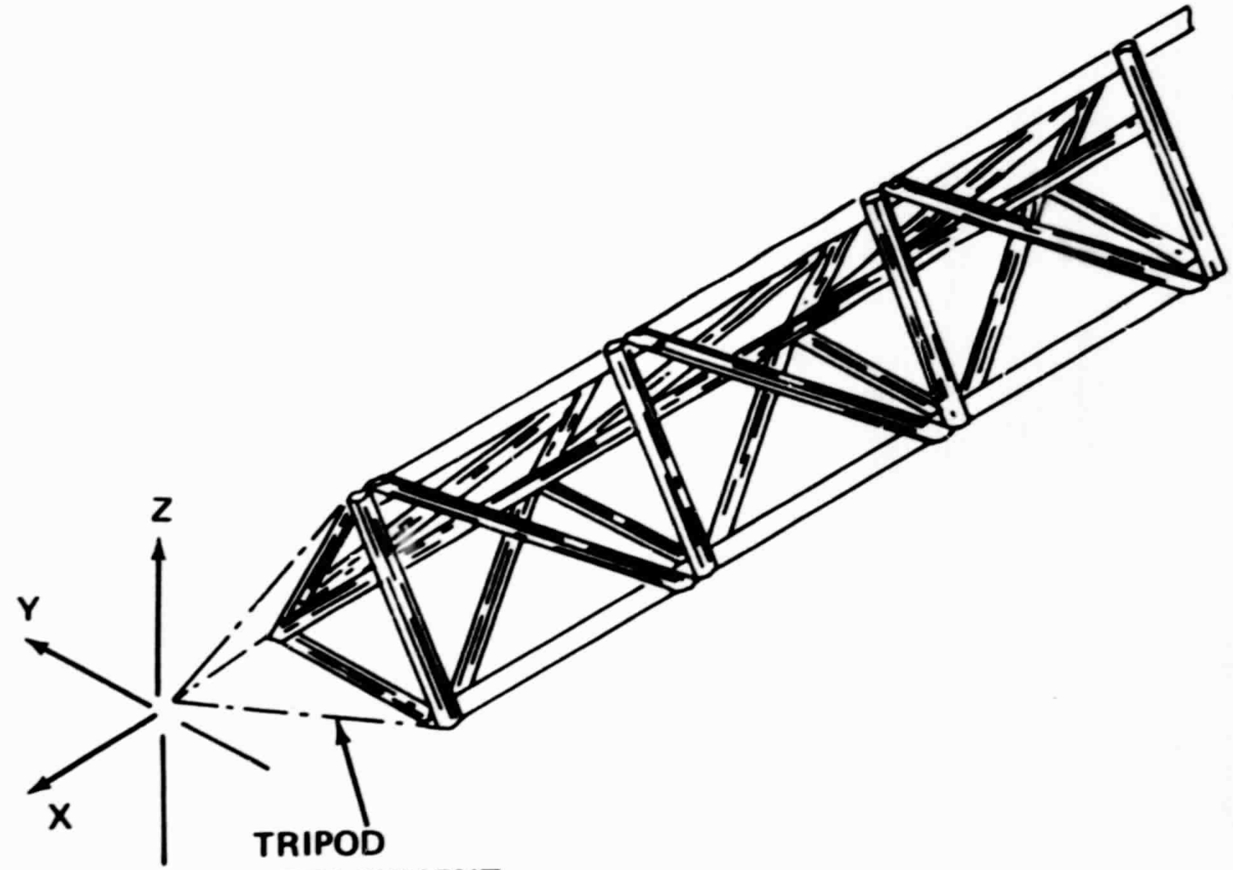
GRUMMAN

2420-234W
WM-79

STRUCTURAL DESIGN CONDITIONS — 1-M DEEP BEAM

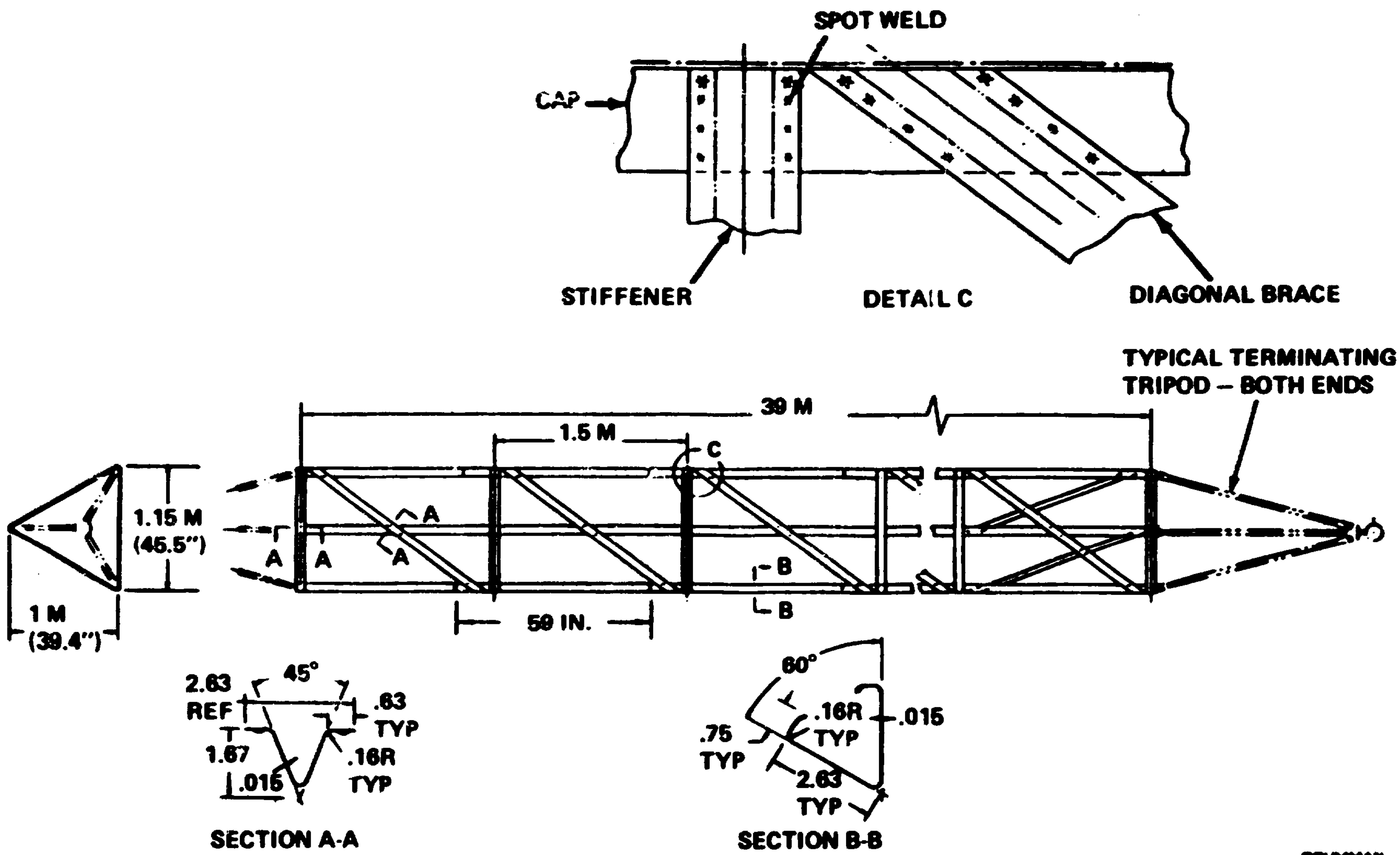
- DESIGN CONDITION I — FABRICATION IN ORBITER PAYLOAD BAY
  - ORBIT 215 N MI 28.5° INCLINATION
  - CRITICAL LOAD COND: ORBITER RCS THRUSTER FIRING
  - THERMAL CONDITION: ORBITER +Y AXIS EARTH POINTING
- DESIGN CONDITION II — SATELLITE SOLAR POWER SYSTEM (SSPS)
  - ORBIT: GEOSYNCHRONOUS, SUN ORIENTED
  - CRITICAL LOAD COND: STATION KEEPING MANEUVER
  - THERMAL COND: SOLAR ARRAY — SUN POINTING
    MW ANTENNA — EARTH POINTING

"BUILDING BLOCK" TRUSS – 1-M DEPTH



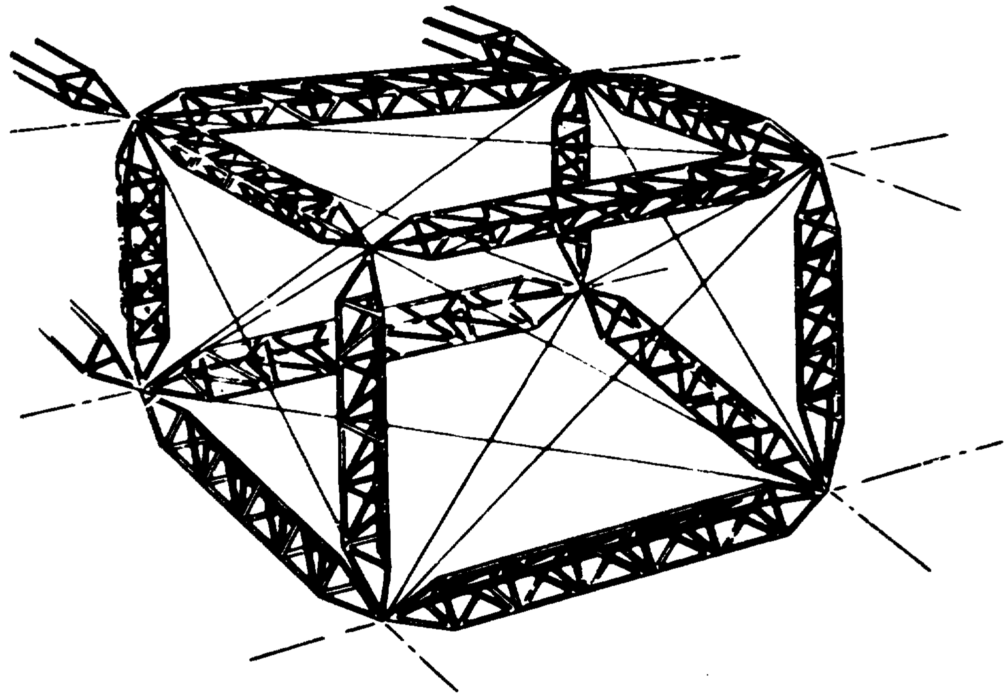
2420-067W
AA-12

1-M BEAM DESIGN



2420-074W
AA-19

LARGE SPACE STRUCTURE COMPARISON STUDY



TYPICAL MODULE
LARGE SPACE STRUCTURE

MATERIAL COMPARISON

MATERIALS	ALUMINUM* 2219-T8	GRAPHITE/EPOXY	GRAPHITE/POLYETHER-SULFONE
F_{TU}, KSI	54	69	69
F_{TY}, KSI	36	—	—
F_{CY}, KSI	38	66	66
E, KSI	10.5×10^3	7.7×10^3	7.7×10^3
ρ, LB/IN.^{3}	.103	.065	.058
α, IN./IN./°F	12.4×10^{-6}	$.1 \times 10^{-6}$	$.1 \times 10^{-6}$
TEMP LIMIT, °F	350	350	440
HANDLING QUALITY DURING FAB	GOOD	• MUST BE "C" STAGE • PARTIALLY FORMED	GOOD
THERMAL COATING	FAIR APPLY COATING TO BASIC MATERIAL IN GRD PROCESS, MUST BE REMOVED FOR JOINING	EXCELLENT INCORPORATED INTO RESIN MATERIAL DURING PROCESSING GROUND	EXCELLENT INCORPORATED INTO RESIN MATERIAL DURING PROCESSING GROUND
JOINING	EXCELLENT CAN USE ANY OF THE FOLLOWING: ULTRASONIC WELD, PRESSURE WELD, MECHANICAL ATTACHMENT	POOR BONDING REQUIRES MELT & CURE	VERY GOOD ULTRASONIC WELD GIVES GOOD SIMPLE ATTACHMENT
UV DEGRADATION	EXCELLENT	NOT KNOWN	NOT KNOWN
STATE-OF-THE-ART OF APPLICATION	EXCELLENT	GOOD	NOT KNOWN

*PROPERTIES OF 2024-T3 AND 6061-T6 APPROXIMATELY THE SAME

2420-063W
AA-8

COMPOSITE BEAM DESIGN STUDIES

- BEAM CONFIGURATION IS SAME AS ALUMINUM DESIGN
- SELECTED CANDIDATE LAYUP CONFIGURATION OF 2.5 MIL, TYPE AS, GRAPHITE PLIES WITH POLYETHERSULFONE 3501-5 RESIN
- ANALYZED VARIOUS FAILURE MODES
- ESTIMATED WEIGHT SAVING

2420-287W
AA-25

COMPOSITE BEAM DESIGN STUDIES

TYPE AS-3501

LAMINATE	LAYUP* FROM N.A. OUT	TEMP, °F	E_x, MS1	G_{xy}, MS1	EULER, LB	LOCAL BUCKLING, LB	TORSION/ FLEXURE, LB	DES LOAD, LB
$[\pm 45, 0, 90_2]$	3, 3, 1, 2	200°	7.2	2.75	1310	447	282	420
$[\pm 45_2, 0_2, 90_4]$	3, 3, 1, 1, 2	200	9.5	2.3	2006	569	565	420
$[\pm 45, 0_2, \bar{0}]_s$**	3, 3, 1, 1, $\bar{1}$	200	11.5	2.5	844	–	755	420

*1 = 0°PLY, 2 = 90° PLY, 3 = 45° PLY

**[$]_s$ SYMMETRIC

(EACH PLY 2.5 MILS)

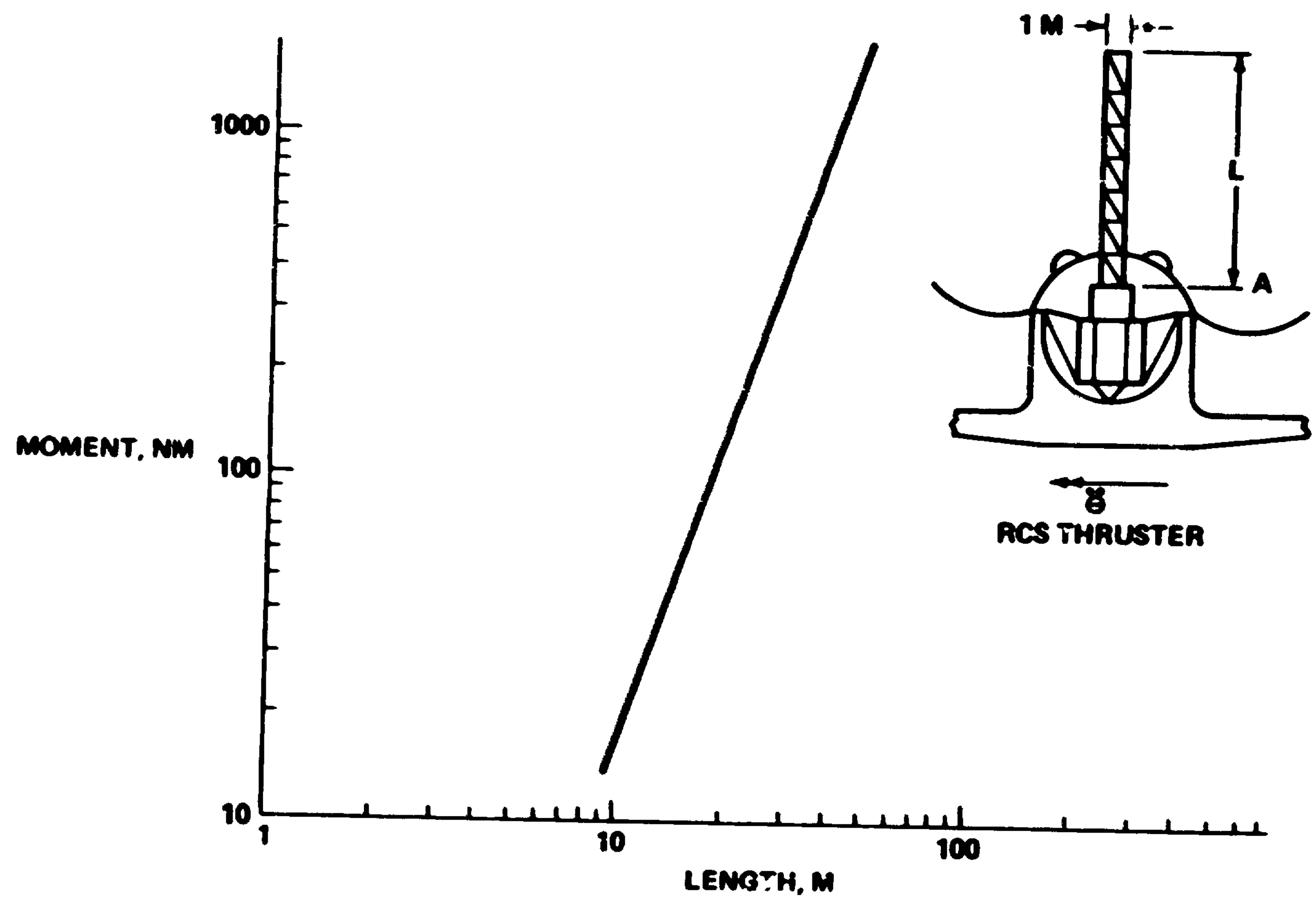
2420-286W
AA-24

COMPOSITE BEAM DESIGN STUDIES

WEIGHT SAVING USING COMPOSITE DESIGN $[\pm 45, 0_2, \bar{0}]_s$ FOR CAPS & $[2/0_0/4]$ FOR BATTENS & DIAGONALS IS 28%

2420-285W
AA-23

ULTIMATE BENDING MOMENT AT POINT A vs BEAM LENGTH RCS FIRING

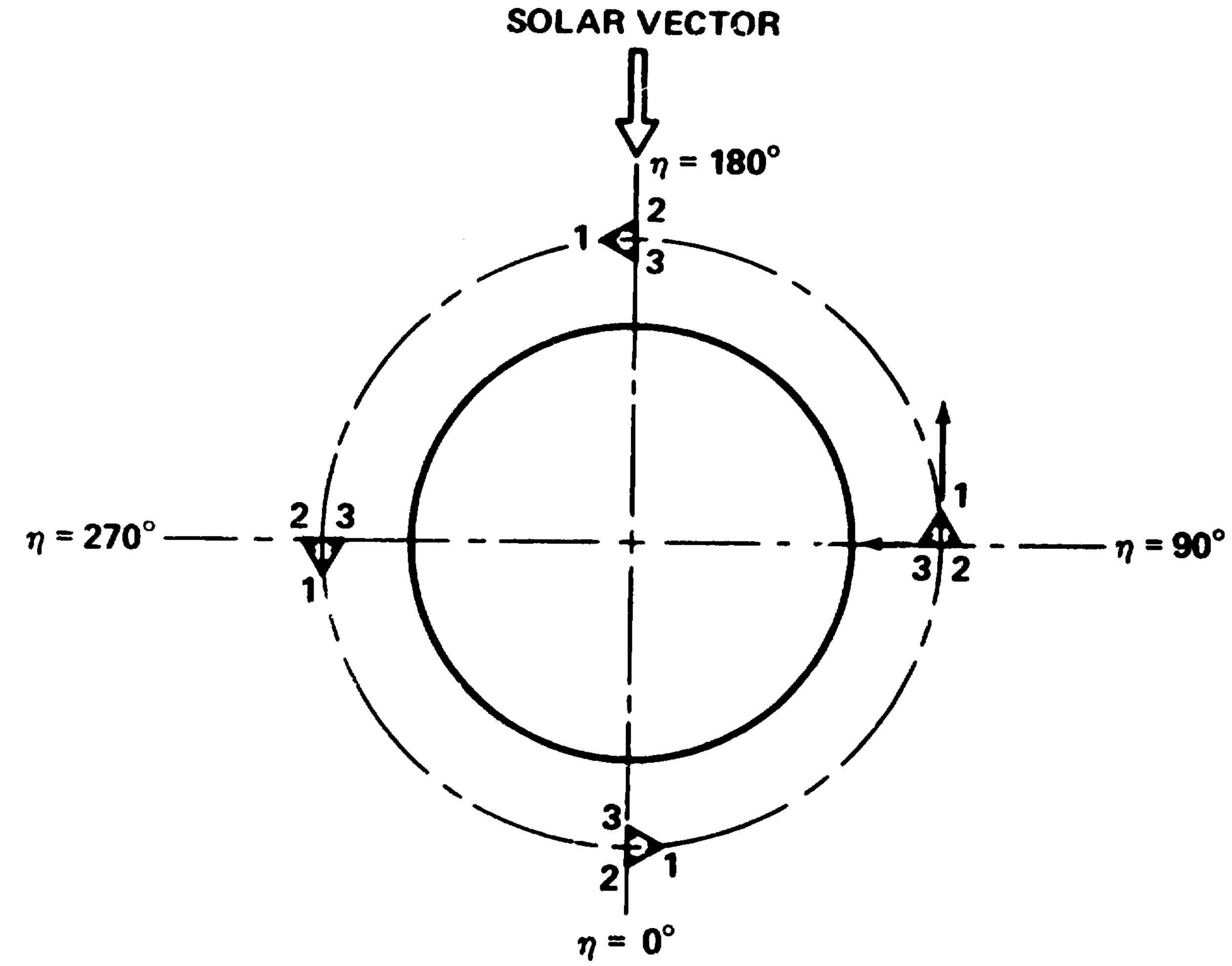


2420-062W
AA-7

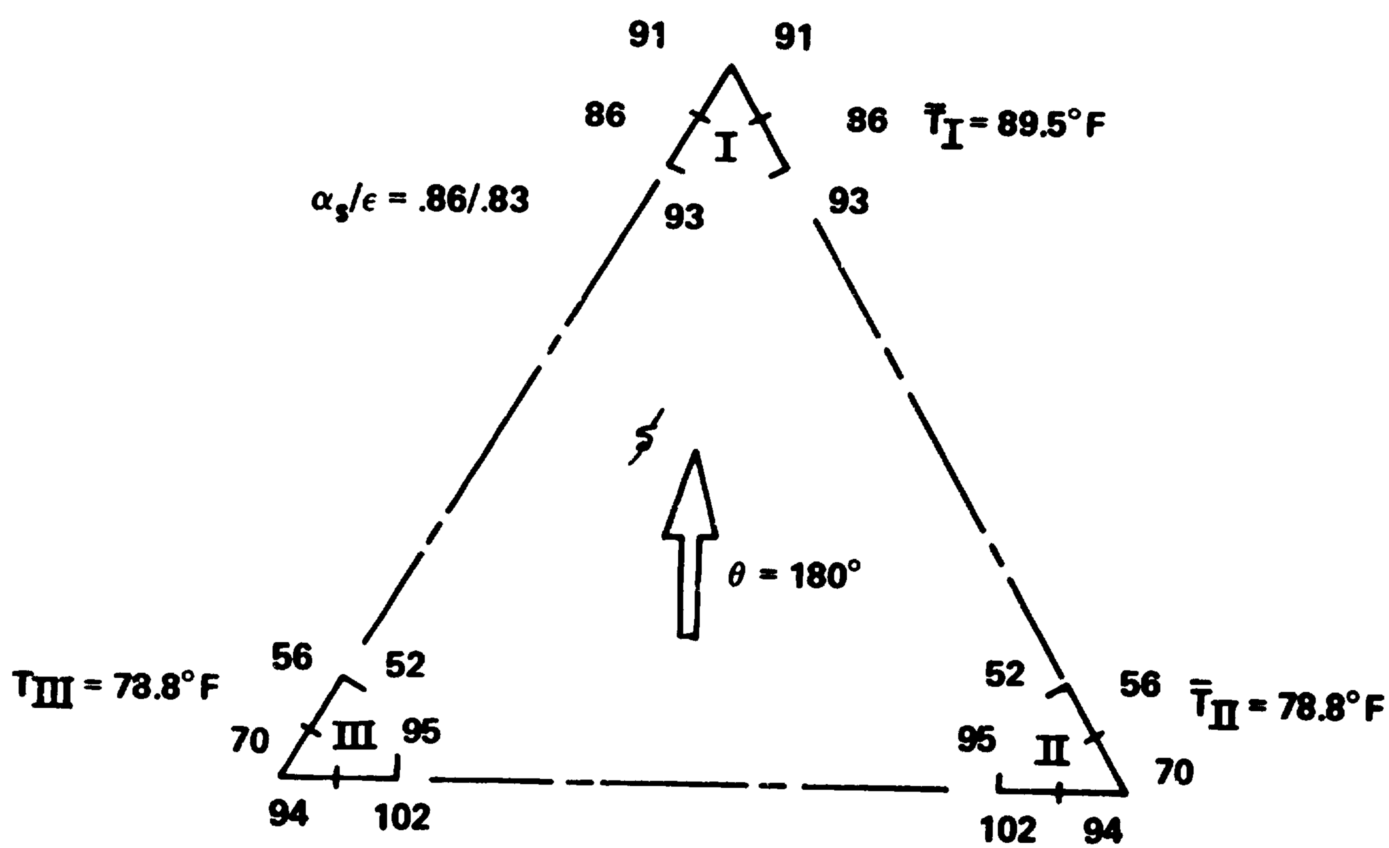
CANDIDATE THERMAL COATINGS

- BLACK ANODIZE MIL A-8625
  - ELECTROLYTICALLY PRODUCED DYED OXIDE COATING
  - THICKNESS .01 TO .1 MILS
  - ABSORPTANCE TO EMITTANCE RATIO $\leq$ 1.00
- SPRAY PAINTS
  - POLYURETHANE
  - FLUOROCARBON
  - THICKNESS APPROX .8 TO 1 MIL
  - $\alpha = .96$, $\epsilon = .91$

BEAM ORBITAL ORIENTATION



TEMPERATURE DATA θ = 180°

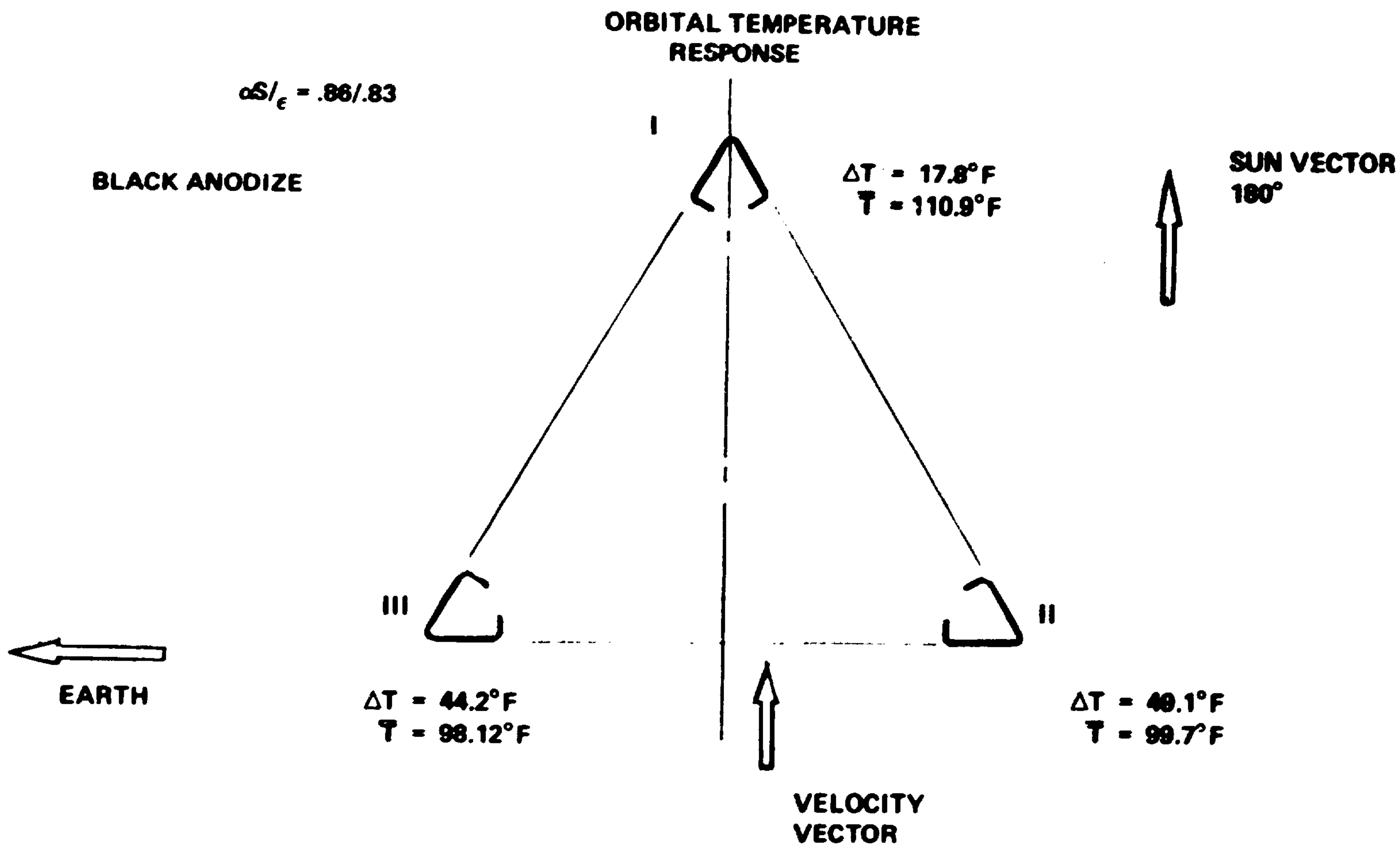


$\Delta\bar{\bar{T}}_{MAX} = \bar{\bar{T}}_I - \bar{\bar{T}}_{II} = 10.7°F$

$\widehat{\Delta T}_{MAX} = 102 - 52 = 50°F$

2420-060W
AA-5

ORBITAL TEMPERATURE RESPONSE

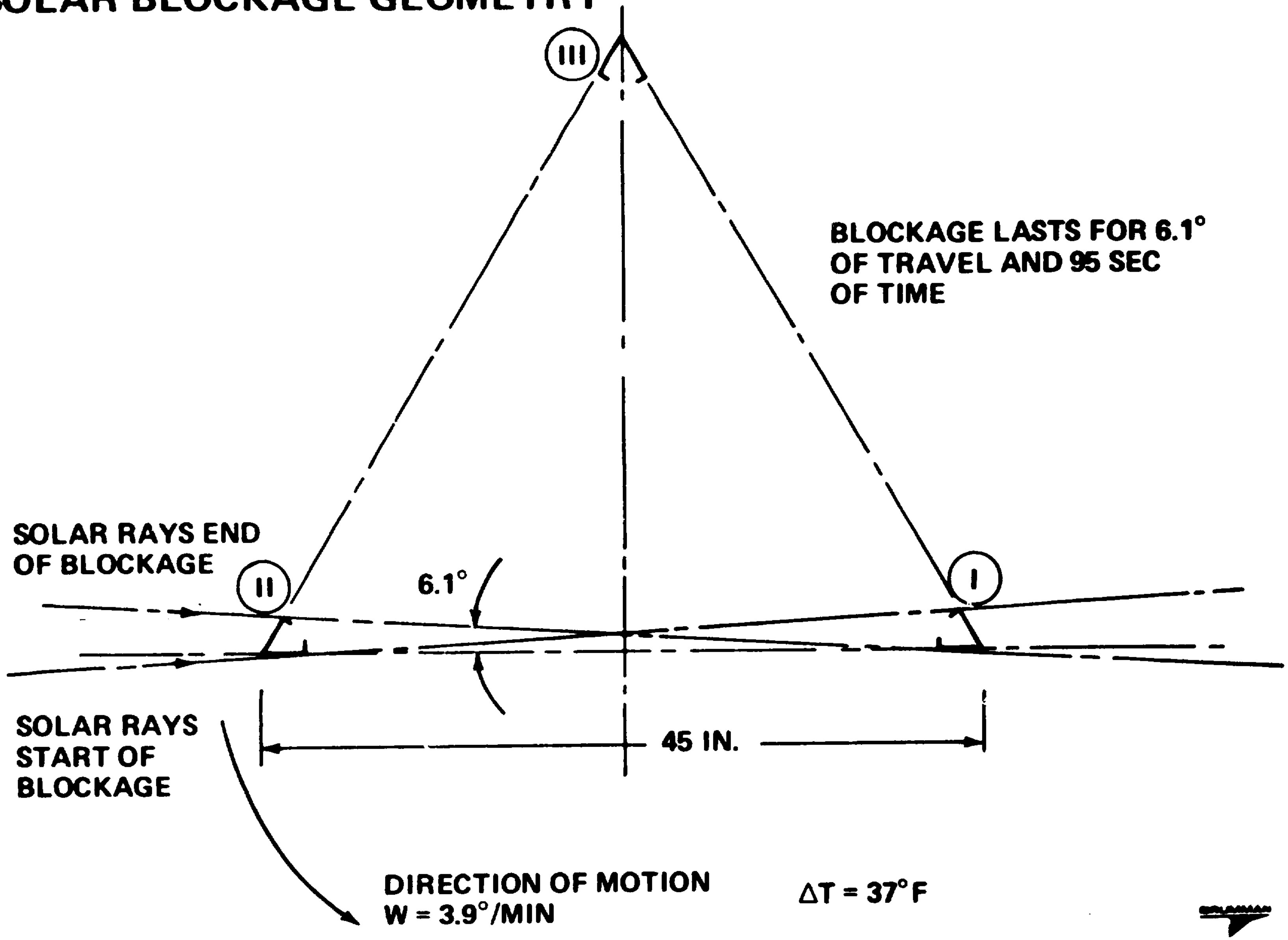


ΔT = 49.1°F MAX TEMP DIFFERENCE IN TRIANGLE

$\Delta \bar{T}_{AV}$ = 12.8°F MAX TEMP DIFFERENCE BETWEEN TRIANGLES AREA WEIGHTED

2420-071W
AA-16

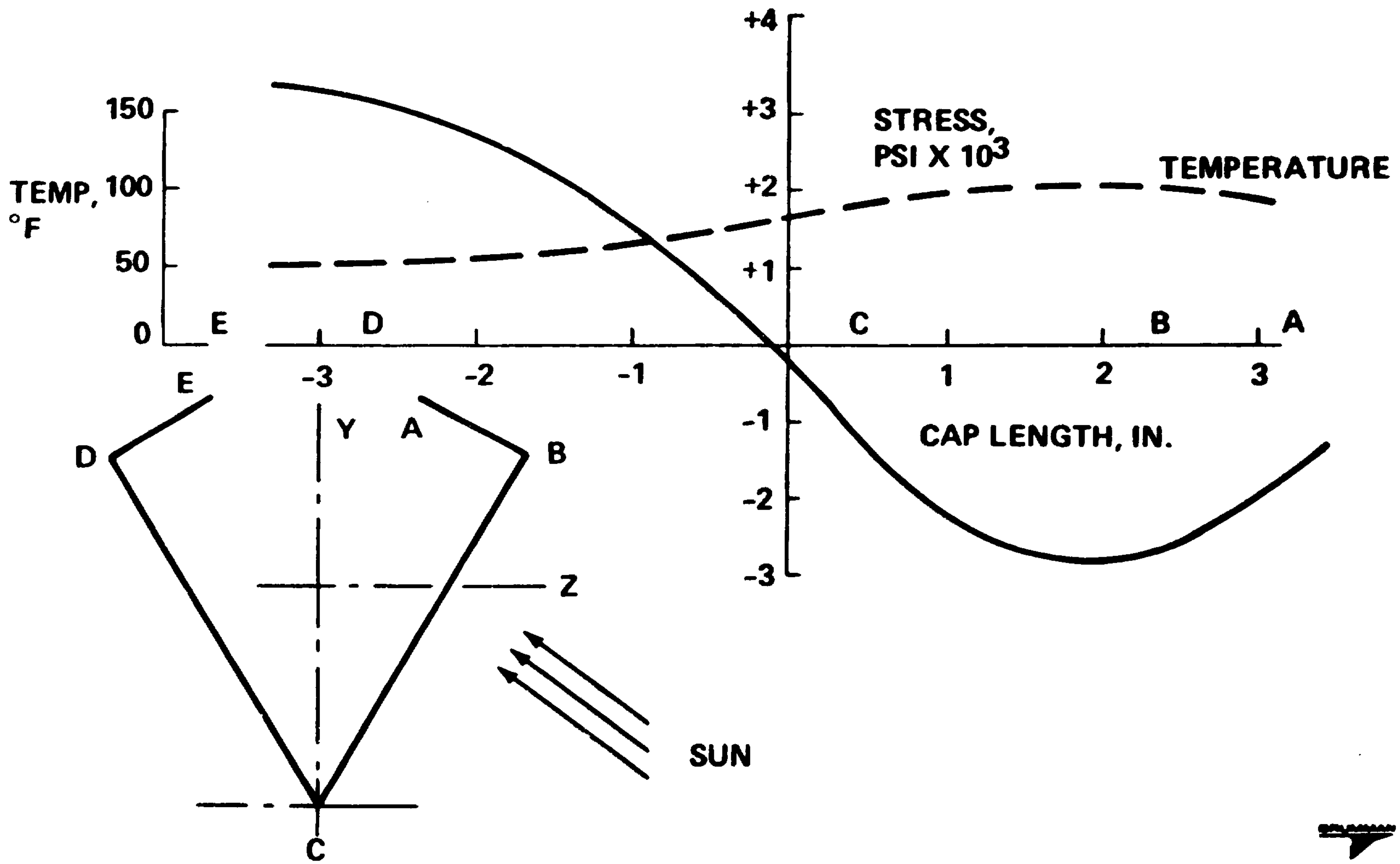
SOLAR BLOCKAGE GEOMETRY



$\Delta T = 37°F$

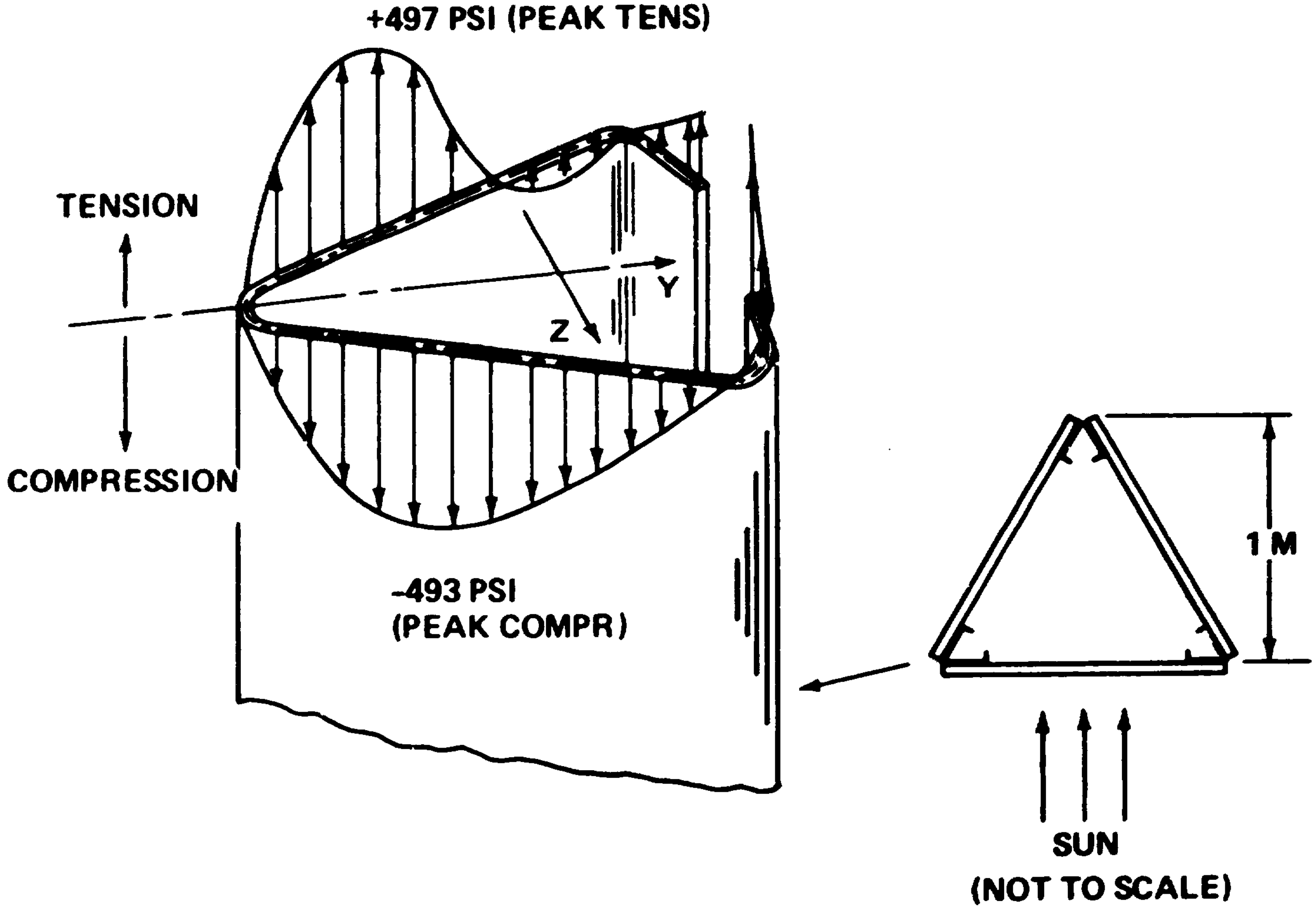
2420-066W
AA-11

THERMAL STRESS IN 1.5-M LONG CAP MEMBER DUE TO THERMAL GRADIENT, FULLY RESTRAINED IN ROTATION ABOUT Y AND Z AXES



2420-058W
AA-3

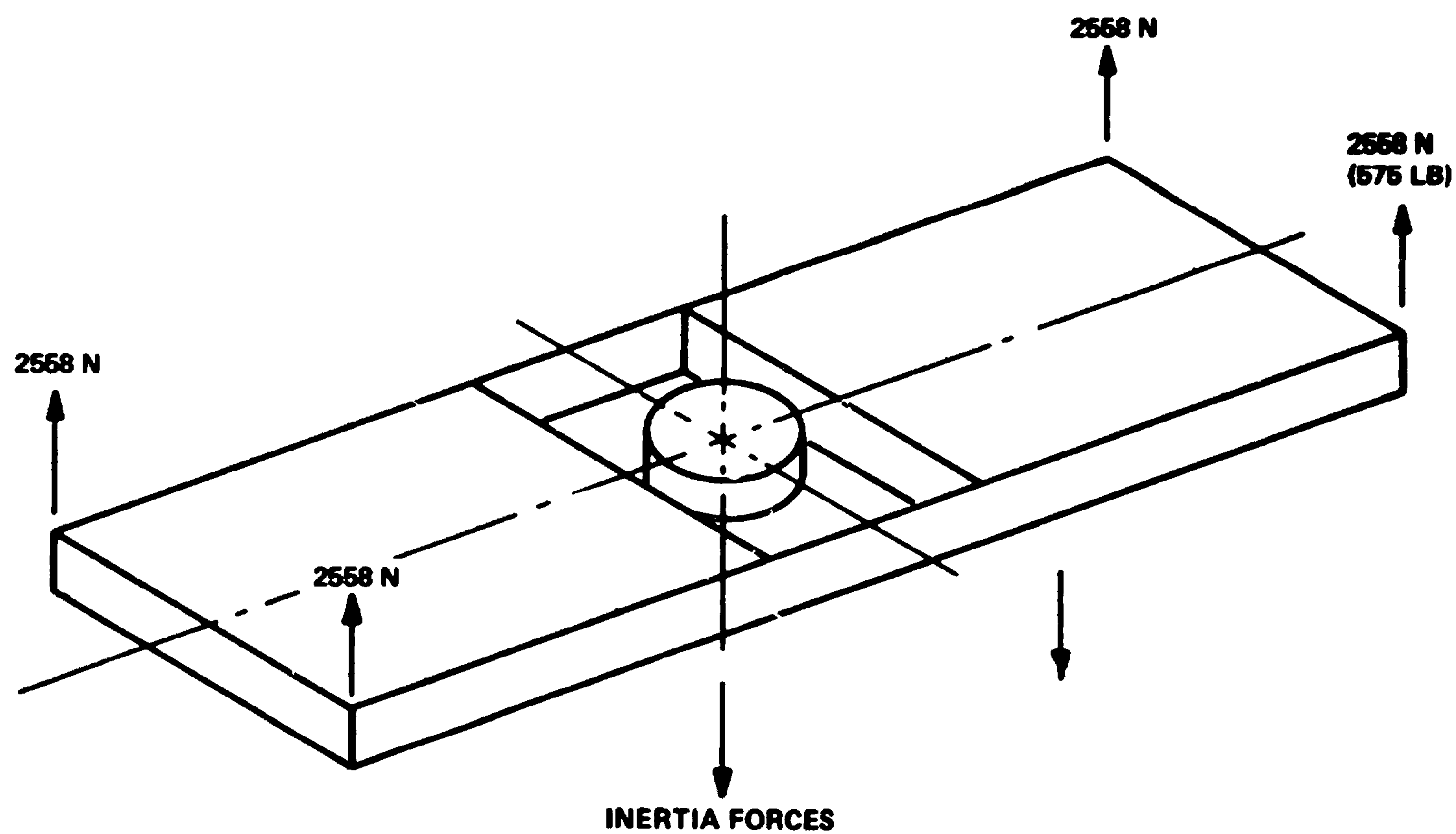
THERMAL STRESS IN CAP — 1-M TRUSS



2420-057W
AA-2

SPACE FAB DEMO SYSTEM – WBS 1.2.1

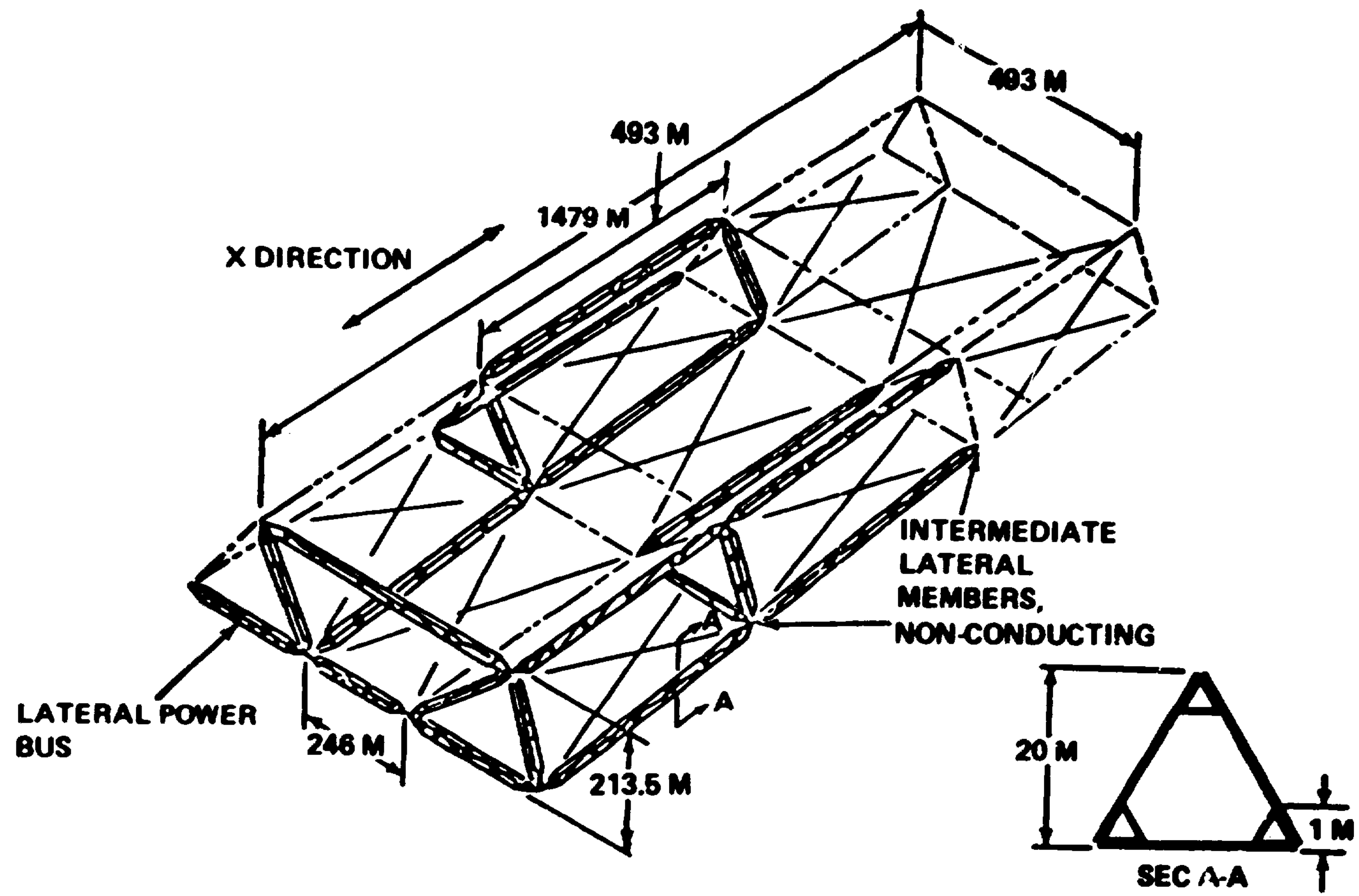
DESIGN CONDITION II – SSPS STATIONKEEPING MANEUVER



MAXIMUM APPLIED THRUSTER FORCES INCREASED BY DYNAMIC MAGNIFICATION FACTOR = 2.0, FACTOR OF SAFETY = 1.40

2420-072W
AA-17

ISOMETRIC VIEW OF ONE-BAY SSPS



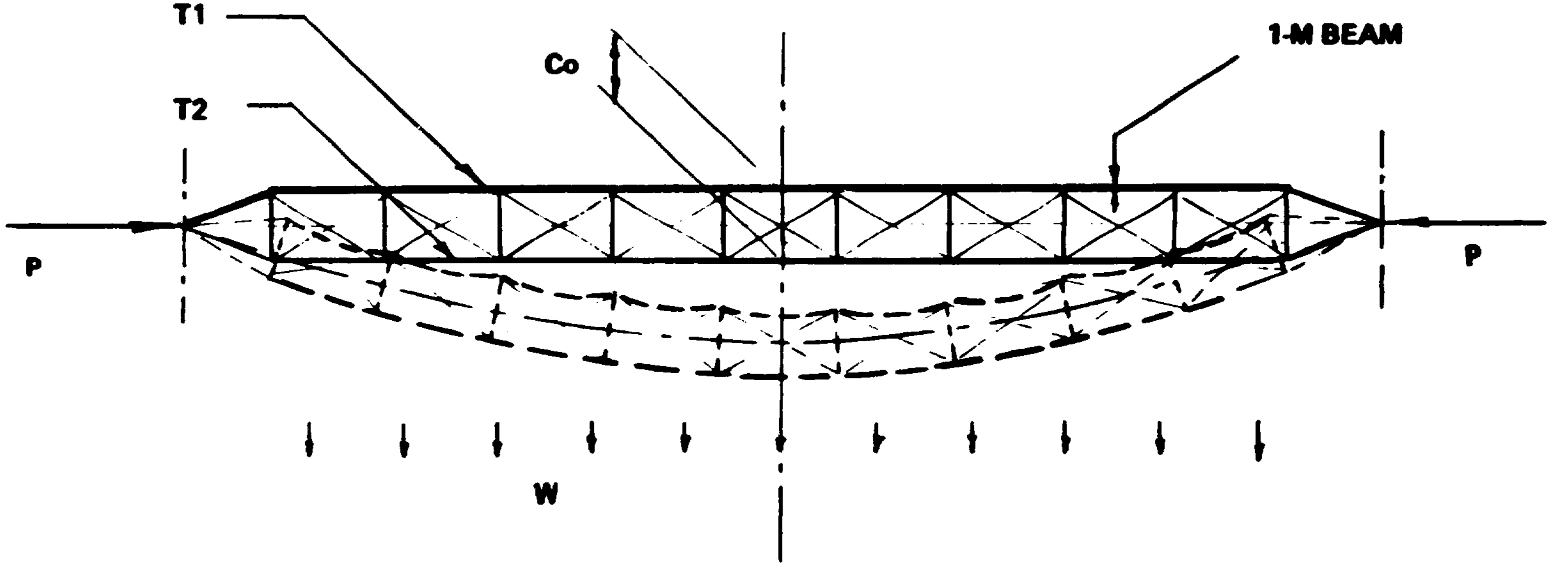
2420-070W
AA-15

DESIGN CONDITION II

SSPS 1 X 40 M BEAM CRITICAL CAP LOAD FUNCTION OF FOLLOWING:

- AXIAL LOAD DUE TO BENDING – STATIONKEEPING
- REFLECTOR PRELOAD
- MANUFACTURING MISALIGNMENT OF 20 X 493 M BEAM
- THERMAL GRADIENT/DEFLECTION OF 20 X 493 M BEAM
- MANUFACTURING MISALIGNMENT OF THE 1 X 40 M BEAM
- THERMAL GRADIENT/DEFLECTION OF THE 1 X 40 M BEAM

DESIGN LOADING CONDITION – 20 x 483 M BEAM



P = 3630 N
W = 1.21 N/M
LIMIT

MAXIMUM BEAM CAP STRESSES – 1 X 40 M BEAM

- DESIGN CONDITION I:

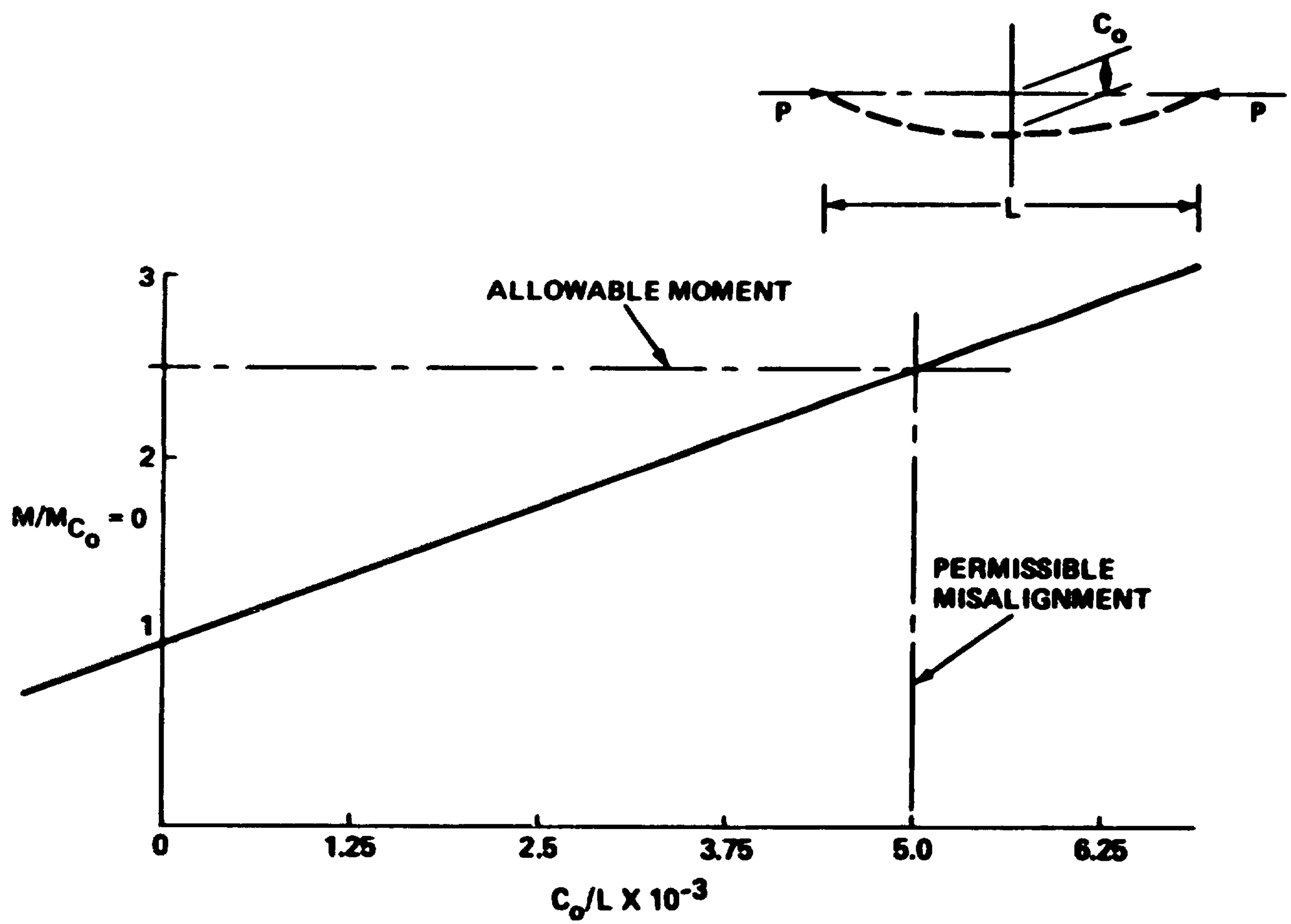
– COMPRESSION STRESS	– APPLIED LOADS	–	2505 PSI
	– THERMAL GRADIENT	–	690 PSI
	TOTAL	–	3195 PSI

- DESIGN CONDITION II (SSPS):

–COMPRESSION STRESS	– APPLIED LOADS	–	2272 PSI
	– THERMAL GRADIENT	–	690 PSI
	TOTAL	–	2962 PSI

– ALLOWABLE AVERAGE COMPR STRESS BASED ON STATIC TEST – 4421 PSI

EFFECT OF MANUFACTURING MISALIGNMENT ON BEAM MOMENT (APPLIES IN X-Z PLANE ONLY)*



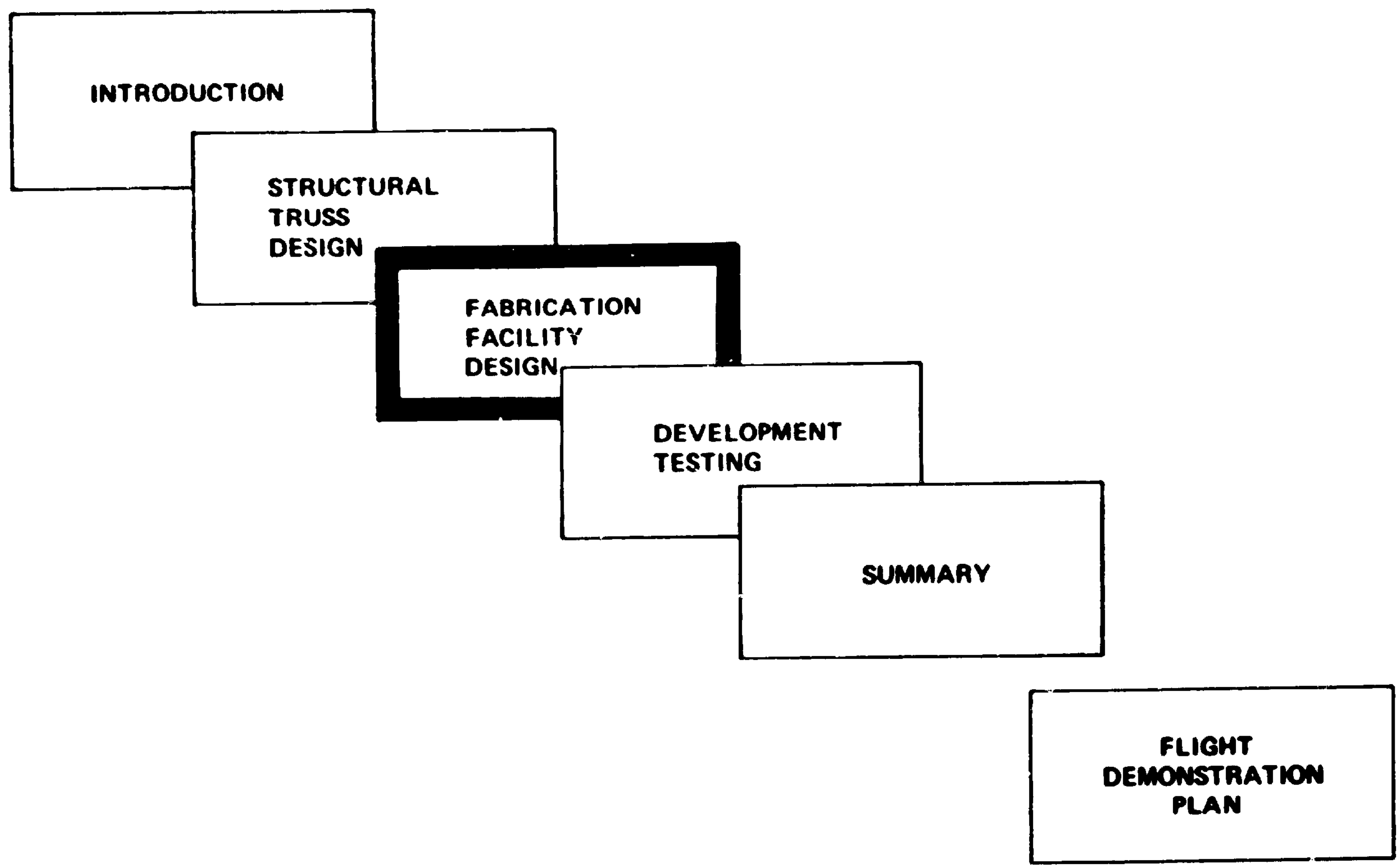
*MISALIGNMENT IN X-Y PLANE INDUCES TORSION

2420-073W
AA-20

CONCLUSIONS

- DESIGN LOADS AND TEMPERATURES EVALUATED FOR:
  - I FABRICATION IN ORBITER PAYLOAD BAY
  - II SSPS VEHICLE
- MATERIALS AND PROCESSES SELECTED MEET REQUIREMENTS
  - 2024-T3; 2219-T6; 6061-T6
  - THERMAL COATINGS
  - ROLL FORMING
  - SPOTWELDING
- BEAM DESIGN HAS BEEN DEFINED AND SATISFIES CRITICAL CONDITIONS
- FABRICATION ACCURACY REQUIREMENT FOR BEAM DEFINED FOR FABRICATION FACILITY
- STRUCTURAL TEST ON NOV 1976 ESTABLISHES CONFIDENCE IN BASIC DESIGN

SPACE FAB DEMO SYSTEM – WSB 1.2.2



2420-235W
WM-80

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

2420-150W
WM-17T

DESIGN REQUIREMENTS

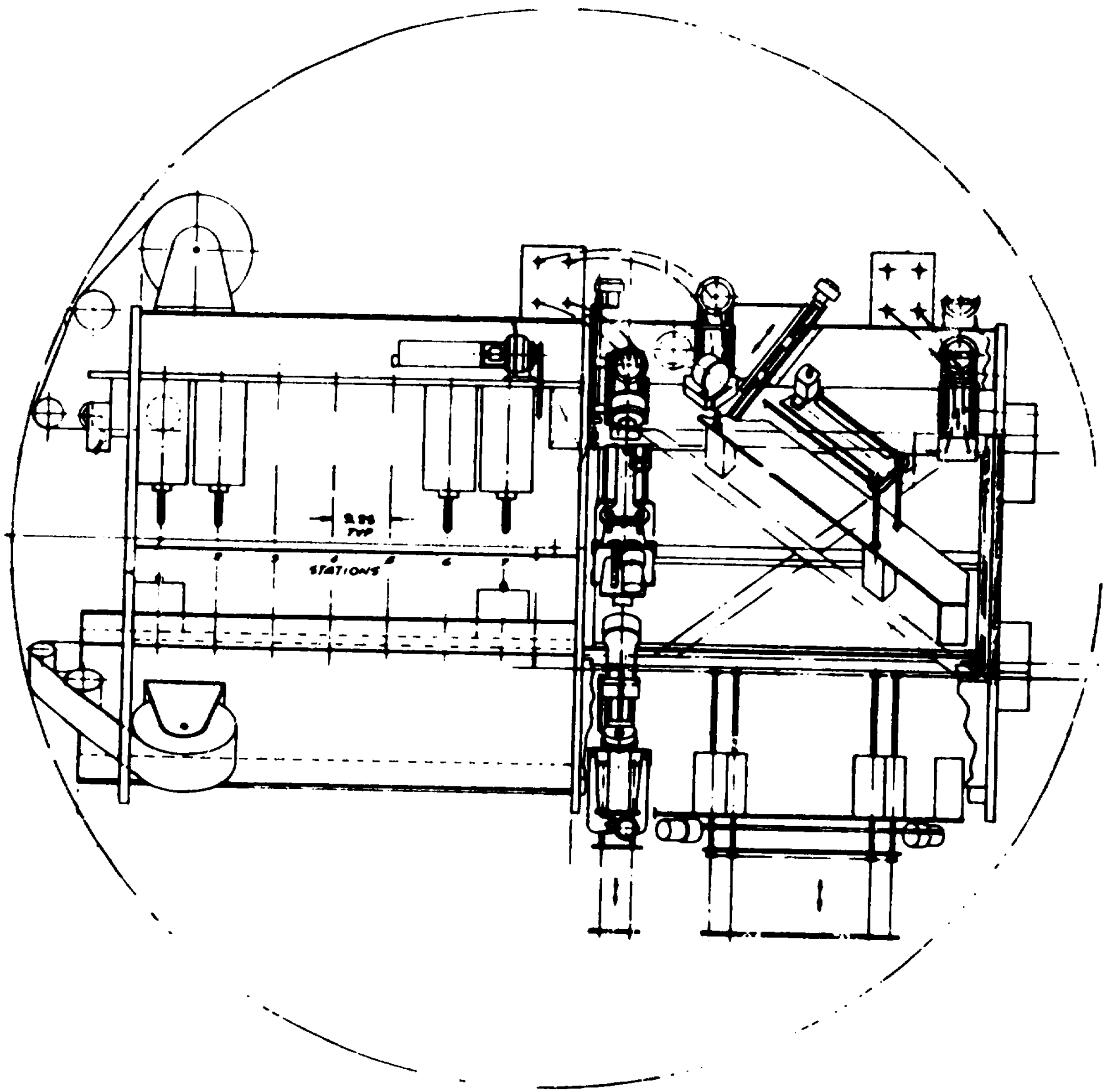
- LOW COST
- COMPLY WITH SHUTTLE PAYLOAD CONSTRAINTS
- MAXIMUM USE OF COMMERCIAL "OFF-THE-SHELF" HARDWARE
- MAXIMUM USE OF EXISTING "STATE-OF-THE-ART" EXPERTISE
- COMPATIBLE WITH FUTURE FLIGHT TEST NEEDS
- FULLY AUTOMATED FABRICATION OF TRUSS

PRINCIPAL MACHINE PROCESSES

- ROLL-FORM CAP MEMBERS
- MAGAZINE STORE PREFAB BRACES
- RESISTANCE-WELD ATTACHMENT
- COMPUTER CONTROL CAP ALIGNMENT

2420-148W
WM-15T

SELECTED BEAM BUILDER



2420-199W
WM-18T

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

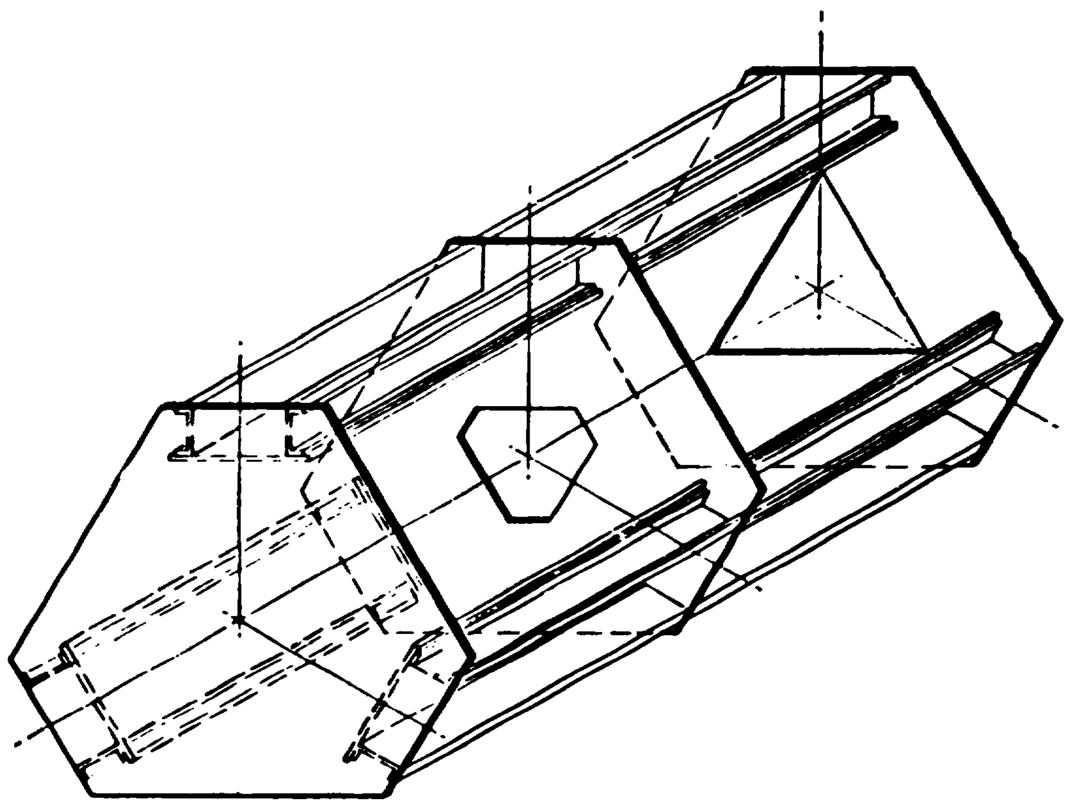
SUPPORT STRUCTURE

OBJECTIVES

- SUPPORT OPERATING MACHINERY WITHIN SHUTTLE GEOMETRIC CONFIGURATION
- GUIDE TRUSS DURING FABRICATION

EXTERNAL SUPPORT STRUCTURE

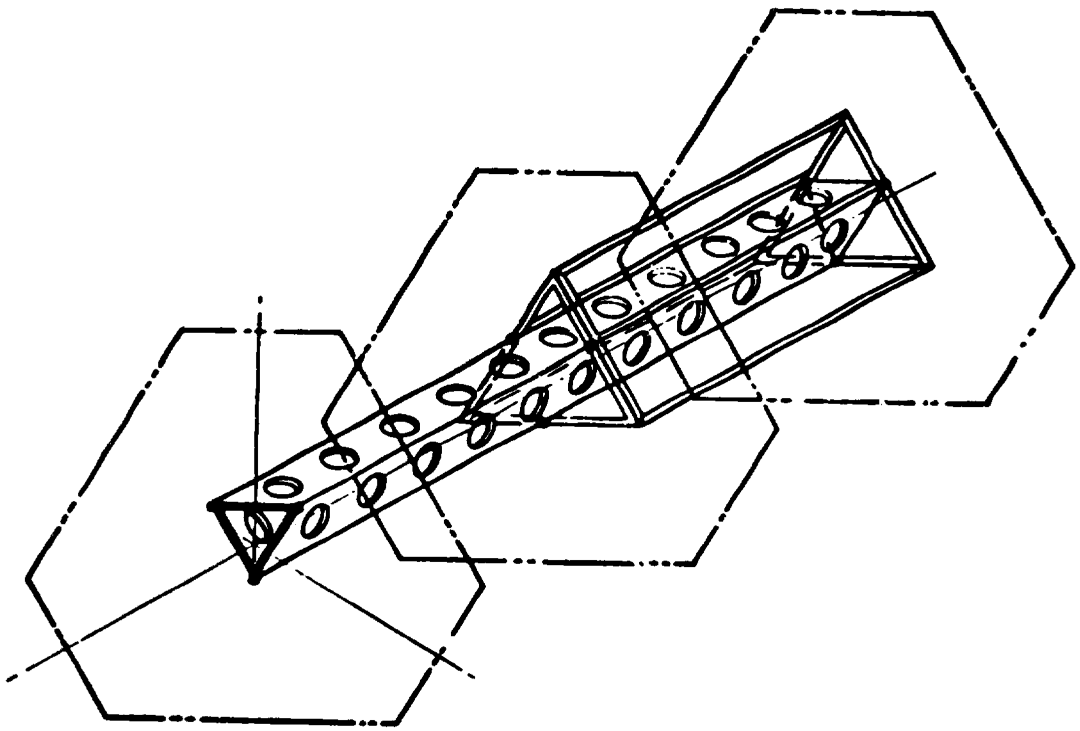
- MATERIAL — HOT ROLLED STEEL
- ARC WELD AND BOLTED CONSTRUCTION
- DWG NO. RDM 447-2070



2420-154W
WM-22T

INTERNAL SUPPORT STRUCTURE

- MATERIAL — HOT ROLLED STEEL
- ARC WELD AND BOLTED CONSTRUCTION
- DWG NO. RDM 447-2069



2420-155W
WM-23T

SUPPORT STRUCTURE

STATUS

- ICDR – COMPLETED 9/29/77
- BOX BEAMS – WELDMENT AND MACHINING COMPLETE
- BULKHEAD – WELDMENTS COMPLETE, READY FOR MACHINING
- BASE FRAME – WELDMENT COMPLETE, READY FOR INSTALLATION
- BRACKETS – COMPLETE, READY FOR ASSEMBLY
- INTERNAL STRUCTURE – WELDMENT COMPLETE, READY FOR MACHINING

FACILITY DESIGN

AREAS OF DISCUSSION

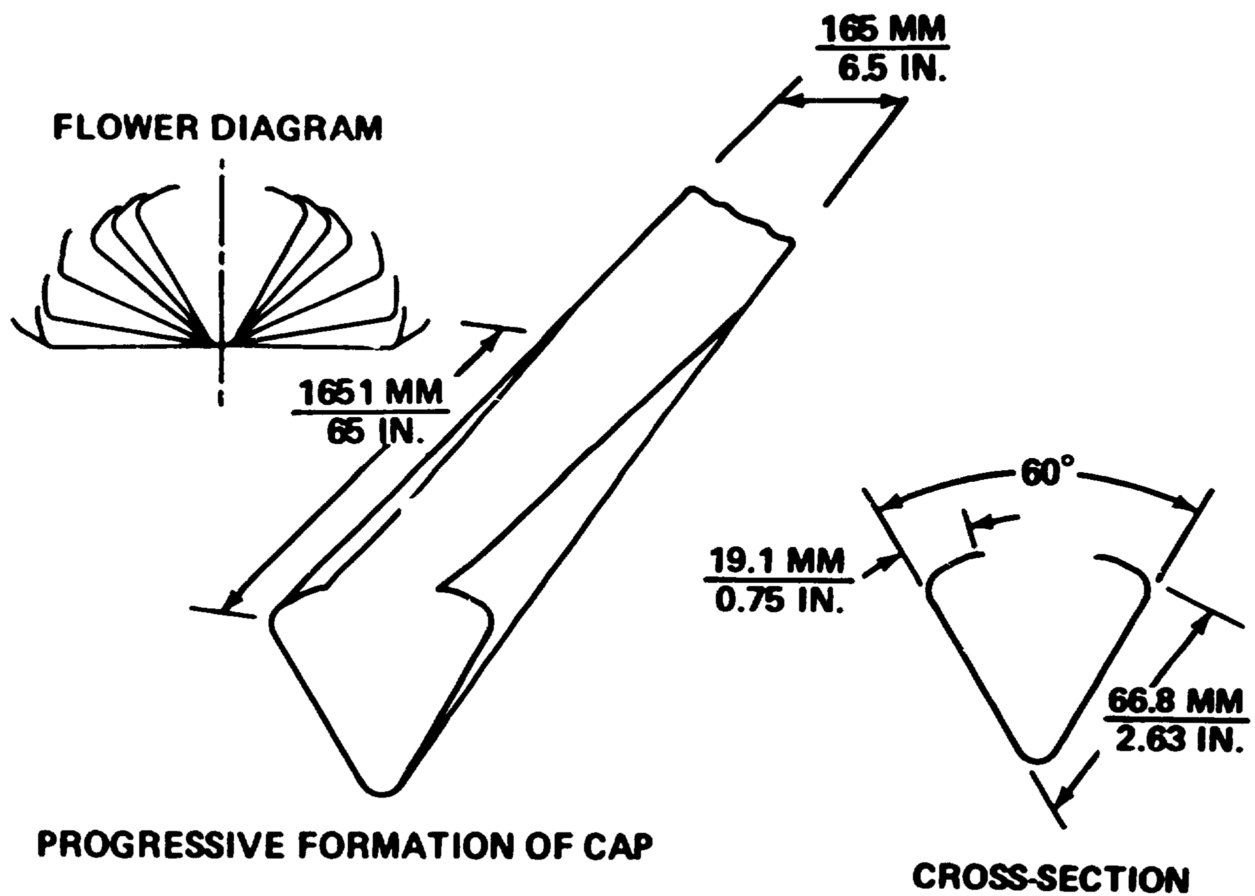
- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

ROLL FORMING EQUIPMENT

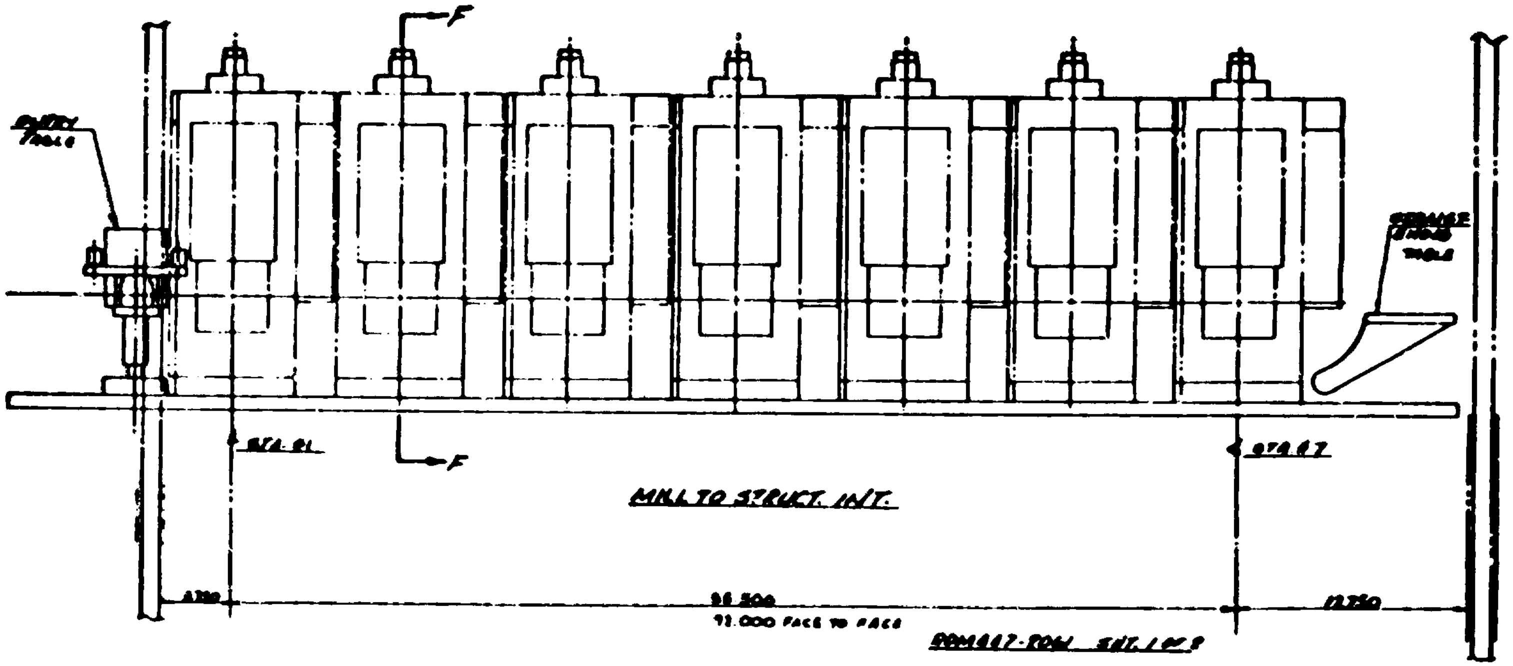
OBJECTIVE

PROGRESSIVE ROLL FORM THREE CAP MEMBERS
FROM FLAT ALUMINUM STRIP STOCK

ROLL-FORMING CAP MEMBER



SPACE FAB DEMO SYSTEM – WBS 1.2.2



2420-200W
WM-25T

DEVELOPMENT TEST SUMMARY

TASK	RESULTS	ACTION
ESTABLISH 2219-T62, 2024-T3 SPRING BACK	2219-T62 (10 DEG) 2024-T3 (2 DEG)	PRELIMINARY ROLL DESIGN
REDUCE ROLL STATIONS	STATION REQMTS 8 → 7	ESTABLISH 65-IN LENGTH
PRELIMINARY CONFIGURATION EVALUATION	• RIPPLED FLANGE • LONGITUDINAL BOW	MODIFY ENTRY AND TRANSITION ROLLS
CONFIGURATION REFINEMENT	• IMPROVED FLANGE • ELIMINATE BOW	REDESIGN TRANSITION ROLLS
FLANGE EVALUATION	• MINIMAL WAVE	• ADD CROWN TO FLANGE • PROCEED WITH FINAL DESIGN

2420-181W
WM-54T

ROLL FORMING EQUIPMENT

STATUS

- ICDR COMPLETED 9/29/77
- ROLLING MILLS & TOOLING IN ACCEPTANCE TESTING AT YODER
- PROJECT EQUIPMENT DELIVERY TO GAC WEEK OF 10/24

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

BRACE MEMBER MAGAZINE AND DISPENSER

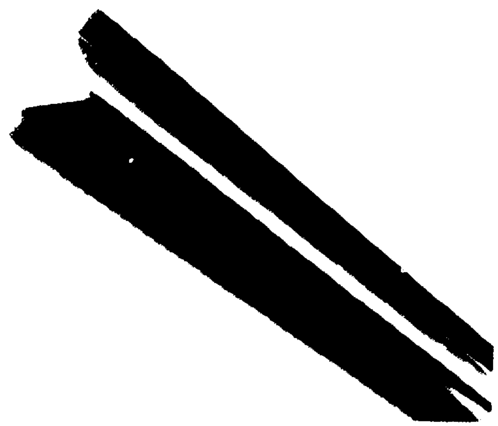
OBJECTIVES

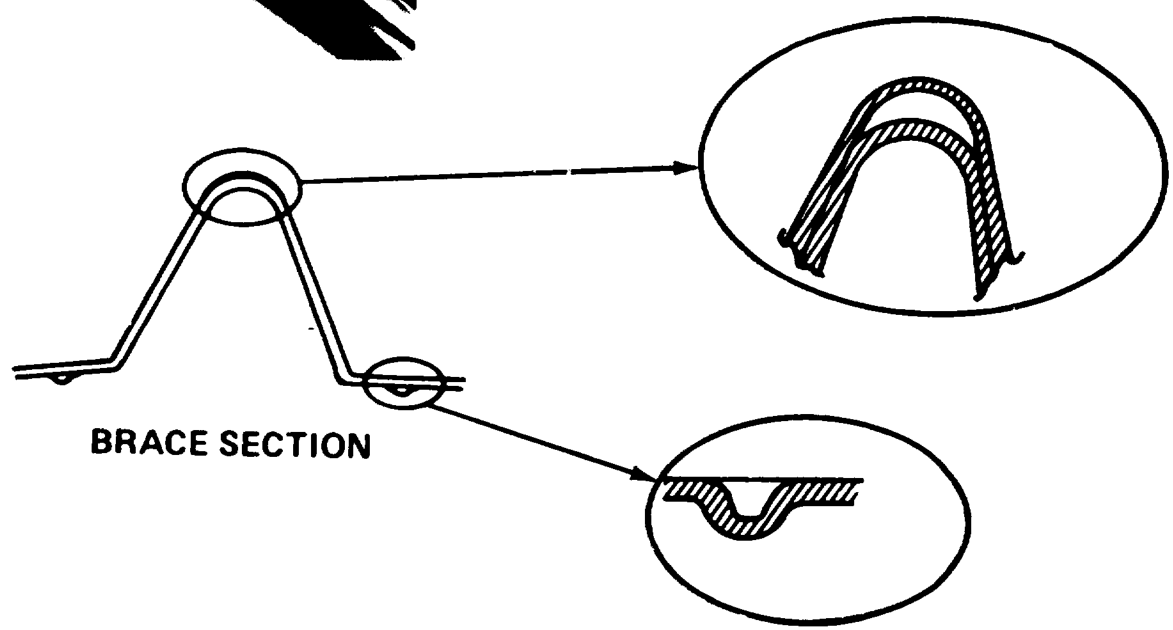
- STORE BRACES NESTED IN A MAGAZINE
- DISPENSE THEM INTO THE PROPER POSITION ON THE CAP MEMBER

SPACE FAB DEMO SYSTEM WBS 1.2.2

BRACE FABRICATION

- SLIT MATERIAL
- ROLL SECTION
- ADD DIMPLES OR SPACERS
- ANODIZE (FLIGHT ARTICLE)

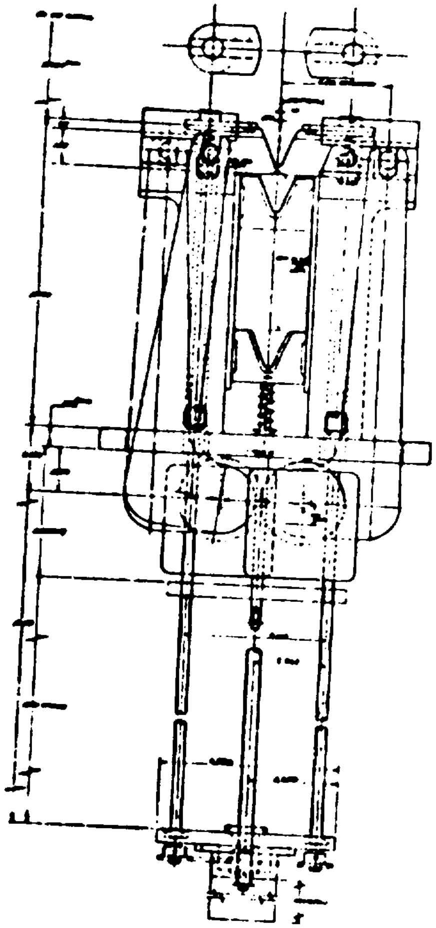


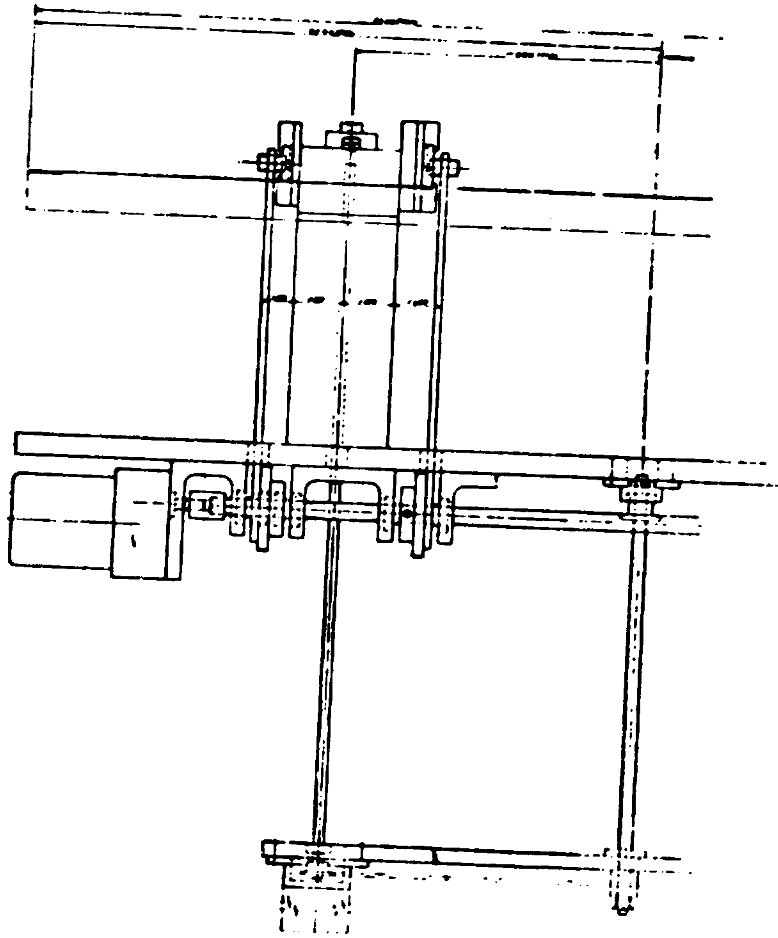


BRACE SECTION

2420-279W
WM-75

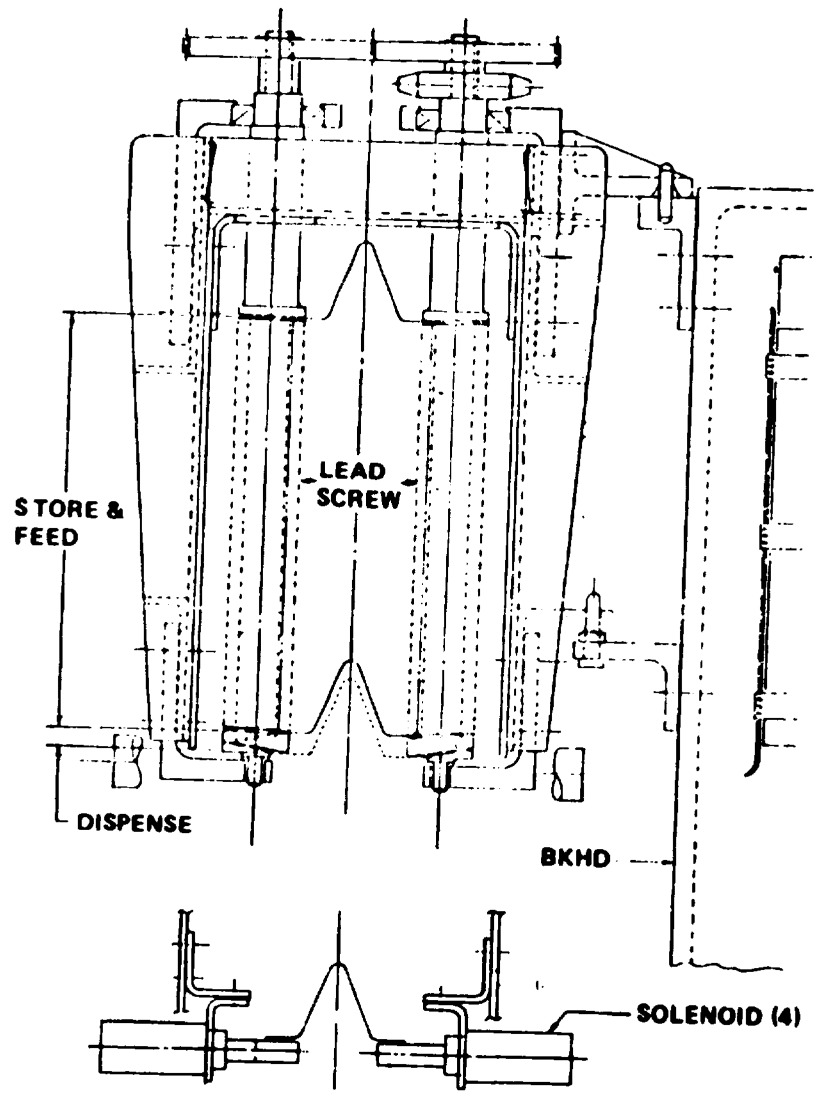
VERTICAL MAGAZINE





2420-305
WM-89

MAGAZINE/DISPENSER SUBSYSTEM



2420-312W
WM-91

BRACE MEMBER MAGAZINE AND DISPENSER

STATUS

- I CDR SCHEDULED FOR 12/14/77
- MOCKUP BUILT FOR BASELINE APPROACH
- MOCKUP BUILT FOR REVISED SYSTEM
- YODER TO TEST ROLL FORM TOOLING IN OCT.

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

2420-292W
WM-76

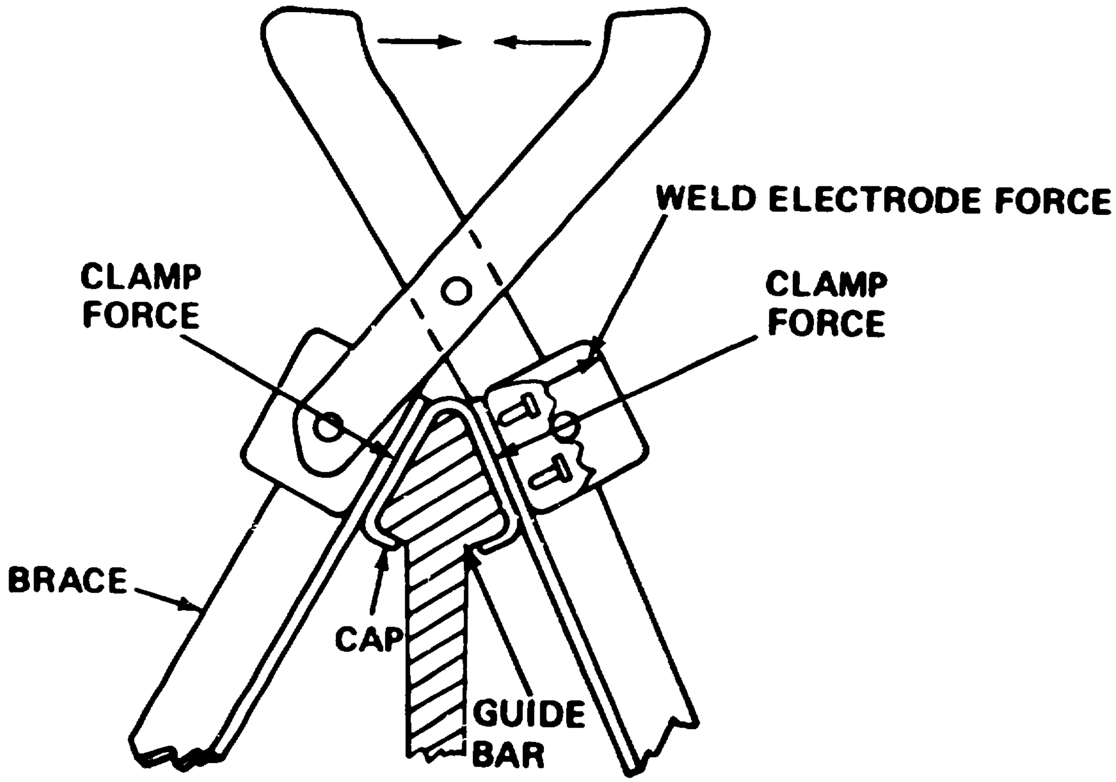
WELD CLAMP MECHANISM

OBJECTIVES

- HOLD BRACE MEMBER TO CAP
- POSITION WELD ELECTRODES
- PROVIDE WELD ELECTRODE CLAMP FORCE

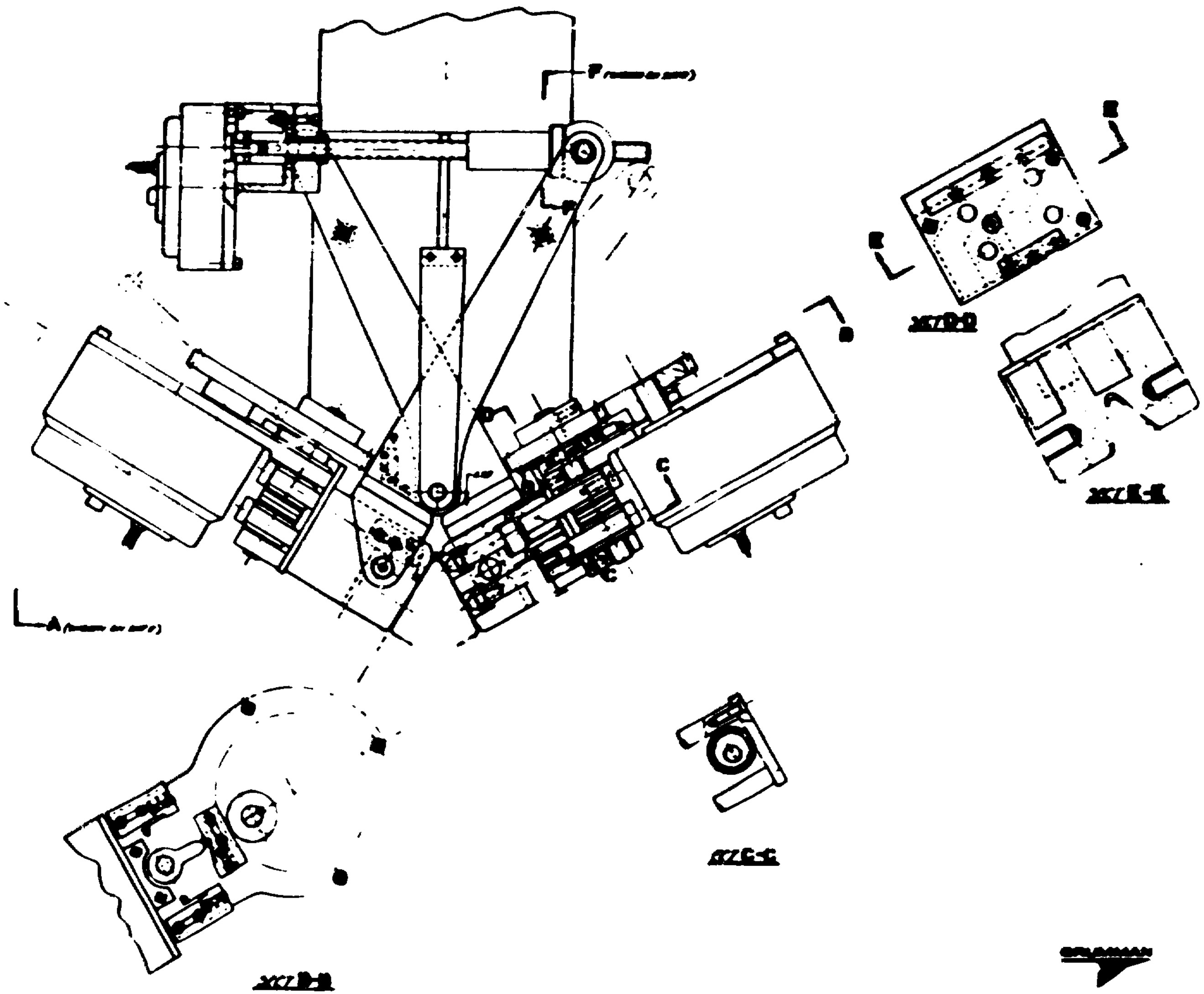
2420-254
WM-65

CLAMP MECHANISM PRINCIPAL FORCES



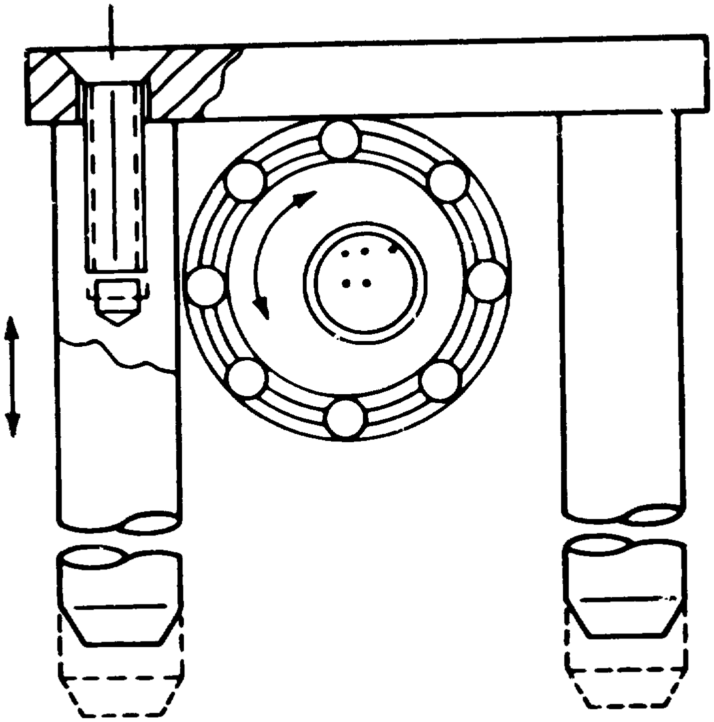
SPACE FAB DEMO SYSTEM – WBS 1.2.2

VERTICAL CLAMP MECHANISM WITH ELECTRODES FOR WELD



2420-202W
WM-31T

WELD ELECTRODE DRIVE



- CAM ACTUATION
- SPRING FORCE ON ELECTRODE

2420-163W
WM-37T

WELD CLAMP MECHANISM

STATUS

- I CDR SCHEDULED FOR 10/31
- DRAWINGS SENT TO MSFC 10/18/77
- MOCKUP OF MECHANISM BUILT

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

BRACE ATTACHMENT

OBJECTIVE

JOIN VERTICAL AND DIAGONAL
BRACE MEMBERS TO CAPS

BRACE ATTACHMENT

PRIMARY SYSTEM

- RESISTANCE SPOT-WELDING

ALTERNATES CONSIDERED

- ULTRASONICS
- HOLLOW INTEGRAL RIVET
- INTEGRAL RIVET
- STAPLING
- ELECTRON-BEAM WELDING
- ADHESIVE BONDING

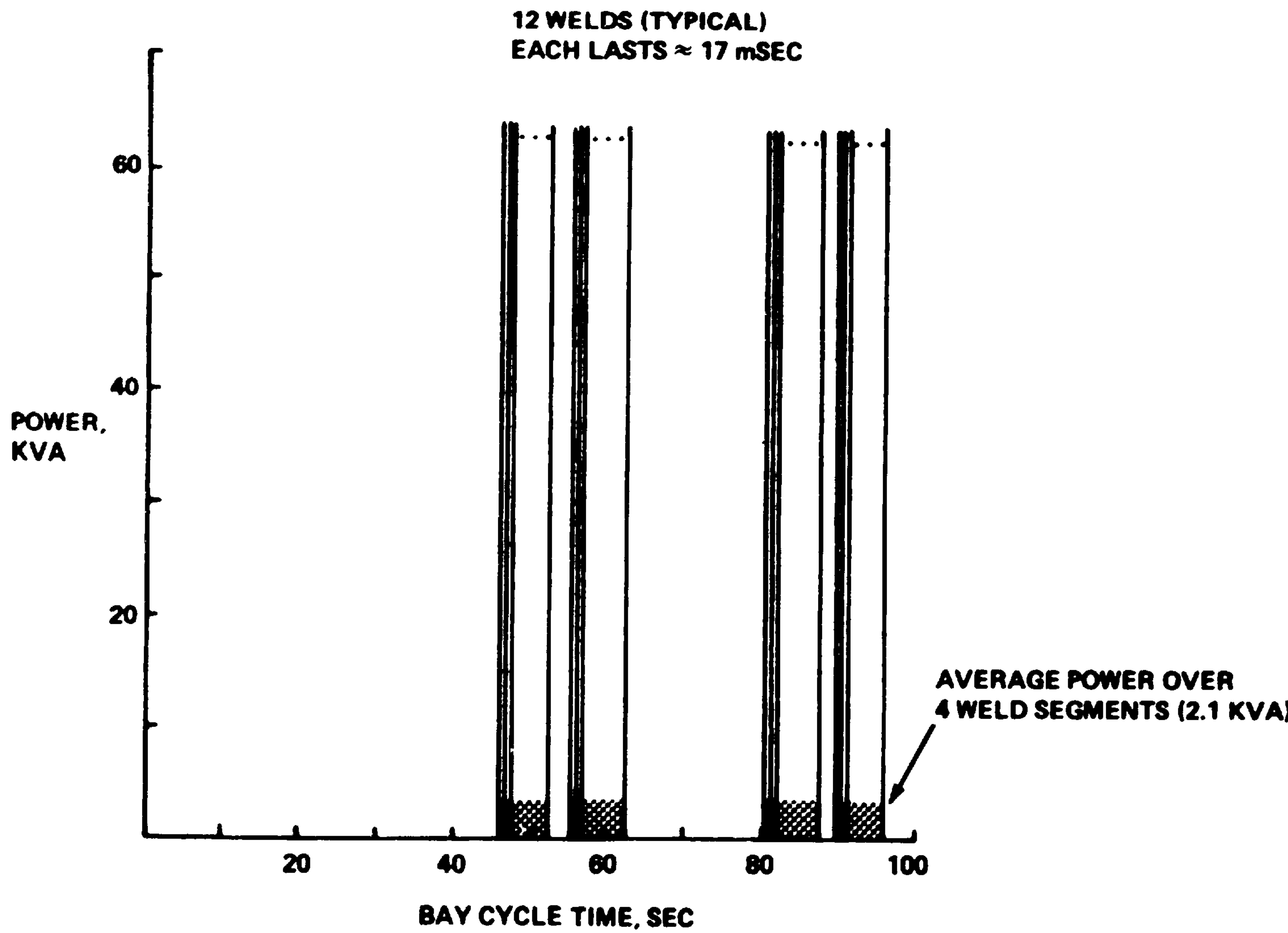
WELD SYSTEM
PRINCIPAL COMPONENTS

- TRANSFORMER
- CONTROLLER
- POWER CABLES
- ELECTRODES

WELD POWER SUPPLY GROUND DEMONSTRATION SYSTEM

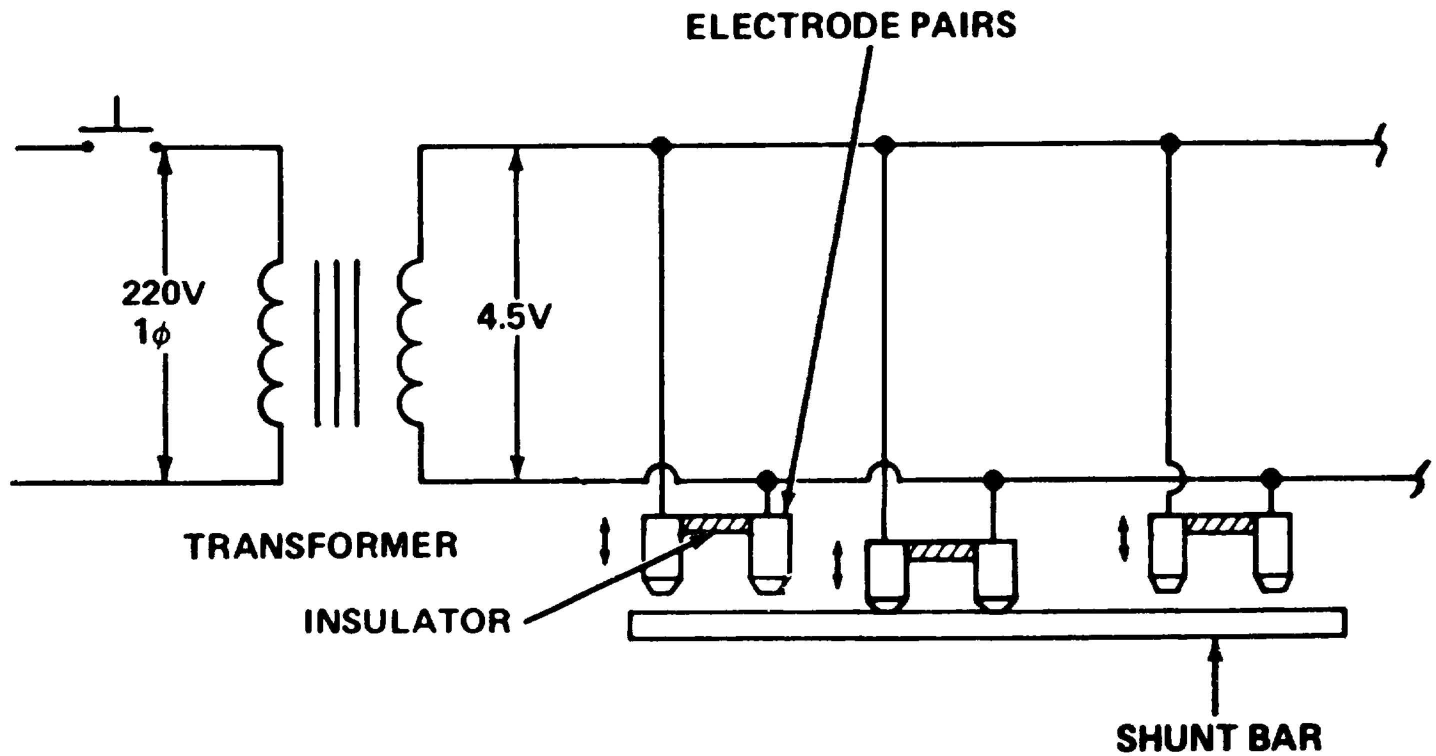
- MANUFACTURER – SCIAKY
- QUANTITY – 6
- TYPE – SOLID-STATE A/C
- COOLANT – WATER
- OUTPUT – 63 KVA, 4.5 V
- DUTY CYCLE – APPRX. 0.01%
- WEIGHT – 91 KG (200 LBS)
- SIZE – 25.4 x 30.5 x 50.8 CM (10 x 12 x 20 IN.)

WELD PEAK ENERGY REQUIREMENTS



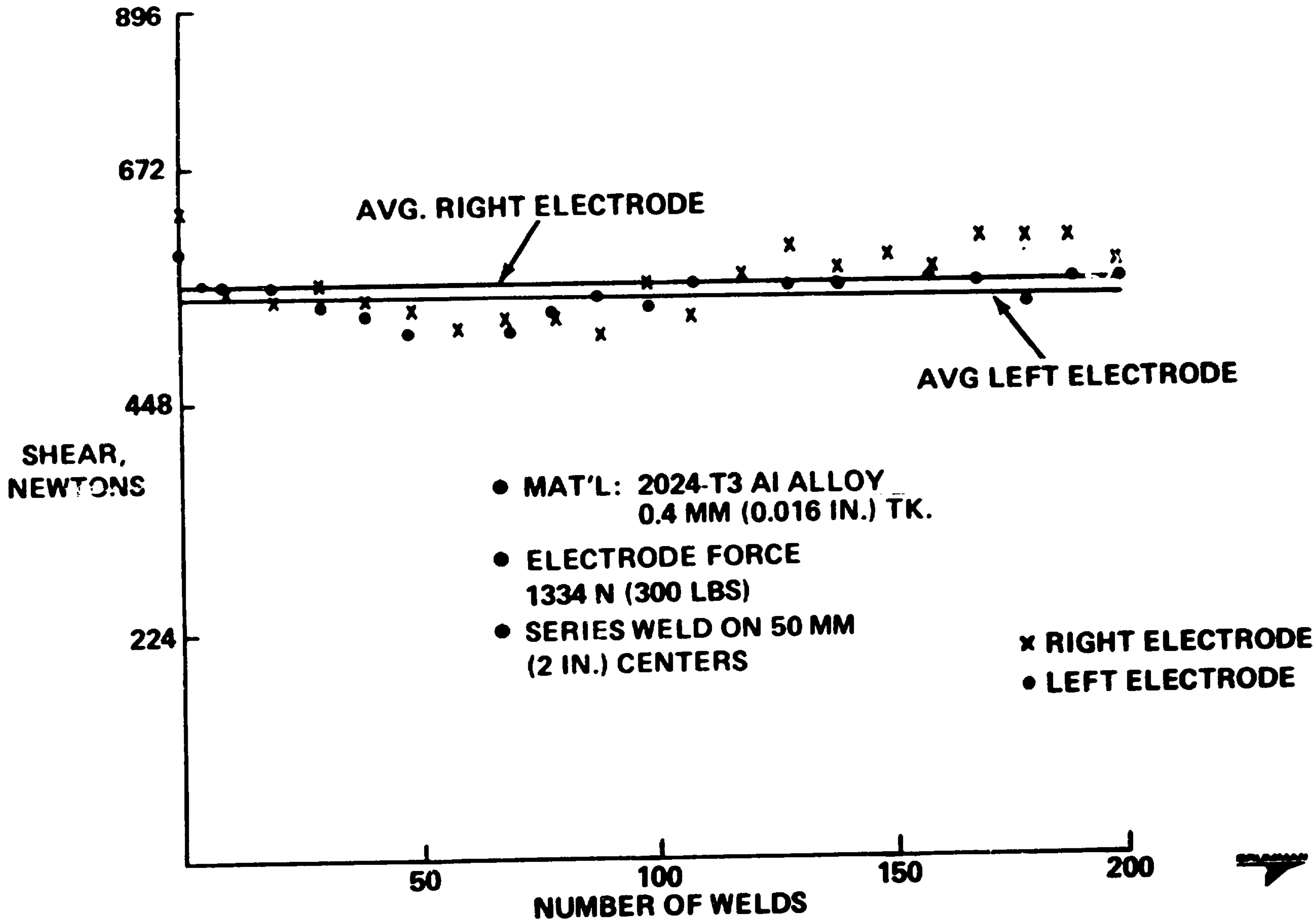
2420-209W
WM-35T

WELDING PROCESS SCHEMATIC



2420-162W
WM-36T

WELD ELECTRODE LIFE TEST



2420-182W
WM-55T

BRACE ATTACHMENT

SPACE FAB DEMO SYSTEM – WSB 1.2.2

STATUS

- I CDR SCHEDULED FOR 10/31
- WELD EQUIPMENT ON ORDER DUE END OF NOV.
- ELECTRODE LIFE TESTS COMPLETED
- SIX WELD JOINT TESTS COMPLETED

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

2420-164W
WM-38T

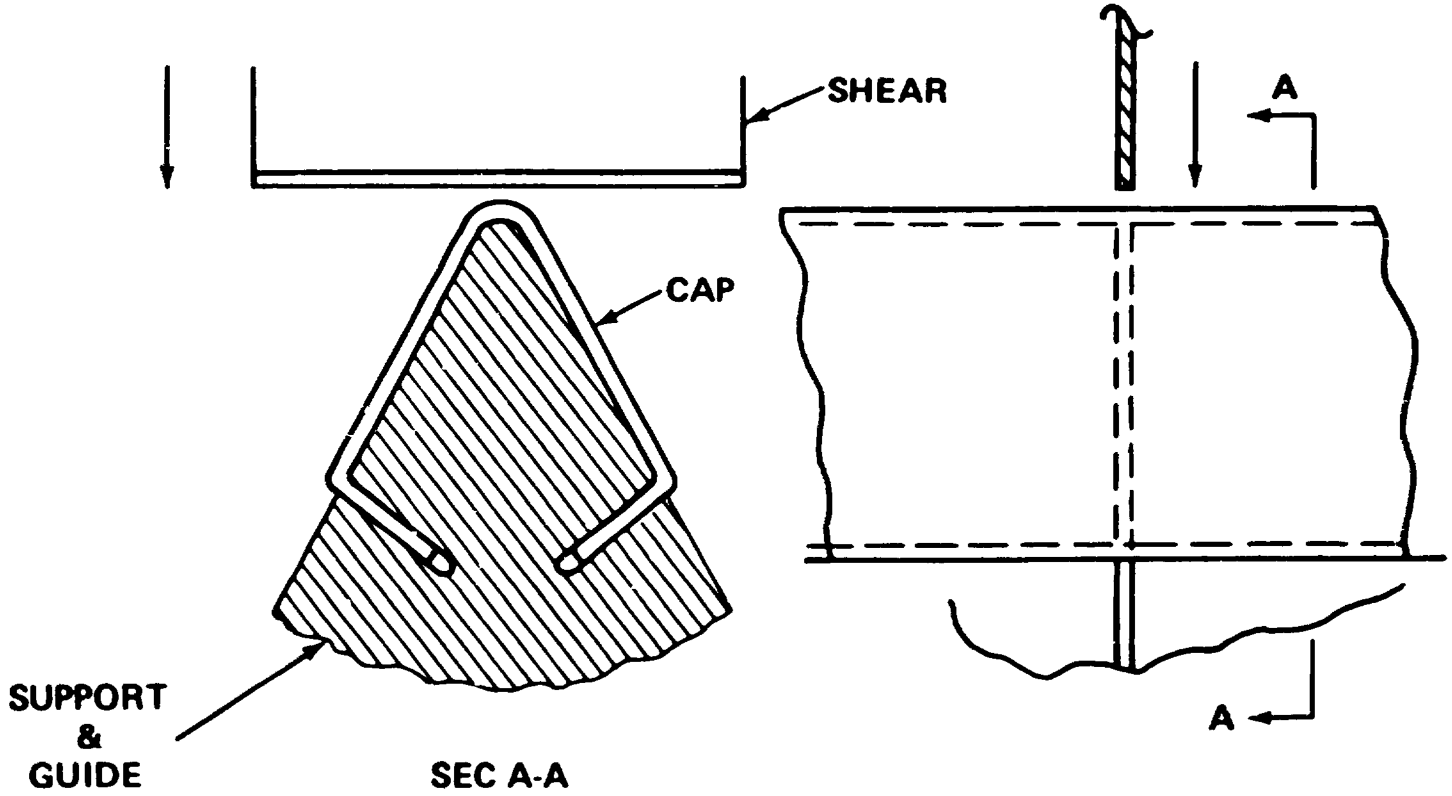
TRUSS CUT OFF MECHANISM

OBJECTIVE

PROVIDE CLEAN CUTOFF OF THREE CAP MEMBERS TO END TRUSS

2420-259
WM-70

BEAM CUT-OFF MECHANISM



2420-166W
WM-40AT

TRUSS CUTOFF MECHANISM

STATUS

- ICDR SCHEDULED FOR 10/31
- WORKING MOCKUP FABRICATED

2420-258
WM-69

FACILITY DESIGN

AREAS OF DISCUSSION

- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

CONTROLS

OBJECTIVES

- ASSURE SYNCHRONOUS ROLL FORMING OF CAP MEMBERS
- SEQUENCE MACHINE OPERATIONS

CONTROL SYSTEM DESIGN GUIDELINES

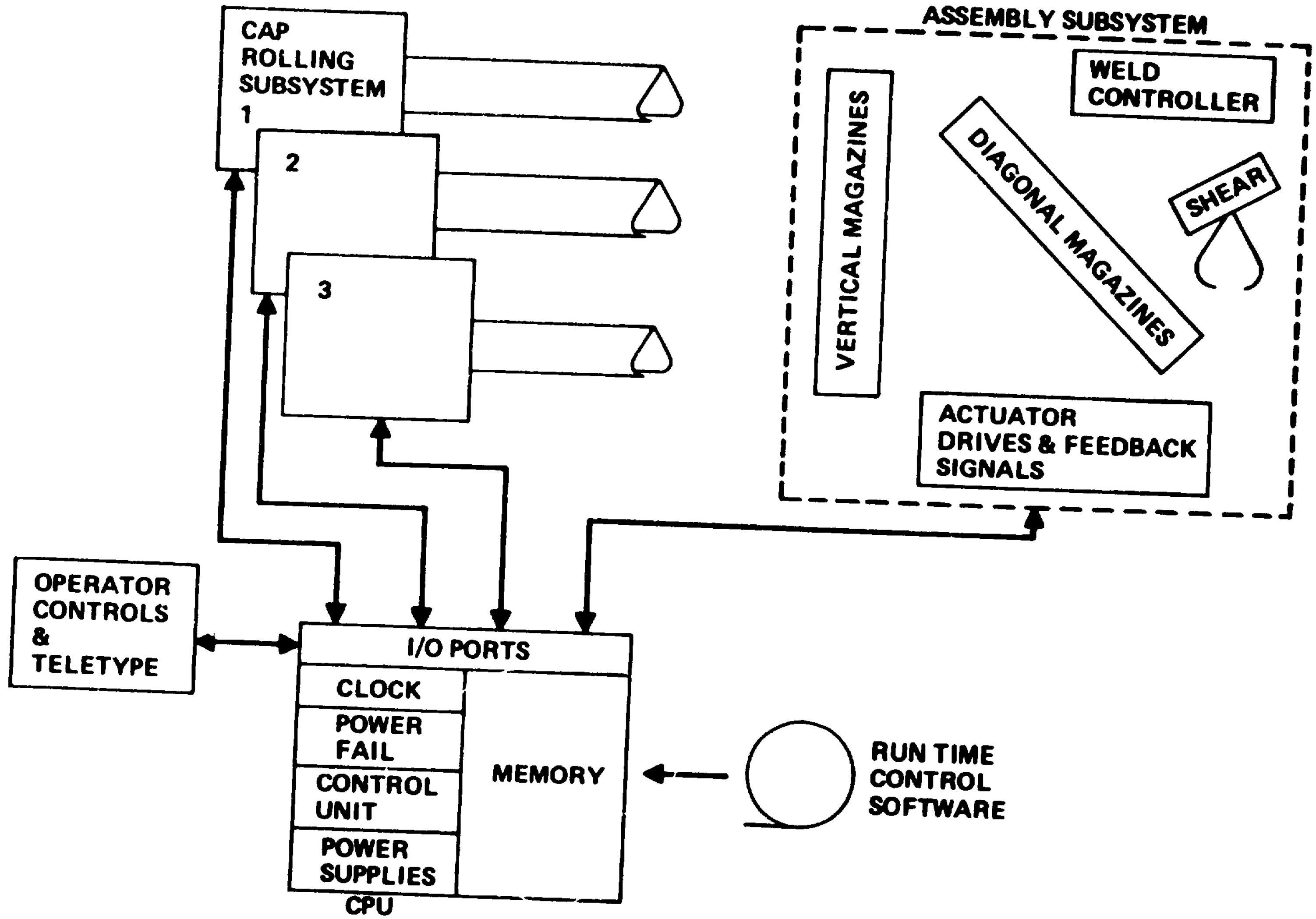
- MAXIMUM USE OF "OFF-THE-SHELF" COMMERCIAL COMPONENTS
- MINIMUM-COST SYSTEM
- INSURE BEAM STRAIGHTNESS
- HIGH RELIABILITY

PRINCIPAL COMPONENTS

- CENTRAL PROCESSOR
- CAP SYSTEM SERVO
- ASSEMBLY SUBSYSTEM
- OPERATOR CONTROL PANEL
- TELETYPE

2420-171W
WM-44T

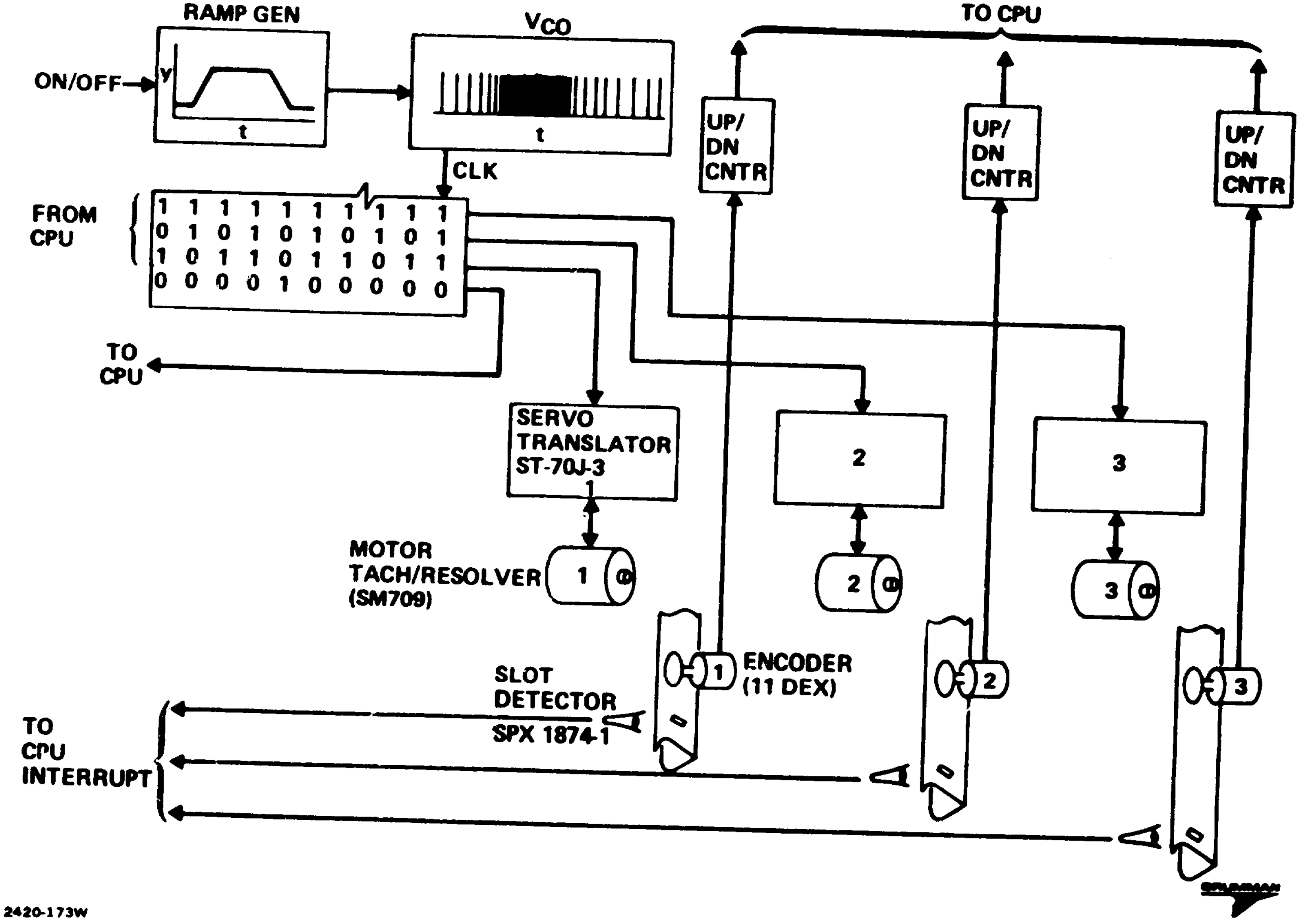
CONTROL SYSTEM OVERVIEW



DIGITAL EQUIPMENT CORP - PDP8/A

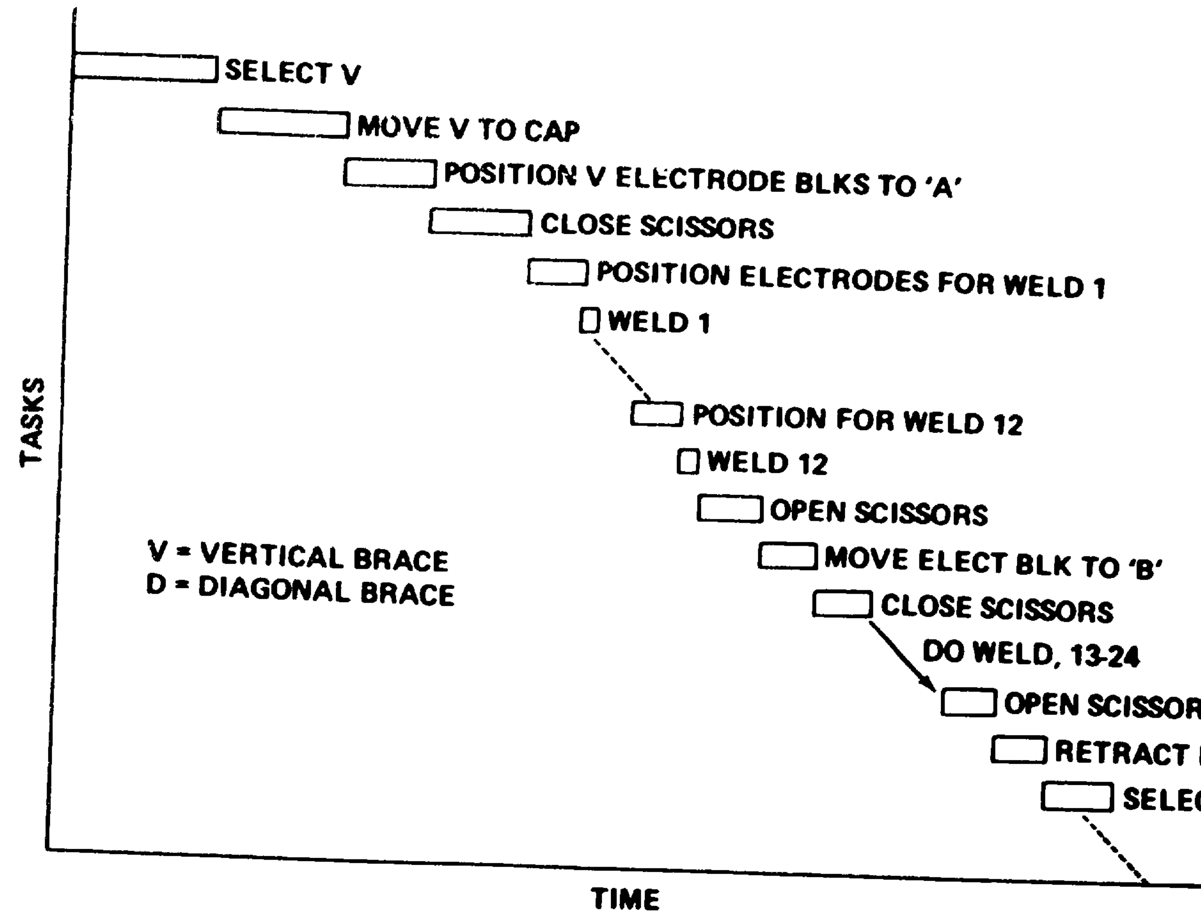
2420-172W
WM-45T

CAP POSITION CONTROLS



2420-173W
WM-46T

ASSEMBLY SUBSYSTEM SEQUENCE



2420-176W
WM-49T

PERFORMANCE SUMMARY

CRITERION	REQUIREMENTS	GOAL
BAY LENGTH (1.5 METERS)	± 0.8 MM	± 0.15 MM
BAY FABRICATION RATE	60 - 300 SEC	100 - 300 SEC
MAXIMUM CAP LENGTH VARIATION (40-METER BEAM)	± 20 MM	± 0.15 MM
ROLLING MILL DRIVE SPEED	1.5 - 3.0 M/MIN	1.5 - 3.3 M/MIN

CONTROLS

SPACE FAB DEMO SYSTEM – WSB 1.2.2

STATUS

- I CDR COMPLETED 9/29/77
- COMPUTER ORDERED, DUE AT GAC END OF NOV.
- DRIVE MOTORS FOR ROLL EQUIP REC'D
- ACTUATOR MOTORS TO BE ORDERED BY NOV. 1
- SOFTWARE FLOW CHARTS COMPLETED

2420-261
WM-72

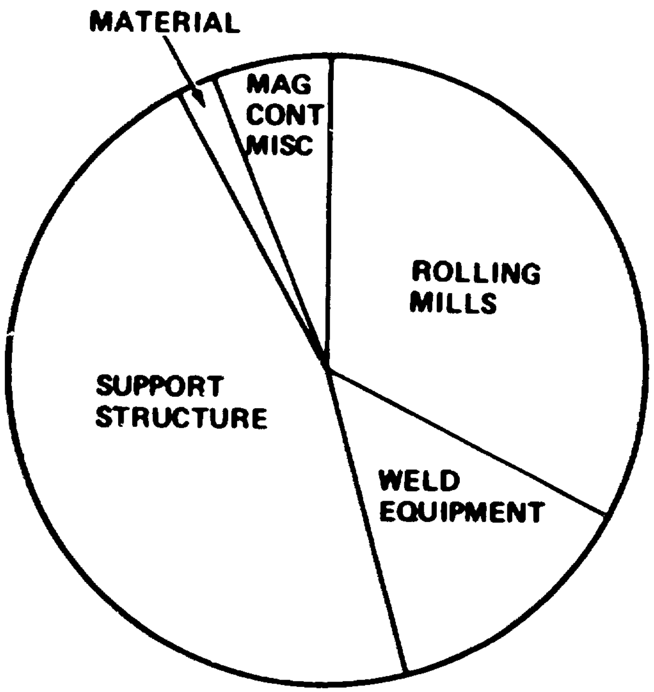
FACILITY DESIGN

AREAS OF DISCUSSION

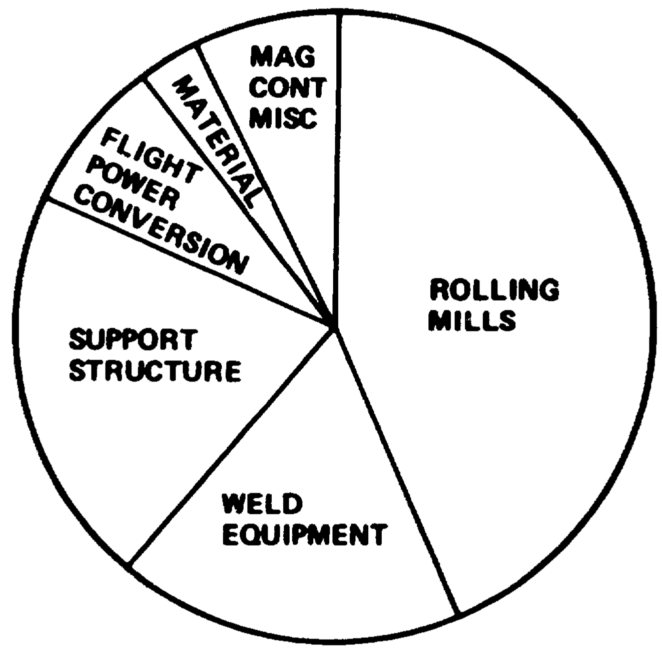
- OVERALL CONFIGURATION
- SUPPORT STRUCTURE
- ROLL-FORMING EQUIPMENT
- BRACE MEMBER MAGAZINE & DISPENSER
- WELD CLAMP MECHANISM
- BRACE ATTACHMENT
- TRUSS CUTOFF
- CONTROLS
- SUMMARY

2420-178W
WM-51T

PROJECTED WEIGHT DISTRIBUTION



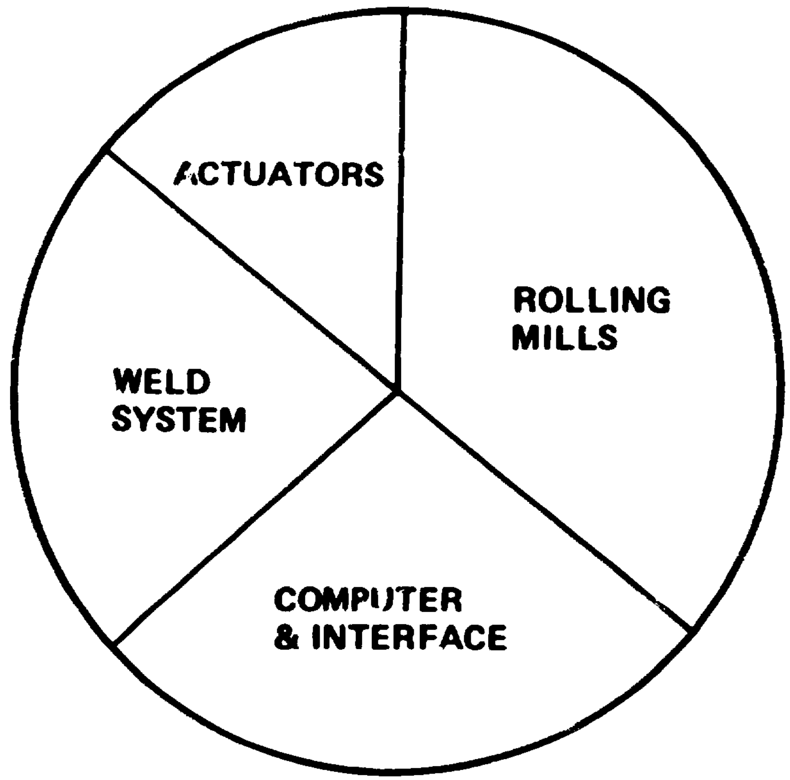
GROUND UNIT
9070 KG
(20,000 LBS)



FLIGHT TEST
7256 KG
(16,000 LBS)

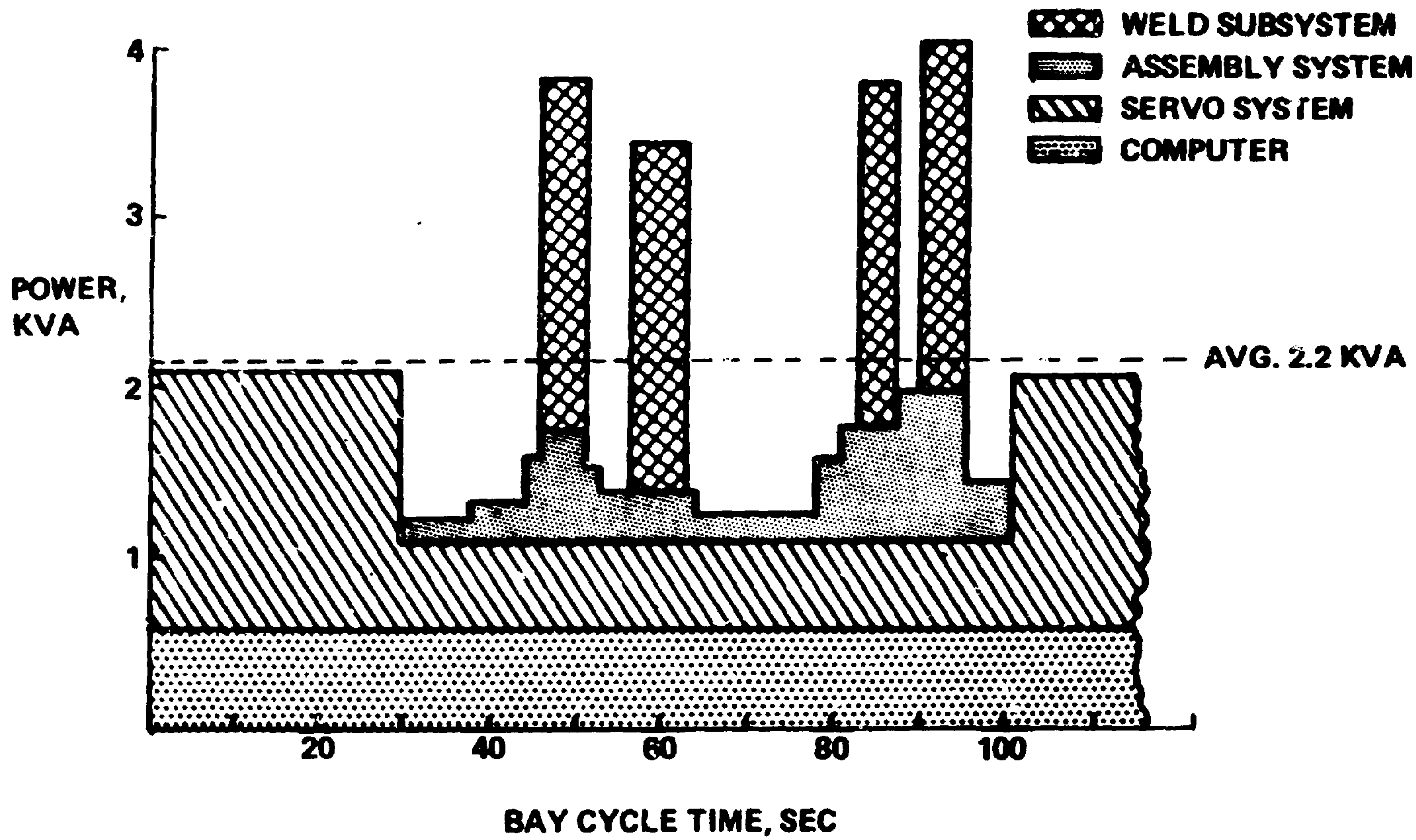
2420-301W
WM-85

PROJECTED AVG POWER DISTRIBUTION



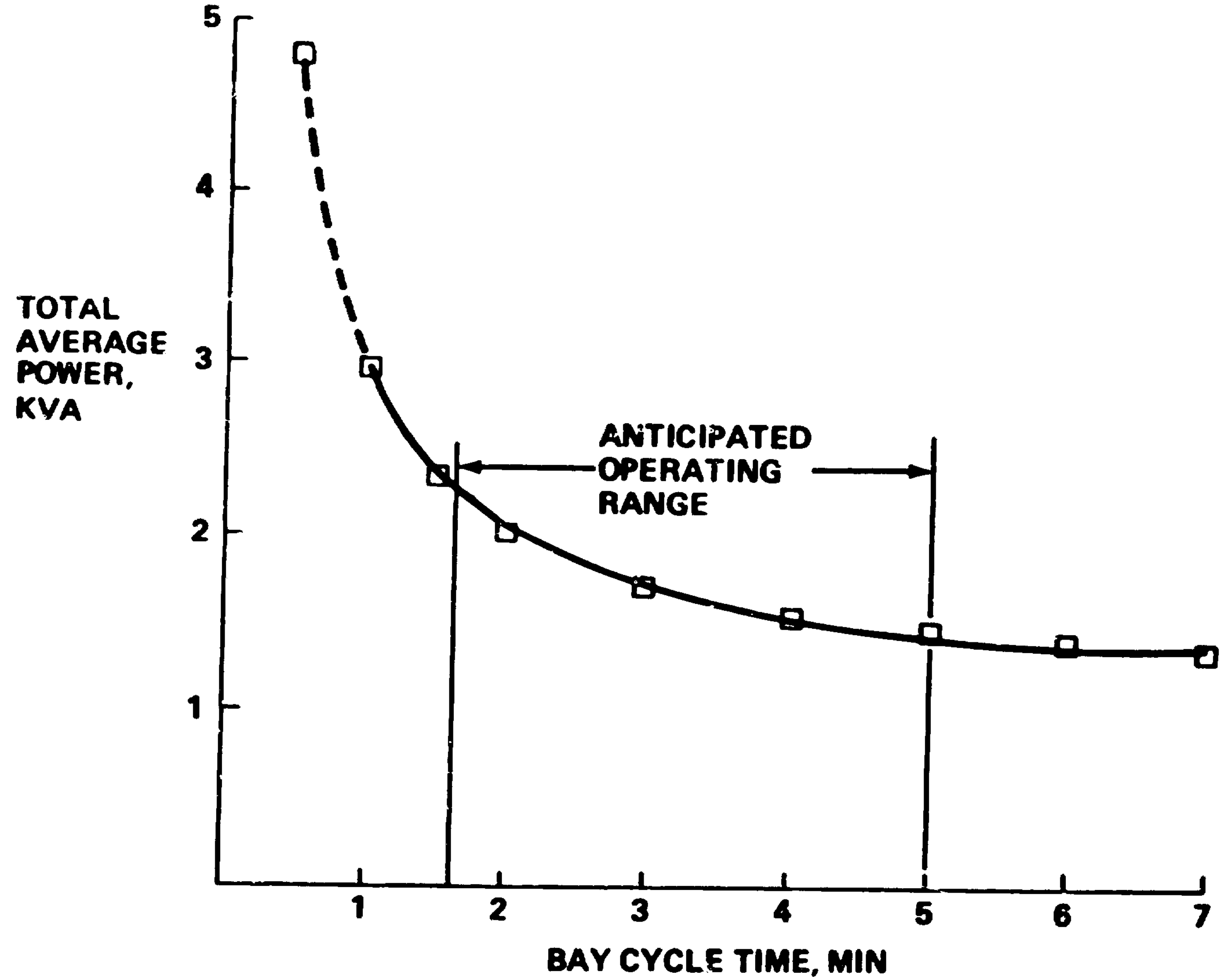
AVG. 2.2 KVA

TOTAL POWER REQUIREMENTS FOR GROUND DEMONSTRATION SYSTEM



2420-154W
WM-20T

AVERAGE POWER vs BAY FABRICATION TIME



2420-151W
WM-19T

SUMMARY-FACILITY DESIGN

	OVERALL CONFIGURATION	ROLL FORMING	BRACE DISPENSER	ATTACHMENT	TRUSS CUTOFF	CONTROLS	
WORKING MOCKUP	✓	–	✓	✓	✓	–	
PRELIMINARY TESTING PERFORMED	NA	✓	✓	✓	✓	✓	
PROVEN COMMERCIAL PROCESS EQUIPMENT	–	✓	–	✓	–	✓	
COMMERCIAL EXPERTISE UTILIZED	–	✓	–	✓	✓	✓	
PDR CONCURRENCE	✓	✓	✓	✓	✓	✓	
COMPATIBLE WITH SHUTTLE GEOMETRY	✓	✓	✓	✓	✓	✓	
COMPATIBLE WITH SHUTTLE POWER REQ'MT	–	✓	✓	✓	✓	✓	

2420-179W
WM-527

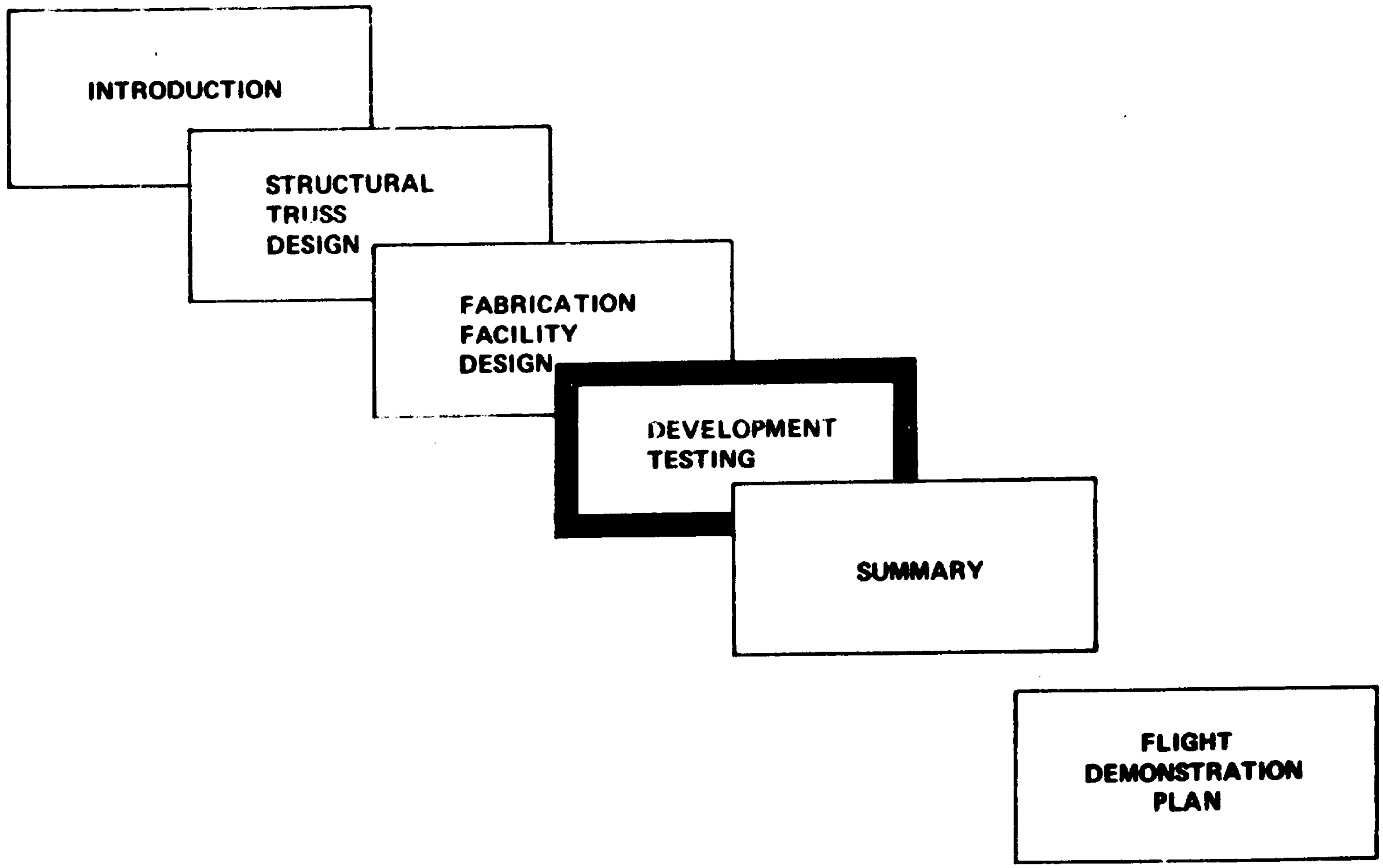
SPACE FAB DEMO SYSTEM – WSB 1.2.2

SUMMARY

	DWGS	MAJOR COMP	DETAIL FAB	ASSY
SUPPORT STRUCT	100%	NA	70%	NOV
ROLL FORM	100%	ACCEPT TEST	NA	OCT/ NOV
BRACE MAG	LAY-OUTS	NA	DEC	JAN
WELD CLAMP	80%	NA	OCT/ NOV	DEC
BRACE ATTACH	NA	DEC	NA	DEC
TRUSS CUTOFF	50%	NA	NOV	DEC
CONTROLS	90%	NOV	NOV/ DEC	JAN/ FEB

2420-262
WM-73

SPACE FAB DEMO SYSTEM – WSB 1.2.2



GRUMMAN

2420-236W
WM-81

ROLL FORMING

TASK	RESULTS	ACTION
ESTABLISH 2219-T62, 2024-T3 SPRING BACK	2219-T62 (10 DEG) 2024-T3 (2 DEG)	PRELIMINARY ROLL DESIGN
REDUCE ROLL STATIONS	STATION REQMTS 8 → 7	ESTABLISH 65-IN LENGTH
PRELIMINARY CONFIGURATION EVALUATION	• RIPPLED FLANGE • LONGITUDINAL BOW	MODIFY ENTRY AND TRANSITION ROLLS
CONFIGURATION REFINEMENT	• IMPROVED FLANGE • ELIMINATE BOW	REDESIGN TRANSITION ROLLS
FLANGE EVALUATION	• MINIMAL WAVE	• ADD CROWN TO FLANGE • PROCEED WITH FINAL DESIGN

2420-311
WM 54AT

BRACE ATTACHMENT

PRIMARY SYSTEM

- RESISTANCE SPOT-WELDING

ALTERNATES CONSIDERED

- ULTRASONICS
- HOLLOW INTEGRAL RIVET
- INTEGRAL RIVET
- STAPLING
- ELECTRON-BEAM WELDING
- ADHESIVE BONDING

SFDS COMPOSITE DEVELOPMENT STATUS

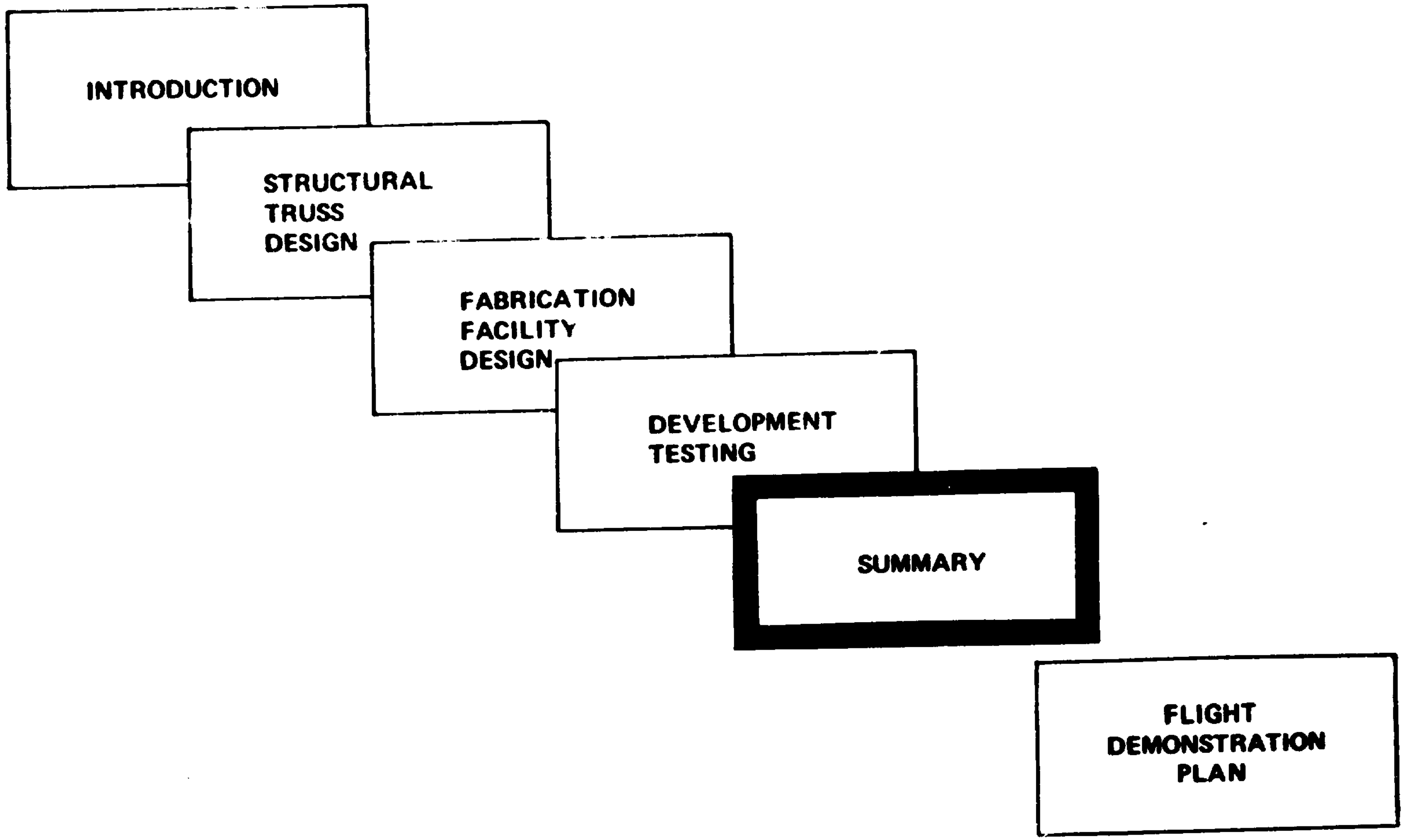
MATERIALS USED

- GRAPHITE/POLYSULFONE
- POLYETHER SULFONE
- GRAPHITE/POLYETHERSULFONE

ROLL FORMING PROCESS

- FOUR SET-UPS
  - MIXED RESULTS
- NEXT APPROACH

SPACE FAB DEMO SYSTEM



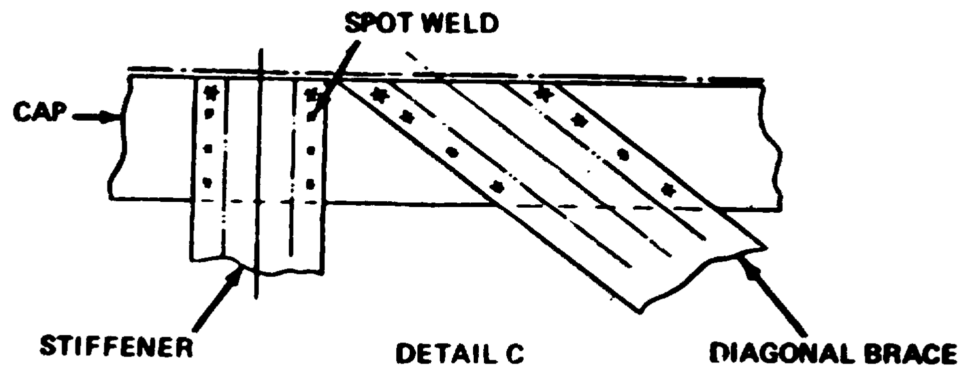
2420-233W
WM-78

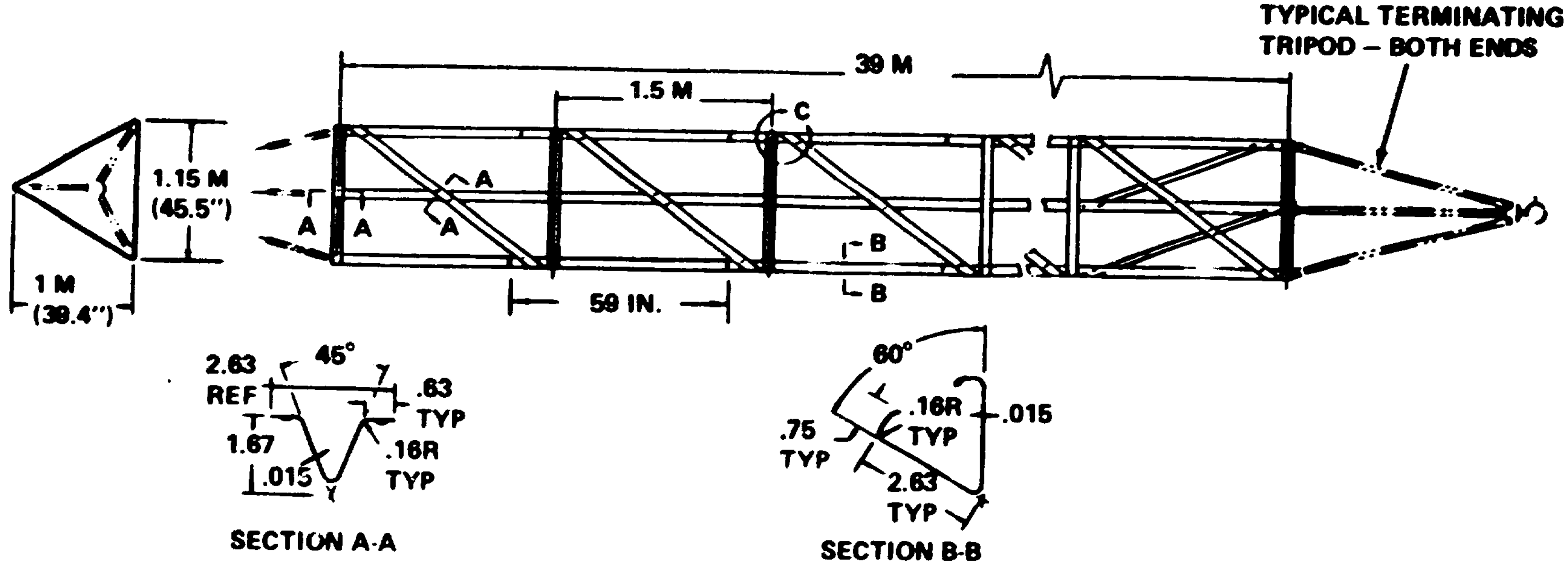
SUMMARY

- STRUCTURAL TRUSS DESIGN
- FABRICATION FACILITY DESIGN
- DEVELOPMENT TESTING
- ICDR TOMORROW
- NEXT PROJECT MILESTONE
- FLIGHT DEMONSTRATION PLAN

2420-184W
WM-57T

1-M BEAM DESIGN





2420-074W
AA-19

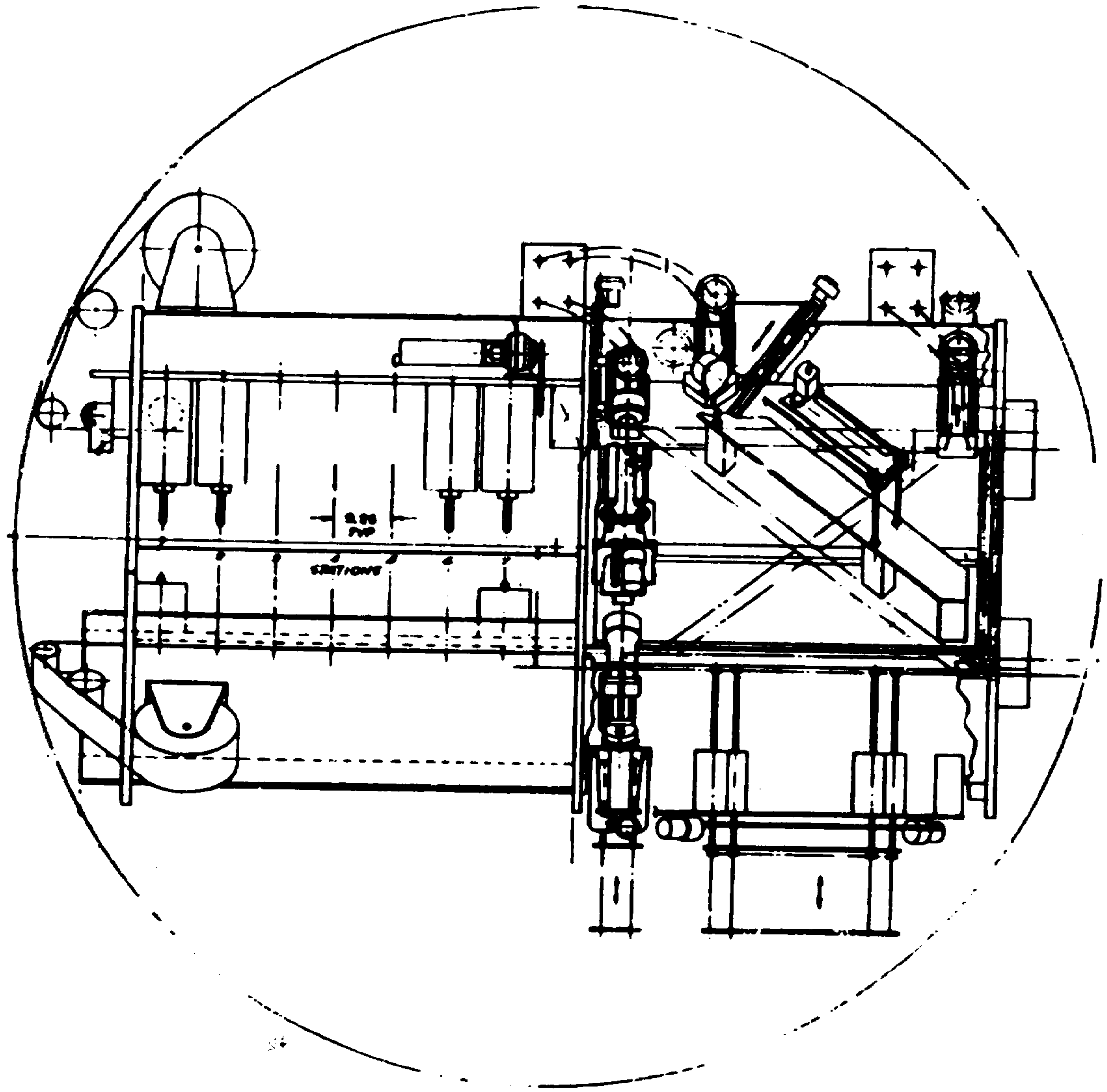
CONCLUSIONS

- DESIGN LOADS & TEMPERATURES EVALUATED FOR:
  I FABRICATION IN ORBITER PAYLOAD BAY
  II SSPS VEHICLE
- MATERIALS & PROCESSES SELECTED MEET REQUIREMENTS
  - 2024-T3; 2219-T6; 6061-T6
  - THERMAL COATINGS
  - ROLL FORMING
  - SPOT WELDING
- BEAM DESIGN HAS BEEN DEFINED & SATISFIED CRITICAL CONDITIONS
- FABRICATION ACCURACY REQUIREMENT FOR BEAM DEFINED FOR FABRICATION FACILITY

2420-295W
WM-79

SELECTED BEAM BUILDER

SPACE FAB DEMO SYSTEM – WBS 1.2.2



2420-199W
WM-18T

DESIGN REQUIREMENTS

- LOW COST
- COMPLY WITH SHUTTLE PAYLOAD CONSTRAINTS
- MAXIMUM USE OF COMMERCIAL "OFF-THE-SHELF" HARDWARE
- MAXIMUM USE OF EXISTING "STATE-OF-THE-ART" EXPERTISE
- COMPATIBLE WITH FUTURE FLIGHT TEST NEEDS
- FULLY AUTOMATED FABRICATION OF TRUSS

FACILITY DESIGN PLAN

- OBTAIN CONCURRENCE WITH MSFC ON DESIGN FOR ALL SUBSYSTEMS
- START FABRICATION AND PROCUREMENT OF DETAIL PARTS
- CONTINUE WITH CONSTRUCTION TO MEET EXISTING PROGRAM SCHEDULE REQUIREMENTS

PRINCIPAL SUBSYSTEMS

- SUPPORT
- ROLL FORMING
- MAGAZINE/DISPENSER
- CLAMP/ATTACHMENT
- CUTOFF
- CONTROLS

2420-149W
WM-16T

PERFORMANCE SUMMARY

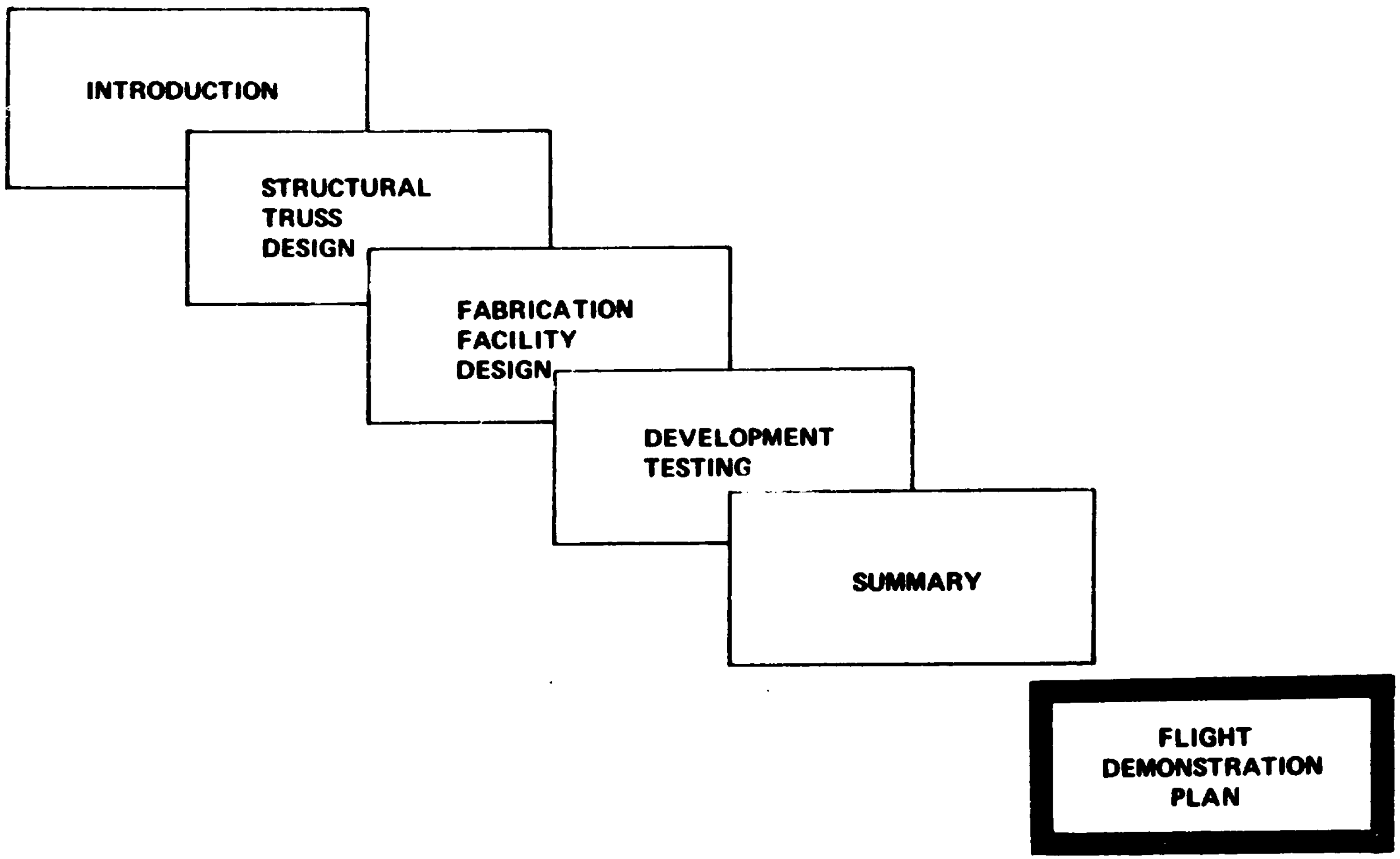
CRITERION	REQUIREMENTS	GOAL
BAY LENGTH (1.5 METERS)	± 0.8 MM	± 0.15 MM
BAY FABRICATION RATE	60 - 300 SEC	100 - 300 SEC
MAXIMUM CAP LENGTH VARIATION (40-METER BEAM)	± 20 MM	± 0.15 MM
ROLLING MILL DRIVE SPEED	1.5 - 3.0 M/MIN	1.5 - 3.3 M/MIN

ITEMS TO BE ADDRESSED

- ELECTRODE LIFE FOR WELDS IN VACUUM
- MECHANICAL ATTACHMENT
- WELD ELECTRODE AUTO CLEANING
- AUTO THREADING OF RESUPPLY REEL
- MODIFICATION FOR SPACE FLIGHT USE

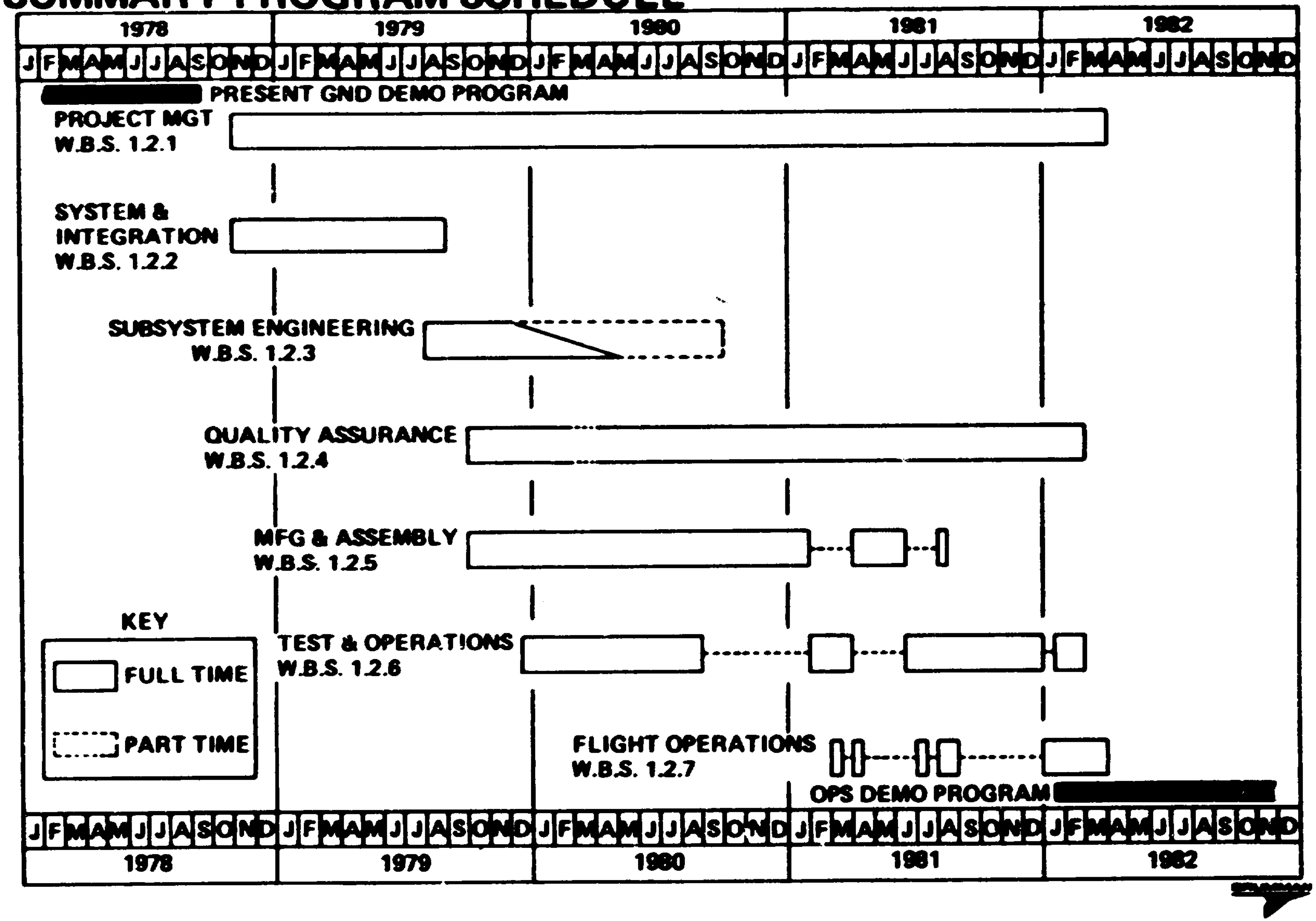
2420-263
WM-74

SPACE FAB DEMO SYSTEM – WBS 1.5



2420-232W
WM-76

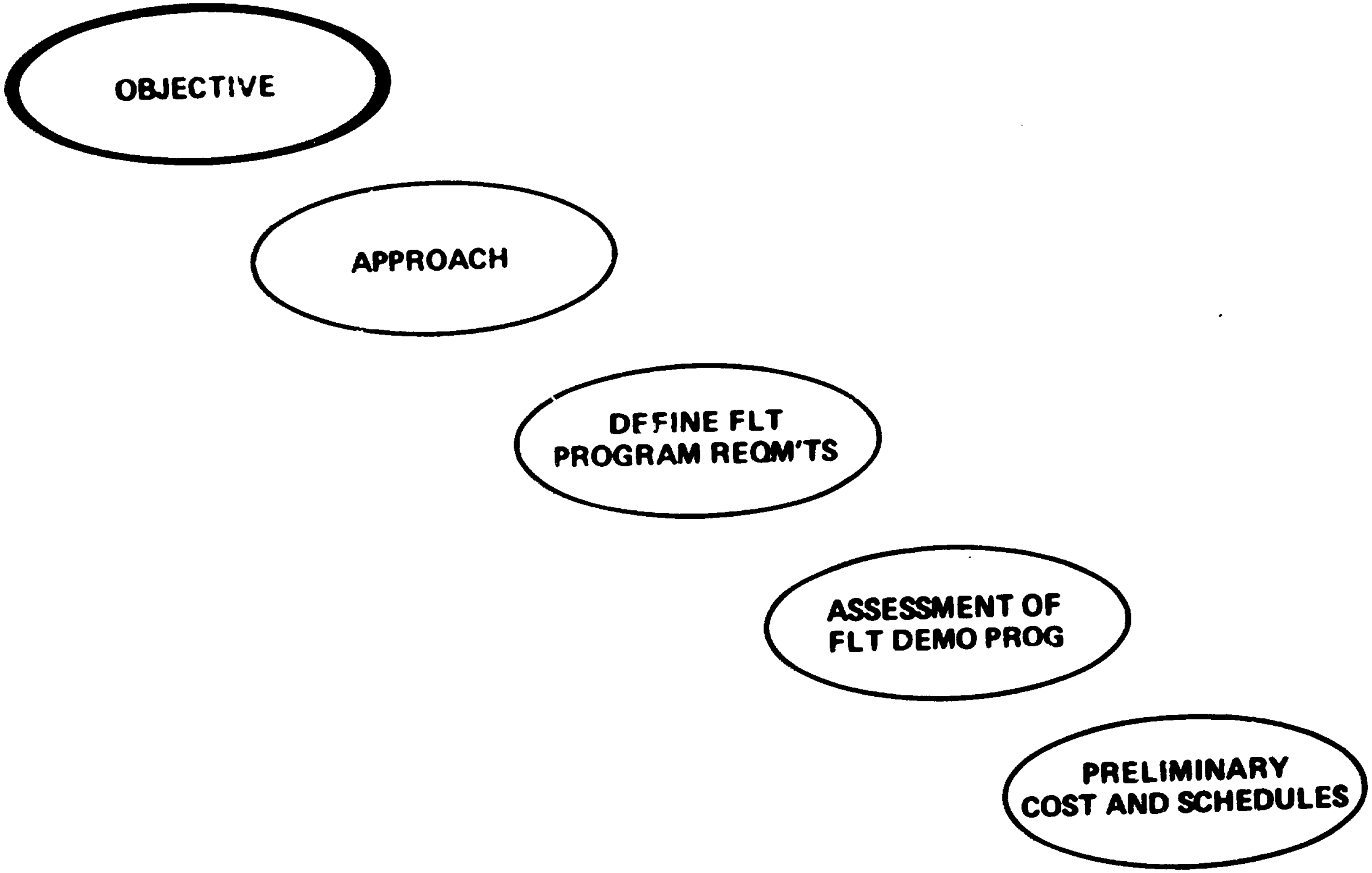
SUMMARY PROGRAM SCHEDULE



2420-096W
HM-19

SPACE FAB DEMO SYSTEM – WBS 1.5.1

PRELIMINARY SFDS FLIGHT DEMONSTRATION PROGRAM PLAN



2420-078W
HM-1

SPACE FAB DEMO SYSTEM — WBS 1.5.1

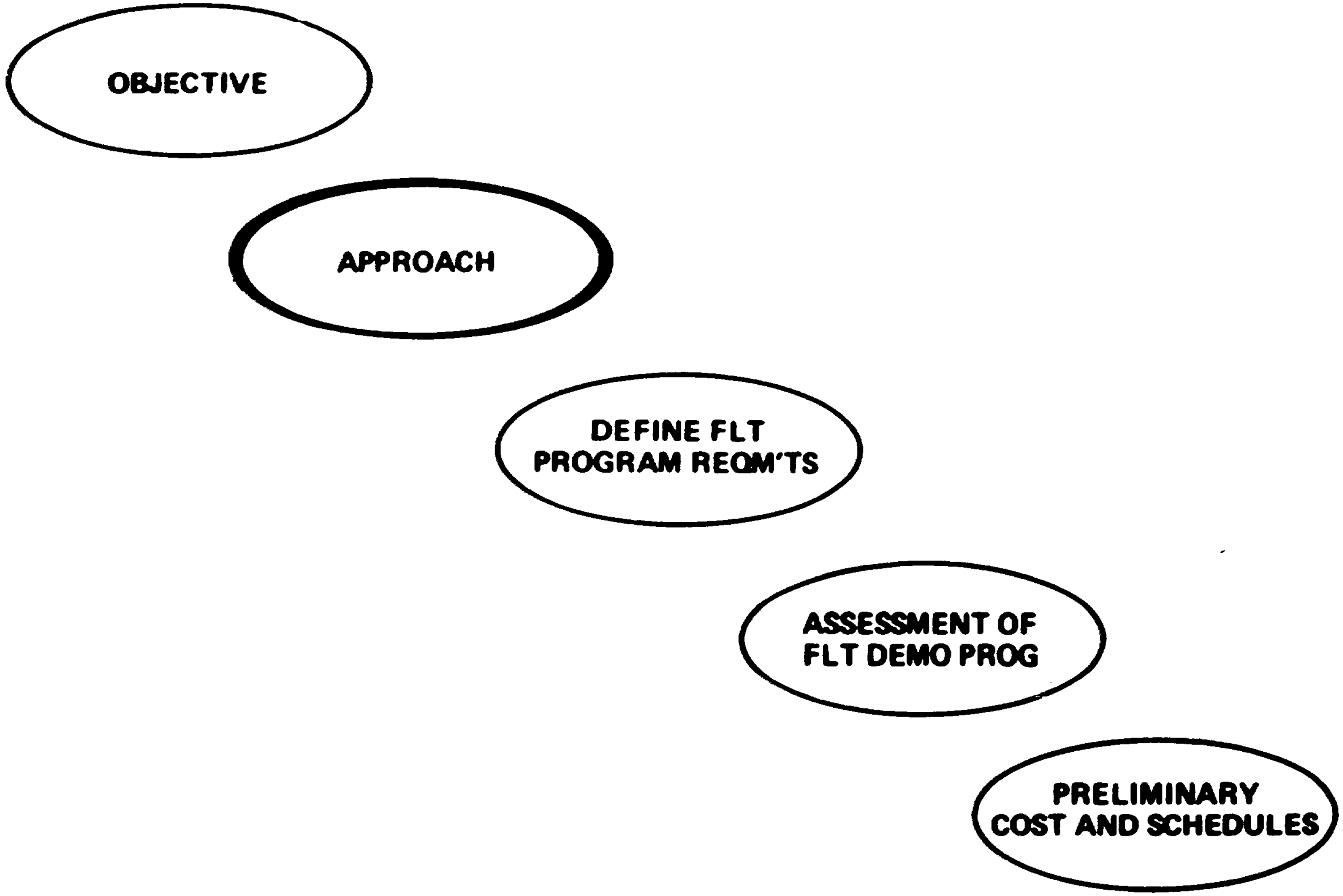
FLIGHT DEMONSTRATION PROGRAM PLAN OBJECTIVE

DEVELOP LOW COST FLIGHT DEMONSTRATION PROGRAM WHICH DEMONSTRATES THE SPACE FABRICATION DEMONSTRATION SYSTEM (SFDS) CAPABILITY AND PROVIDES ORBITAL OPERATIONAL BASE LINE DATA

2420-083W
HM-6

SPACE FAB DEMO SYSTEM – WBS 1.5.1

PRELIMINARY SFDS FLIGHT DEMONSTRATION PROGRAM PLAN



2420-079W
HM-2

APPROACH FOR FLIGHT DEMONSTRATION PROGRAM DEFINITION

- ESTABLISH GUIDELINES AND ASSUMPTIONS CONSISTENT WITH OBJECTIVE
- ESTABLISH DESIGN, QUALIFICATION AND FLIGHT DEMONSTRATION REQUIREMENTS
- ASSESS ABILITY OF SFDS GROUND DEMO HARDWARE TO MEET THESE REQUIREMENTS
- DEFINE THE TASKS REQUIRED TO IMPLEMENT FLIGHT DEMO PROGRAM
- DEVELOP TASK LOGIC AND TIMELINES FOR FLIGHT DEMO PROGRAM
- DEVELOP PRELIMINARY COST ESTIMATES COMENSURATE WITH TASKS AND SCHEDULES

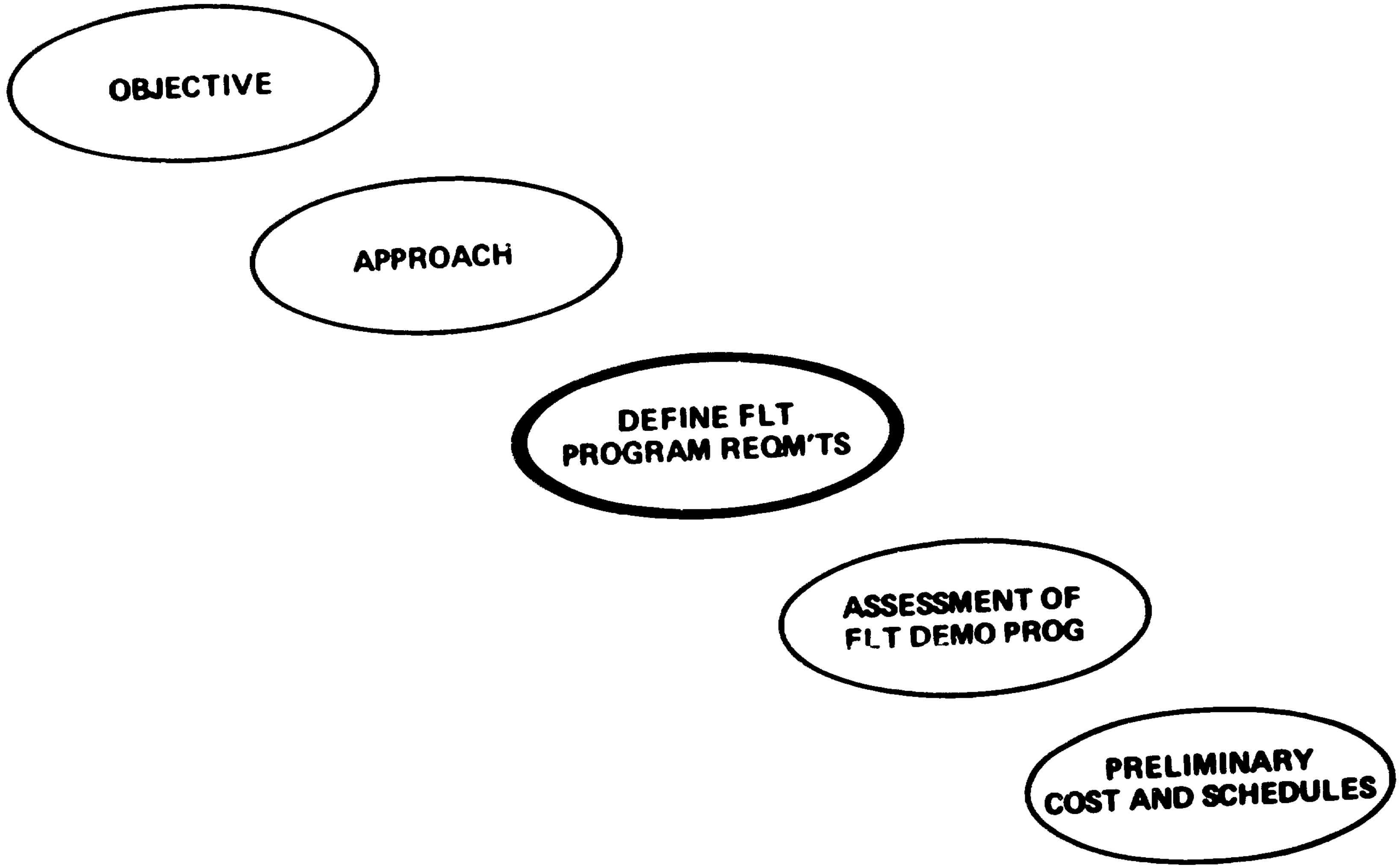
2420-084W
HM-7

SFDS FLIGHT DEMO PROGRAM GUIDELINES AND ASSUMPTIONS

- SFDS FLIGHT ARTICLE MUST OPERATE FROM THE SHUTTLE IN ORBIT
- SFDS CONTAMINATION OF PAYLOAD BAY SHALL BE ELIMINATED OR CONTAINED
- UTILIZE THE SFDS GROUND ARTICLE HARDWARE TO GREATEST EXTENT POSSIBLE AND MODIFY AS REQUIRED
- UTILIZE THE SFDS FLIGHT ARTICLE FOR GROUND QUALIFICATION AND ACCEPTANCE
- UTILIZE POST FLIGHT GROUND TESTS TO VERIFY INTEGRITY OF THE STRUCTURE PRODUCED BY SFDS
- RESERVE PAYLOAD ACCOMMODATIONS 16,000 LB
- FLIGHT TEST ORBITAL PARAMETERS WILL BE SELECTED ON THE BASIS OF GROUND ANALYSIS AND THERMAL VACUUM TESTS

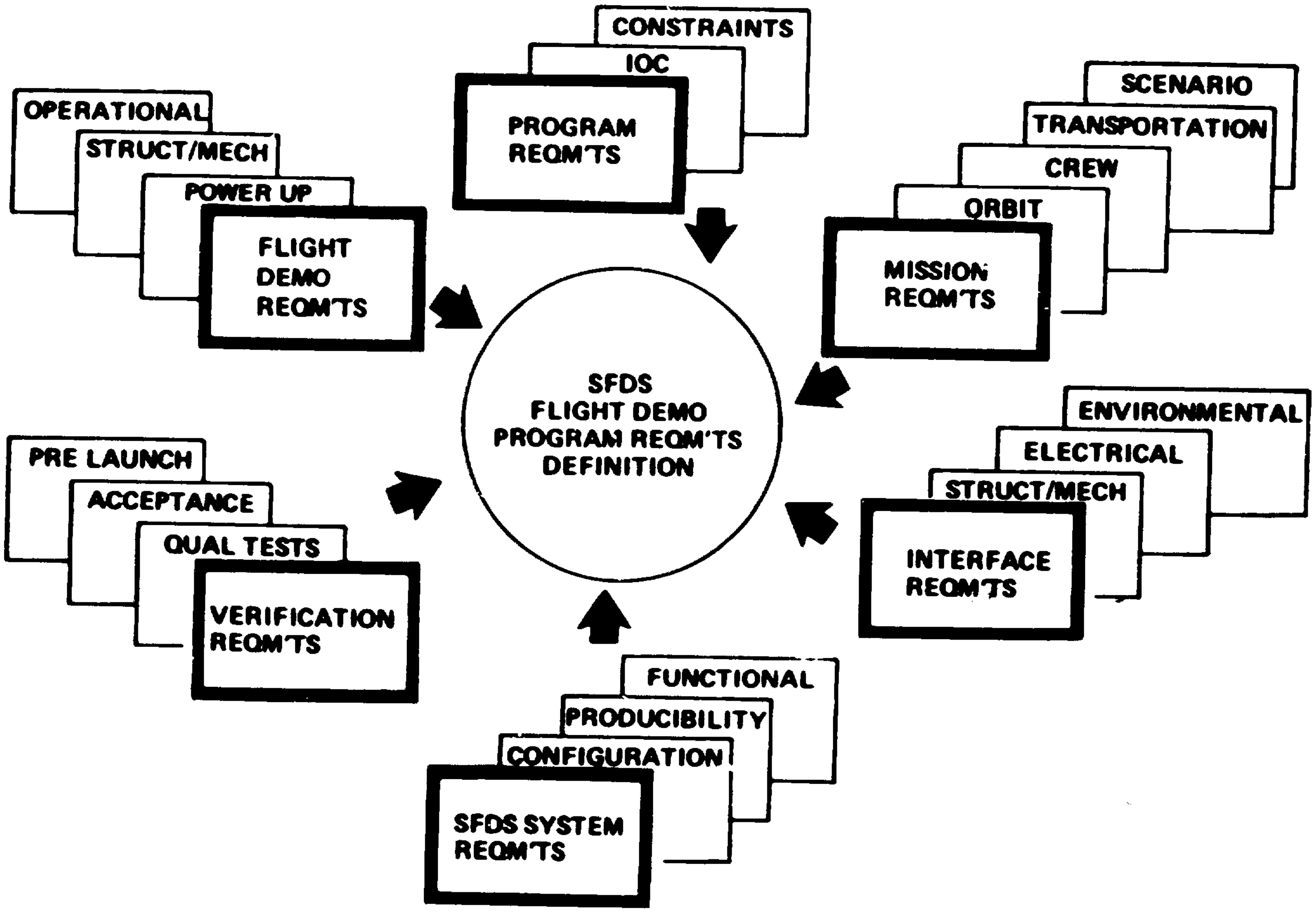
SPACE FAB DEMO SYSTEM – WBS 1.5.1

PRELIMINARY SFDS FLIGHT DEMONSTRATION PROGRAM PLAN



2420-080W
HM-3

SFDS FLIGHT PROGRAM DEVELOPMENT



2420-086W
HM-6

SFDS SYSTEM REQUIREMENTS

- BEAM PRODUCED
  - 1-M BEAM (3 CAPS WITH 90° BATTENS AND 3 40.87° DIAGONALS PER BAY)
  - STRENGTH MAX LOAD 5610 N COMPRESSION
  - MATERIAL 2024-T3, 2219-T6, 6061-T6
  - BEAM LIFE/FATIGUE – TBD
- SFDS
  - FORMING PROCESSING – ROLL FORMING FOR ALL ELEMENTS
  - ATTACHMENT PROCESS – ALL JOINTS SHALL BE WELDED
  - SYSTEM AUTOMATION – ROLL FORMING, MAGAZINE FEED, SPOT-WELDING, TRUSS CUTOFF, STATUS SENSING, ACCURACY CONTROL
  - MAN/MACHINE INTERFACE – REMOTE START/STOP, CAUTION AND WARNING, OVERRIDE MONITORING AND CONTROL
  - POWER AND HEAT REQUIREMENTS – TBD
- PRODUCIBILITY
  - RATE – 1 TO 5 FT/MIN
  - STRAIGHTNESS – 0.5% L
  - CAP CASSETTE CAPACITY 168M, MAGAZINE CAPACITY – 109 PRE-FORMED BATTENS OR BRACES

2420-087W
HM-10

SFDS VERIFICATION REQUIREMENTS

- QUAL TESTS
  - VERIFY CRITICAL COMPONENTS @ 6 DB ABOVE LAUNCH VIBRATION LEVELS AND SUBSYSTEMS/COMPLETE SFDS @ 3 DB ABOVE LAUNCH LEVEL
  - VERIFY SFDS COMPATABILITY WITH ACOUSTIC VIBRATION @ 3 DB ABOVE LAUNCH LEVELS
  - CONDUCT THERMAL VACUUM TESTS OF COMPLETE SFDS
  - FUNCTIONAL TESTS DURING QUAL PROGRAM WILL INCLUDE FABRICATION OF BEAM SECTIONS
- ACCEPTANCE TESTS
  - INTEGRATED WITH SYSTEM LEVEL QUAL TESTS
  - INCLUDE VERIFICATION OF JOINTS
- LAUNCH SITE TESTS
  - VERIFY OPERATION OF SFDS
  - DEMONSTRATE COMPATIBILITY WITH CARGO INTEGRATION TEST EQUIPMENT (CITE)
  - PASSIVE STATUS CHECK @ PAD

2420-088W
HM-11

SFDS QUALIFICATION TEST REQUIREMENTS

QUALIFICATION TEST REQUIREMENT \ ASSEMBLY LEVEL	COMPONENT	SUBSYSTEM	SFDS
(1) VERIFY MOTOR CHARACTERISTICS			
(A) DYNAMIC TORQUE	X		
(B) STALL TORQUE	X		
(C) START-UP TORQUE	X		
(D) POWER UTILIZATION	X		
(E) BRAKING	X		
(2) VERIFY COMPATIBILITY OF MOTOR WITH SPACE ENVIRONMENT			
(A) RANDOM VIBRATION	X		
(B) ACOUSTIC LAUNCH VIBRATION			X
(C) THERMAL VACUUM	X		X
(3) VERIFY MOTOR EMC WITHIN SHUTTLE	X		X
(4) VERIFY COMPATIBILITY OF ROLLER FORMING ASSEMBLIES WITH LAUNCH VIBRATION			
(A) 6 db ABOVE LAUNCH	X		
(B) 3 db ABOVE LAUNCH		X	X
(5) VERIFY COMPATIBILITY OF CROSS BRACE MAGAZINE/TRANSFER ASSEMBLIES WITH LAUNCH VIBRATION			
(A) 6 db ABOVE LAUNCH	X		
(B) 3 db ABOVE LAUNCH		X	X
(6) VERIFY COMPATIBILITY OF CROSS BRACE WELD/CLAMP ASSEMBLIES WITH LAUNCH VIBRATION			
(A) 6 db ABOVE LAUNCH	X		
[illegible] LAUNCH		X	
[illegible] ...OTINE ASSEMBLIES [illegible]			

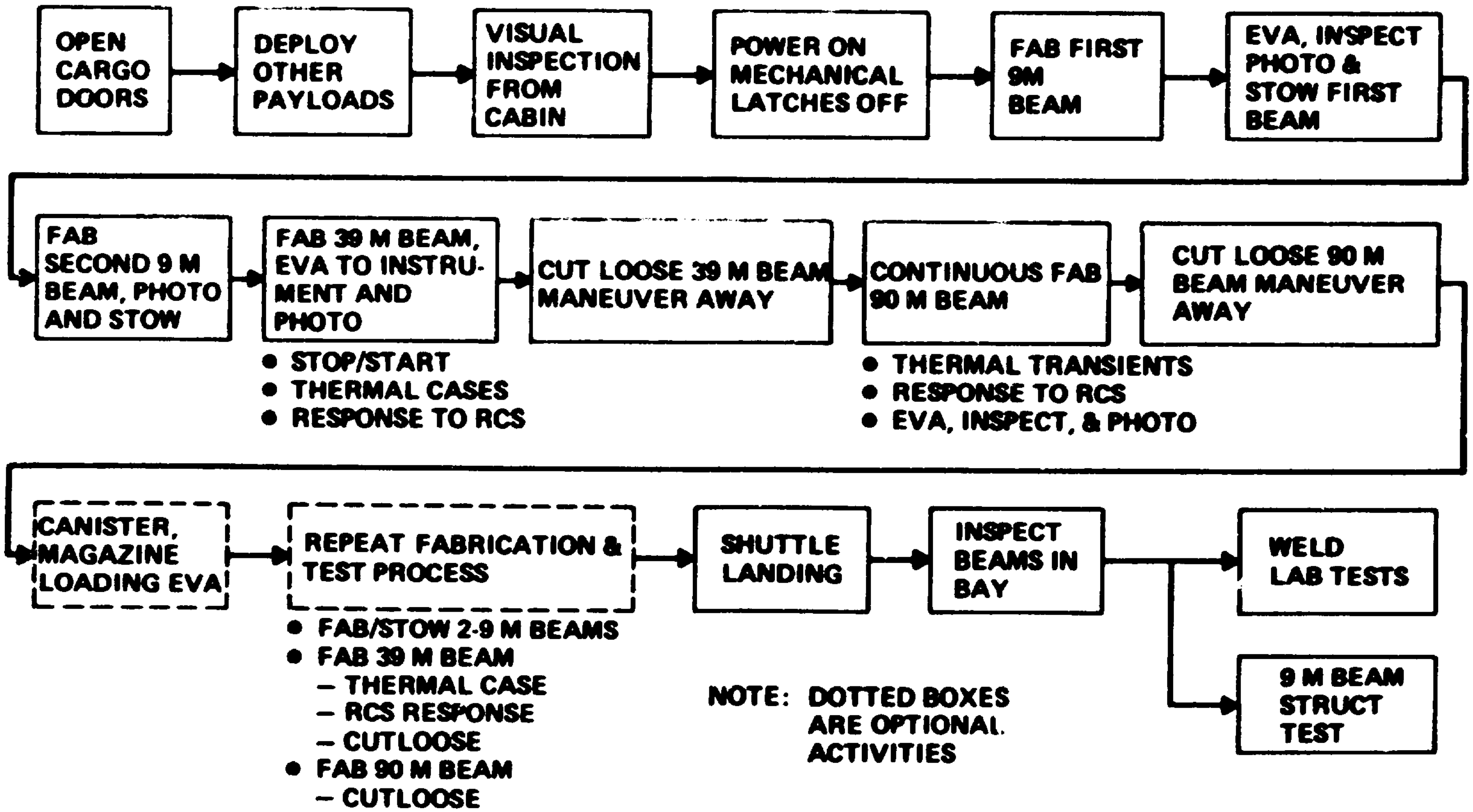
2420-091W
HM-14

SORTIE MISSION TEST REQUIREMENTS

SORTIE MISSION TEST REQUIREMENTS / LOCATION		IN-ORBIT	POST-FLT	
			OPF	SPEC LAB
(1)	VERIFY PROPER ACTIVATION AND POWER-UP	X		
(2)	VERIFY RELEASE OF MECHANICAL CONSTRAINTS	X		
(3)	VERIFY SYSTEM START-UP			
	(A) AFTER COLD CASE SOAK	X		
	(B) AFTER HOT CASE SOAK	X		
	(C) OBLIQUE SUNLIGHT	X		
(4)	VERIFY CONTINUOUS BEAM PRODUCTION			
	(A) FULL SUNLIGHT OPERATION	X		
	(B) FULL ECLIPSE OPERATION	X		
	(C) OBLIQUE SUNLIGHT	X		
	(D) ECLIPSE/SUNLIGHT TRANSITIONS	X		
(5)	DEMONSTRATE CREW PROCEDURES	X		
(6)	VISUAL/PHOTOGRAPHIC INSPECTION OF 9-M BEAMS	X	X	
(7)	VERIFY PROPER WELDS			X
(8)	VERIFY STRUCTURAL INTEGRITY OF 9-M BEAMS			X
(9)	VERIFY DIMENSIONAL ACCURACY OF BEAMS			X
(10)	VERIFY PROPER GUILLOTINE OPERATION	X		
(11)	DEMONSTRATE PRODUCTION OF 30-M BEAM	X		
(12)	DETERMINE EFFECTS OF DYNAMIC RESPONSE TO RCS STATION KEEPING/ATTITUDE HOLD JET FIRINGS	X		
(13)	DEMONSTRATE PRODUCTION OF 90-M BEAM	X		
(14)	VERIFY RELOADING OF CONSUMABLES (OPTIONAL-TBD)			
	(A) CANISTERS	X		
	(B) MAGAZINES	X		

2420-092W
HM-15

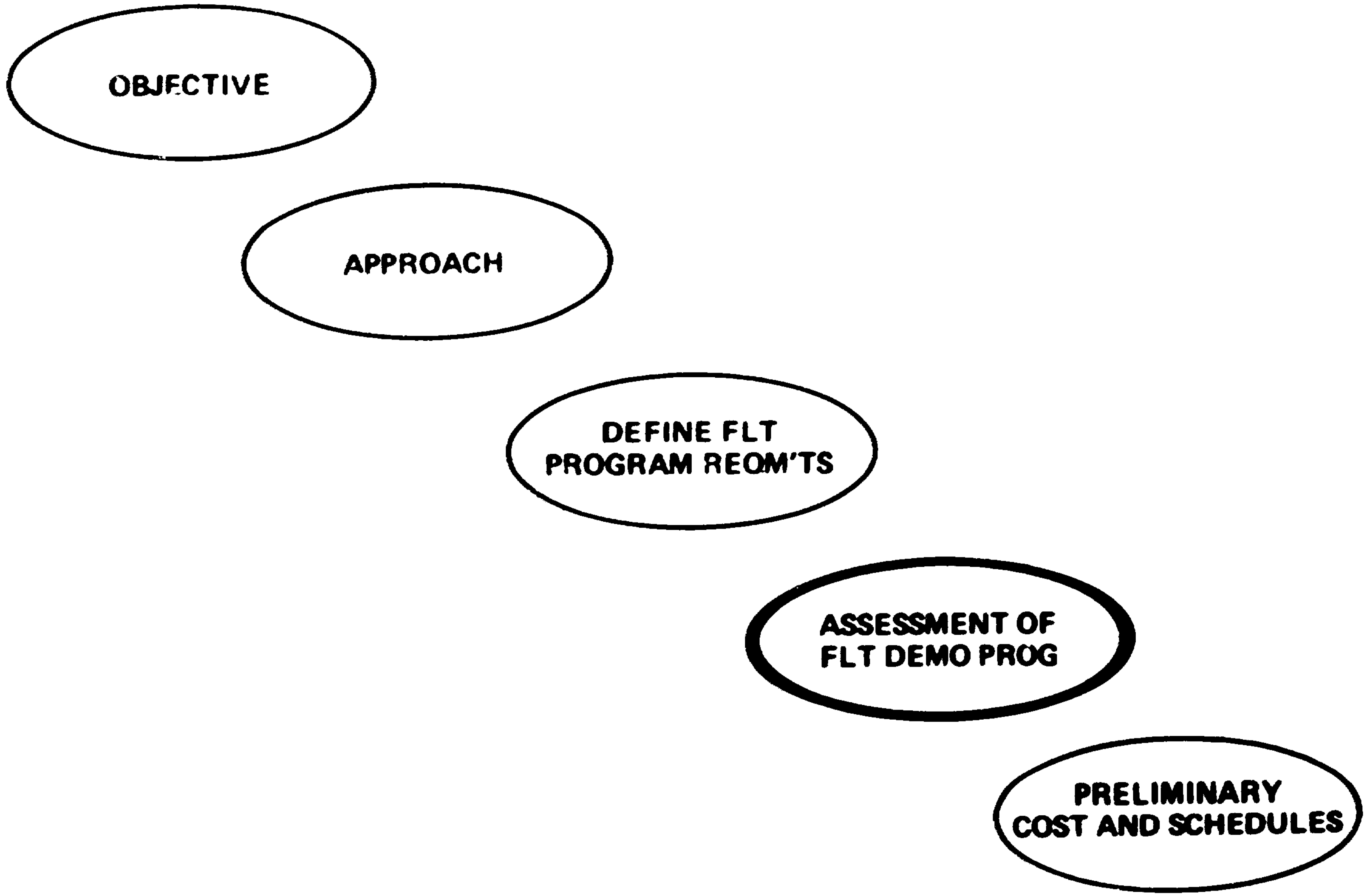
SORTIE MISSION FUNCTIONAL FLOW



NOTE: DOTTED BOXES ARE OPTIONAL ACTIVITIES

2420-093W
HM-16

SPACE FAB DEMO SYSTEM — WBS 1.5.1
PRELIMINARY SFDS FLIGHT DEMONSTRATION PROGRAM PLAN



2420-081W
HM-4

SFDS GND DEMO HARDWARE READILY CONVERTIBLE FOR FLIGHT DEMONSTRATION

SUBSYSTEM	MODS CURRENTLY PLANNED	REMARKS
ROLLING MILL	WEIGHT REDUCTION MODS, LOCKING MECHANISMS, FLIGHT INSTRUMENTATION	ADDITIONAL MODS BASED ON GROUND DEMO TEST RESULTS ↓
MAGAZINE	LOCKING MECHANISMS, FLIGHT INSTRUMENTATION	
WELDING	LOCKING MECHANISMS, FLIGHT INSTRUMENTATION	
GUILLOTINE	LOCKING MECHANISMS, FLIGHT INSTRUMENTATION	
SENSORS/CONTROLS	SPACE CUAL UNITS	

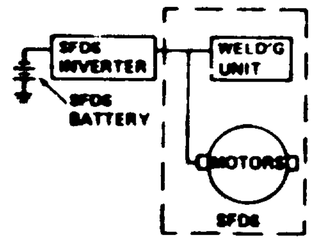
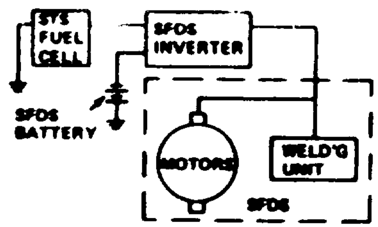
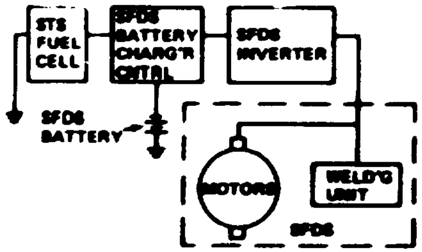
2420-089W
HM-12

FLIGHT DEMONSTRATION PROGRAM CONSIDERATIONS

ITEM	CONSIDERATIONS
• GND TESTS	– COMPONENT QUAL @ 6 DB ABOVE MISSION LEVEL – SYSTEM QUAL @ 3 DB ABOVE MISSION LEVEL – ORBITER INTEGRATION @ MSFC
• THERMAL	– SFDS MAINTAINED @ 21°C ±10°C – COOLING SYSTEM COUPLED TO ORBITER – BLANKETS REQUIRED FOR COLD SOAK
• POWER CONDITIONING	– DELIVER 1.2 KW @ 220V, 60 HZ, SINGLE PHASE – ISOLATE ORBITER FROM 63 KVA .017 SEC SPIKES – MINIMIZE EMI
• REPACKAGE MONITOR & CONTROL SUBSYSTEM	– MINIATURIZED COMPUTER – INCORPORATE CAUTION AND WARNING DISPLAY – CONTROLS AND DISPLAYS INSTALLED @ PAYLOADS SPECIALIST STATION

2420-090W
HM-13

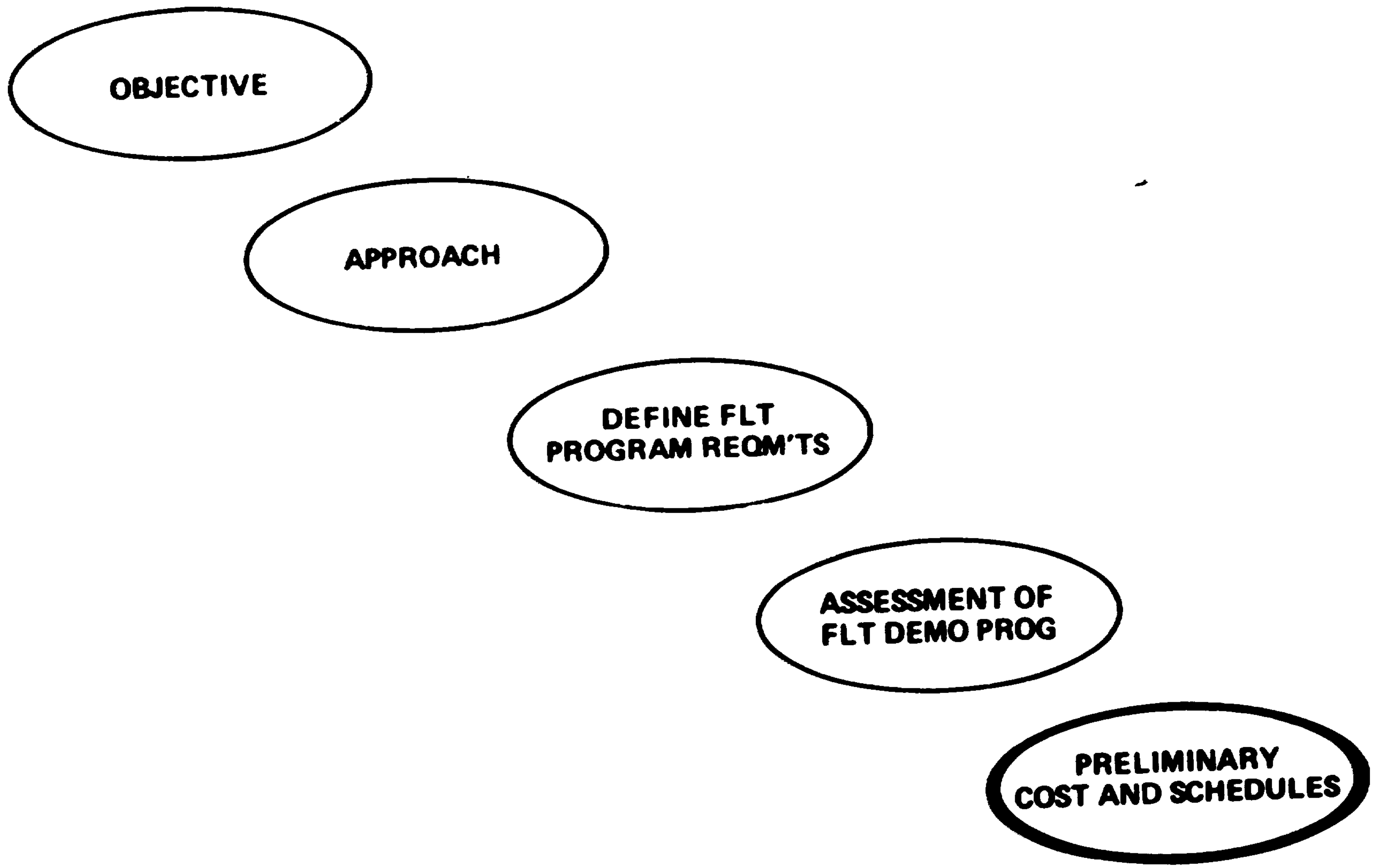
SFDS POWER/CONDITIONING CANDIDATES

SYSTEM	PRIMARY 	SECONDARY 	CONDITIONING 
ADV'TGS	• LOWEST COST • SIMPLEST • MINIMUM INTERFACES	• LOW VOLUME • LOW WEIGHT • UTILIZE STS PWR	• SMALLEST BATTERY • RECHARGEABLE • FULL UTILIZATION OF STS PWR • MISSION UNLIMITED
DISADV'TGS	• MAX WEIGHT • MAX VOLUME • MISSION LIMITED	• INVERTER REQUIRES SPECIAL PWR SWITCHING CONTROLS • MISSION LIMITED	• HIGHEST COST • MOST COMPLEX

2420-094W
HM-17

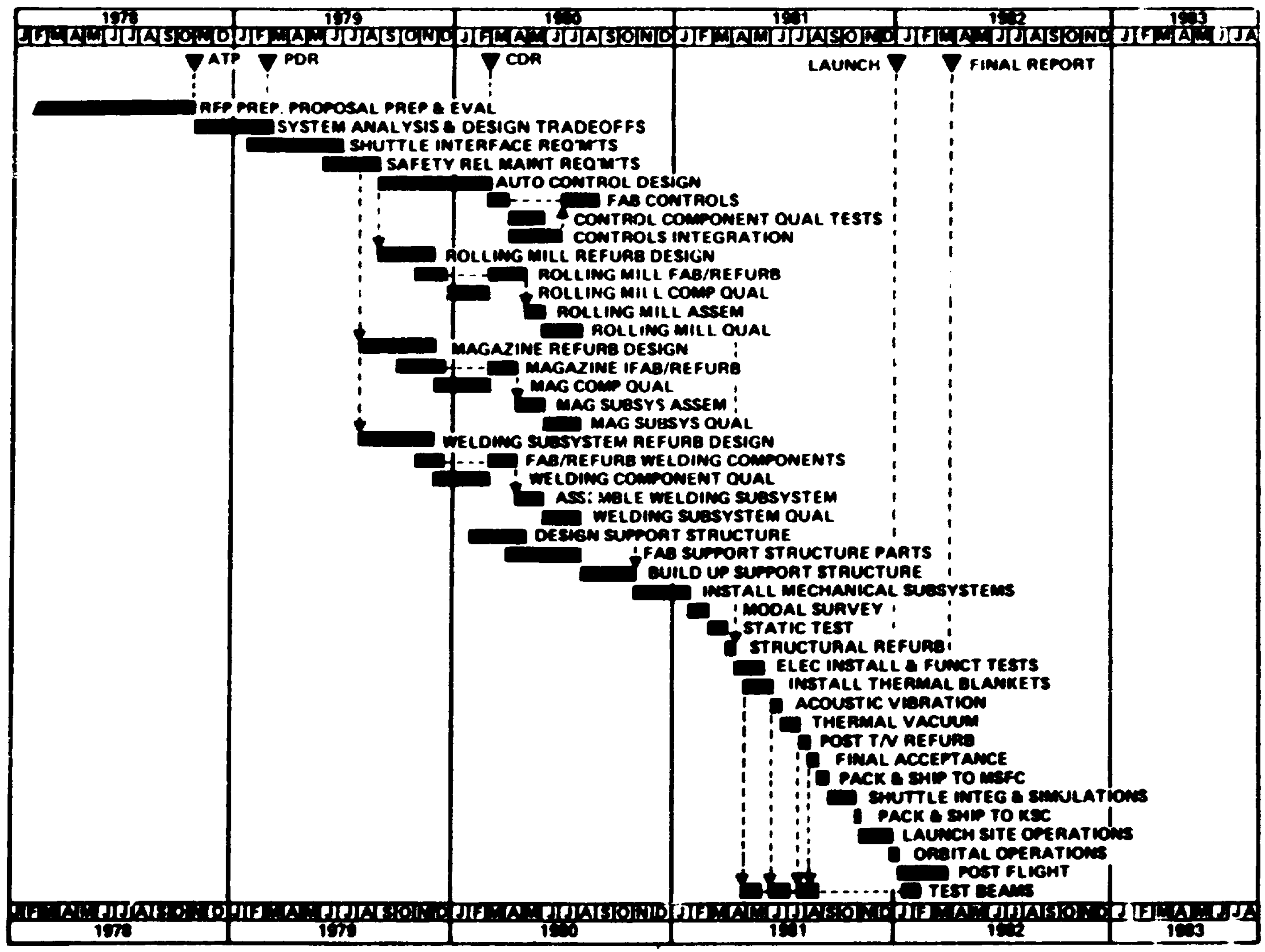
SPACE FAB DEMO SYSTEM – WBS 1.5.1

PRELIMINARY SFDS FLIGHT DEMONSTRATION PROGRAM PLAN



2420-082W
HM-5

SUMMARY TASK SCHEDULE

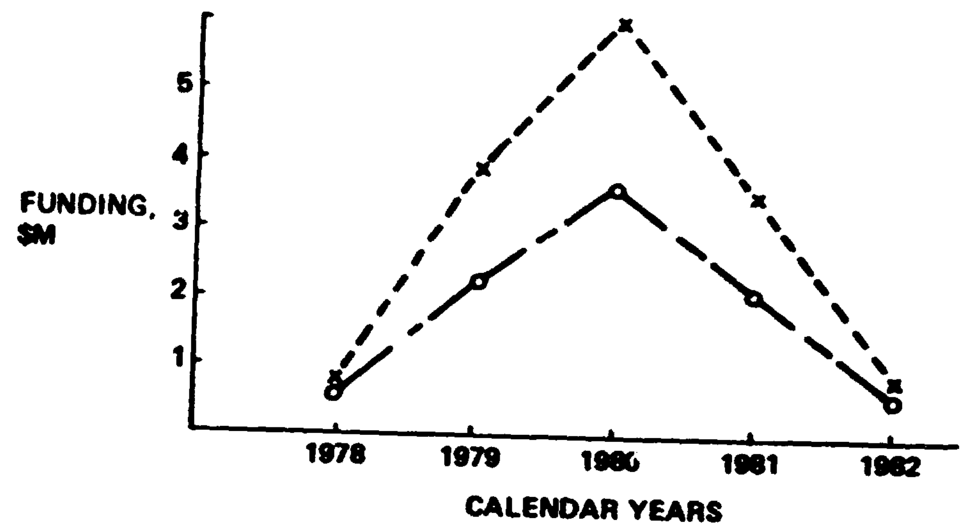


2420-097W
HM-20

SPACE FAB DEMO SYSTEM – WBS 1.5.1

SFDS FLIGHT DEMONSTRATION PROGRAM: PRELIMINARY PROJECTED COSTS

	LOW ($M)	HIGH ($M)
PROGRAM MANAGEMENT	0.63	
SYSTEM ENGINEERING	2.37	
TEST/FLIGHT/OPERATIONS	1.96	
SUBTOTAL	4.96	5.20
SUBSYSTEMS ENGINEERING	1.36	
MANUFACTURING/ASSEMBLY/MATERIAL	1.92	
QUALITY ASSURANCE	0.11	
SUBTOTAL	3.38	8.60
SUBTOTAL	8.34	13.80
GSE	0.83	1.40
TOTAL	9.17	15.20



2420-098W
HM-21

SFDS POWER SYSTEM CANDIDATES

	(A) FUEL CELL/BATTERY INVERTER POWER REQ: FUEL CELL = 2.9KWH BATTERY = 1.4KWH				(B) FUEL CELL/BATTERY CHG CONT'R BATTERY/INVERTER SYST POWER REQ: FUEL CELL = 3.4KWH BATTERY = 9KWH				(C) PRIMARY BATTERY SYSTEM POWER REQ = 4.3 KWH			
	NICKEL-ZINC BATT		SILVER-ZINC BATT		NICKEL-ZINC BATT		SILVER-ZINC BATT		NICKEL-ZINC BATT		SILVER-ZINC BATT	
	WT	VOL	WT	VOL	WT	VOL	WT	VOL	WT	VOL	WT	VOL
CHARGE CONTROLLER	–	–	–	–	50	1.5	50	1.5	–	–	–	–
BATTERY												
NICKEL-ZINC	60	2.0	–	–	50	1.75	–	–	150	4.5	–	–
SILVER-ZINC	–	–	30	1.5	–	–	25	1.5	–	–	75	2.5
INVERTER	300	15.0	300	15.0	300	15.00	300	15.0	300	15.0	300	15.0
TOTALS	360	17.0	330	16.5	400	18.25	375	18.0	450	19.5	375	17.5
PRELIMINARY ESTIMATED COSTS	$400,000		$500,000		$600,000		$700,000		$350,000		$450,000	
	NOTE: WEIGHT = LB VOL = FT^3											

2420-095W
HM-18

FURTHER ACTION REQUIRED

ACTION REQUIRED	ACTION REQ'D BY	
	GRUMMAN	NASA
• COMMENTS ON PRELIMINARY PROGRAM PLAN REQD. BY NOV 1, 1977		X
• FINAL AGREEMENT ON FLIGHT PROGRAM REQMTS BY JUNE 1, 1978	X	X
• UPDATED FLIGHT DEMONSTRATION PLAN DELIVERED BY SEPT 1, 1978	X	

ENCLOSURE (2)

FABRICATION FACILITY

(BEAM BUILDER)

1.2.2 Fabrication Facility Design

The first and second Interum Critical Design Reviews (ICDR) have been completed. The first ICDR was held 9/29/77 at MSFC Huntsville, Alabama and covered the overall equipment support structure and the machine control system. The drawings reviewed at the ICDR are listed in Table I. The second ICDR was held on 10/26/77 at Grumman Aerospace, Bethpage, N.Y. and covered the brace attachment mechanism, resistance spot weld process and the truss cutoff mechanism. The drawings reviewed at this ICDR are listed in Table II. The third and final ICDR is presently scheduled for 12/14/77 and will cover the brace storage magazine, the brace dispensing mechanism and Yoder Roll supply reel, guide and drive.

Roll Forming

The roll forming equipment has been assembled and the tooling is undergoing acceptance testing at the Yoder Co. in Cleveland, Ohio. (Figure 1) The detail parts for the equipment support structure are in the final phases of fabrication. The three bulkhead weldments RDM 447-2063-1, -2065-1 and 2067-1 Fig. 2 have been welded, stress relieved and are being final machined. The three box beam weldments RDM447-2082-1 Fig. 3 are complete and awaiting delivery of Yoder rolling mills to be mounted on them. The internal support structure RDM 447-2076-1 Fig. 4 has been welded, stress relieved and is being final machined. The base frame and all brackets Fig. 5 are complete and ready for assembly operations.

Welding and Clamp Mechanism

The brace attachment design was changed from an earlier concept of eight spot welds per joint to six welds per joint. The integrity of the six spot weld joint was tested Fig. 6 and the results in Table III indicated that the six weld joint was satisfactory. The design of the weld mechanism was modified from an eight weld system to a six weld system to achieve the following overall system benefits

- o increase weld electrode life
- o reduced weld power requirements
- o simplified brace attachment mechanism

The electrode weld life was improved by a factor of two because previously four electrodes were located in the weld clamp block assembly and were used two times at two different positions to achieve an eight weld joint configuration. The modified design has six electrodes located in the weld block assembly and they are used only once to provide the necessary six weld per joint configuration. The additional motion, stops and feedback data for a two position per joint weld system has been eliminated by going to the one stop six weld joint simplifying the overall weld mechanism. The weld power requirments were reduced by 25% in reducing the number of spot welds per joint from eight to six. Details for the brace attachment mechanism are being fabricated. Figure 7 shows some of these details prior to final machining.

Static and fatigue characteristics of spot welded 2024T3 aluminum joints was evaluated as discussed in Appendix "A".

Brace Magazine and Dispensing Mechanism

As a result of the August Quarterly Program Review the brace dispensing mechanism has been redesigned to improve reloading of brace members and replacement of entire unit as a separate module. A preliminary design for both the vertical and diagonal braces is shown in Figure 10. The unit uses a rotating Helix as the brace selector device. The Helix separates one brace member from the stack stored in the magazine. A separate handling carriage Figure II then grips the selected brace member and is used to move the braces 12 13/16 inches from the magazine to the position for welding on the cap member. The entire magazine unit is designed as a module to be readily removed from the machine. A series of hinge points on each of the magazines Fig. 12 will be used to provide easy re-loading directly on the machine. A mock-up Fig. 13 of the brace magazine and helix dispenser has been built and was successfully demonstrated as part of an October program review.

Truss Cutoff

The truss cutoff mechanism Fig. 14 is a screw driven guillotine double shear device with the lower die section retractable to clear the brace members when the truss section is in motion. The shear blade is .170 inches thick and will remove .170 inches of material from the truss during the shear operation. The excess material is captured in a cavity of the lower die. A mockup of the cutoff approach Fig. 15 has been made and evaluated. The principal advantages of the approach are the lack of extraneous particles and clean cut achieved by using the double shear cutting action. The double shear action also means no transverse motion of the overall truss assembly must be made to obtain the shearing action.

Controls

All major actuator motors have been selected. Table IV shows each subsystems' motor and gear reduction if applicable. Speed torque requirements versus speed-torque obtainable from each motor is also shown. The motor designations and location are shown on the Motor Cross Reference in Appendix B. Appendix B also shows the limit switch designation/location and the confidence signals which are derived from these switches. The individual bit assignments to the computer have been made for both the motor and confidence feedback signals. These are shown in Appendix B along with the device codes for each of the I/O ports. The motor control circuits will consist of electromechanical relays to perform the direction control and on/off function.

The preliminary layout of the operator control panel is shown in Figure 16. In the manual mode the operator can drive the 3 rolling mills synchronously, and can perform a manual shear or assembly cycle. In the automatic mode the operator can select the continuous operation with the "start" switch or single task control using the "single cycle" switch. The "Initialize" push button is used to tell the controller to perform the special functions required when starting a new beam.

The coding for the task controller major modules used for the assembly subsystem is complete. Figure 17 shows the general flow of events in this task controller. At the time a task is to be implemented it is placed into a task queue along with any other tasks which are to be made active at the same time. The task activator routine continually sweeps through this queue and makes the tasks active. That is, the task activator turns on or off the discrete output signals called for by the particular task that is being swept out of the task que. Examples of tasks are:

- o Turn on motor to close top vertical scissor
- o Turn on motor to drive right diagonal carriage up

The tasks made active are taken out of the task que and placed in the "ACTIVE TASK" table. This table is constantly being serviced by the task completion monitor which looks at the confidence input signals and sees if they satisfy the completion requirements for the task. When they do, the completion control' routine will turn off or on the discrete outputs called for by the task. This task then waits in a wait que until any interlocking tasks are also complete. When all interlocking tasks are together in the wait que they signal the "Task Selector" routine to fetch the task from the task resident table that is pointed to by the completing tasks. The task selector then takes the tasks from the task resident table, along with any parallel tasks from the residenttable, and places these tasks into the task que. The completed tasks in the wait que are then destroyed.

Major modules for the cap rolling system software are being integrated to implement the basis control algorithm described in earlier reports for maintaining synchronized cap rolling. The primary difficulty in synchronized rolling is due to random slippage in the rolling mills. This slippage has been measured for the Yoder mill now at Grumman and is shown in Figure 18. This data was the amount of material going into the rolling mill. Since there are three mills, the magnitude of the problem is something like that shown in Figure 19, which superimposes three similar curves with an arbitrary phase shift.

Since the control algorithm attempts to correct for slippage based on encoder feedback and projections of continued slippage, there is always a possibility of under or overshooting the final target. To correct for this possibility, the control algorithm is being modified to reduce the maximum number of pulses that are loaded into the FIFO as a function of remaining distance to the target. This approach will reduce the final positioning error.

In order to determine how well the control algorithm might work, a computer simulation of the machine was developed using the three superimposed slippage curves as input to the program. The simulation indicates that the maximum cap length variation during rolling is about 0.0418 inches (1.062 mm) indicated as MAX-ERROR on the printout. At the end points, however, the cap length variation is reduced to an insignificant amount (0.0005 in. = 0.0125 mm) indicated as END-ERROR on the printout. The simulation was written in PL/1 and run on an IBM 360/67. The program listing, input file and sample output is shown in Appendix C.

Assembly subsystem software major module assembly is in progress. Coded source files have been transferred to a disc for assembly and preliminary debugging.

Analysis of actuator requirements for the redesigned Electrode block cams is complete with final control system redesign to be completed next month. Preliminary analysis of redesigned magazine actuator requirements is underway.

Control system wire run lists are being computerized to facilitate rapid correction and modifications.

TABLE I ICDR #1 DRAWINGS

STRUCTURE

Drawing Number	Title
RMD 447-1701 Sht. 2	Roll Die Configuration
RDM 447-2060 Sht. 1	Yoder Base Plast
RDM 447-2061 Sht. 1	Yoder Mach. W/Base
RDM 447-2061 Sht. 2	Section Thru Mill
RDM 447-2063 Sht. 1	Bulkhd. #1 Weld & Mach
RDM 447-2065 Sht. 1	Bulkhd. #2 Weld & Mach
RDM 447-2067 Sht. 1	Bulkhead #3 Weld & Mach
RDM 447-2068 Sht. 1	Internal Struct. Brkt.
RDM 447-2069 Sht. 2	Int. Weld Block Sub-Ass'y.
RDM 447-2070 Sht. 1	Structural Sub-Ass'y.
RDM 447-2071 Sht. 1	Yoder Mill-Box Beam Ass'y.
RDM 447-2072 Sht. 2	Bulkhd. #1 Bracketry
RDM 447-2072 Sht. 2	Bulkhd. #2 Bracketry
RDM 447-2072 Sht. 3	Bulkhd. #3 Bracketry
RDM 447-2073 Sht. 2	Int. Weld Blk Supp Det .
RDM 447-2076 Sht. 1	Int. Struct Frame
RDM 447-2076 Sht. 2	Section at Bulkhd. #3
RDM 447-2076 Sht. 3	Section at Bulkhd. #2
RDM 447-2075 Sht. 4	Section at Bulkhd. #1
RDM 447-2077 Sht. 1	Base Frame
RDM 447-2082 Sht. 1	Box Beam Weldment
Sht. 2	Box Beam Machining
RDM 447-2083	Inst. Tool
RMD 447-2116	Brackets
RDM 447-2115	Drawing Tree
RDM 447-2079	Base Tie Down Bracket
RDM 447-2050	Configuration

TABLE I (continued)

CONTROLS

Drawing Number	Title
RDM 447-2001	Assembly Diagram
RDM 447-2002	System Cabling
RDM 447-2003	Interface Rack Utilization
RDM 447-2004	Control Panel Configuration
RDM 447-2005	Control System Functional Diagram
RDM 447-2006	Lamp Drivers
RDM 447-2010	Material Position Registers
RDM 447-2011	Voltage Controlled Oscillator and Linear Ramp Generator
RMD 447-2012	Fifo Buffer and Control
RDM 447-2013	Isolators and Line Drivers
RDM 447-2014	Slot Sense Detectors
RDM 447-2015	Limit Switch Filter Network
RDM 447-2016	Motor Control Relay Junction Box Layout
RDM 447-2017	Motor Control Relay Junction Box Wiring
RDM 447-2018	Typical Motor, Solendid Control Circuits
RDM 447-2019	115VAC Power Supply Control
RDM 447-2020	Motor Power Supplies
RDM 447-2021	Emergency Stop Wiring
RDM 447-2022	Limit Switch Wiring

TABLE II ICDR #2 Drawings

Weld Mechanism

Drawing No.		Title
RDM 447-2051	Sht. 1	Vertical Clamp Mech
	Sht. 2	
RDM 447-2091	Sht. 1	
	Sht. 2	Scissor Mech (Vert Clamp)
	Sht. 3	
	Sht. 4	
RDM 447-2092	Sht. 1	Weld Block Assembly (Vert. Clamp)
	Sht. 2	
RDM 447-2093	Sht. 1	Scissor Mech Details (Aft Diag Clamp)
	Sht. 2	
RDM 447-2094	Sht. 1	Weld Support Block Assembly (For Aft and Fwd. Diag Clamp)
RDM 447-2095	Sht. 1	Scissor Mech Details (Fwd Diag. Clamp)
RDM 447-2096	Sht. 1	Weld Block Assembly (For Fwd & Aft Diag Clamp)
	Sht. 2	
RDM 447-2103	Sht. 1	Aft Clamp Mech. Assembly
	Sht. 2	
RDM 447-2104	Sht. 1	Fwd Clamp Mech. Assembly
	Sht. 2	

Cut-Off

RDM 447-2121	Sht. 1	Upper Movable Die Details
	Sht. 2	
RDM 447-2122	Sht. 1	Stationary Die Details
RDM 447-2123	Sht. 1	Lower Movable Die Details
	Sht. 2	
	Sht. 3	
RDM 447-2107	Sht. 1	Upper Movable Die Sub-Assy
RDM 447-2108	Sht. 1	Stationary Die Sub-Assy
RDM 447 2109	Sht. 1	Lower Movable Die Sub- Assy
RDM 447-2081	Sht. 1	Cut-Off Mechanism Assy
	Sht. 2	

Table III Weld Configuration Test

Spots/Joint	Pitch, In.	Max Load to Failure, Lbs.
6	1.38	775
6	1.25	778
8	0.5/0.75/0.5	765

TABLE IV

BASIC MOTOR CHARACTERISTICS

FUNCTION	MOTOR TYPE	QUANTITY REQUIRED	TORQUE (IN. LBS.) REQUIRED	TORQUE (IN. LBS.) AVAILABLE	SPEED (RPM) REQUIRED	SPEED (RPM) AVAILABLE
Rolling Mill Drives	A	3	235	751	53.3	58.6
Vert./Horiz. Magazine Banking, Selecting	B	12	96	144	4	7.3
Cherry Pickers						
Rotate	C	6	3	5	20	20
Translate	D	6	1.3	2.3	312	290
Electrode Block						
Clamp	E	9	80	100	120	120
Scissors	E	9	23	100	96	120
Cams	E	12	86	200	30	30

MOTOR TYPES

Type	Manufacturer - Model No.
A	Control Systems Research SM709
B	Elinco - AS 281 180:1 Gear
C	Bodine - KCI-24T3-#750
D	Bodine - NCI-12R-#406
E	PMI MOtors - U9FG

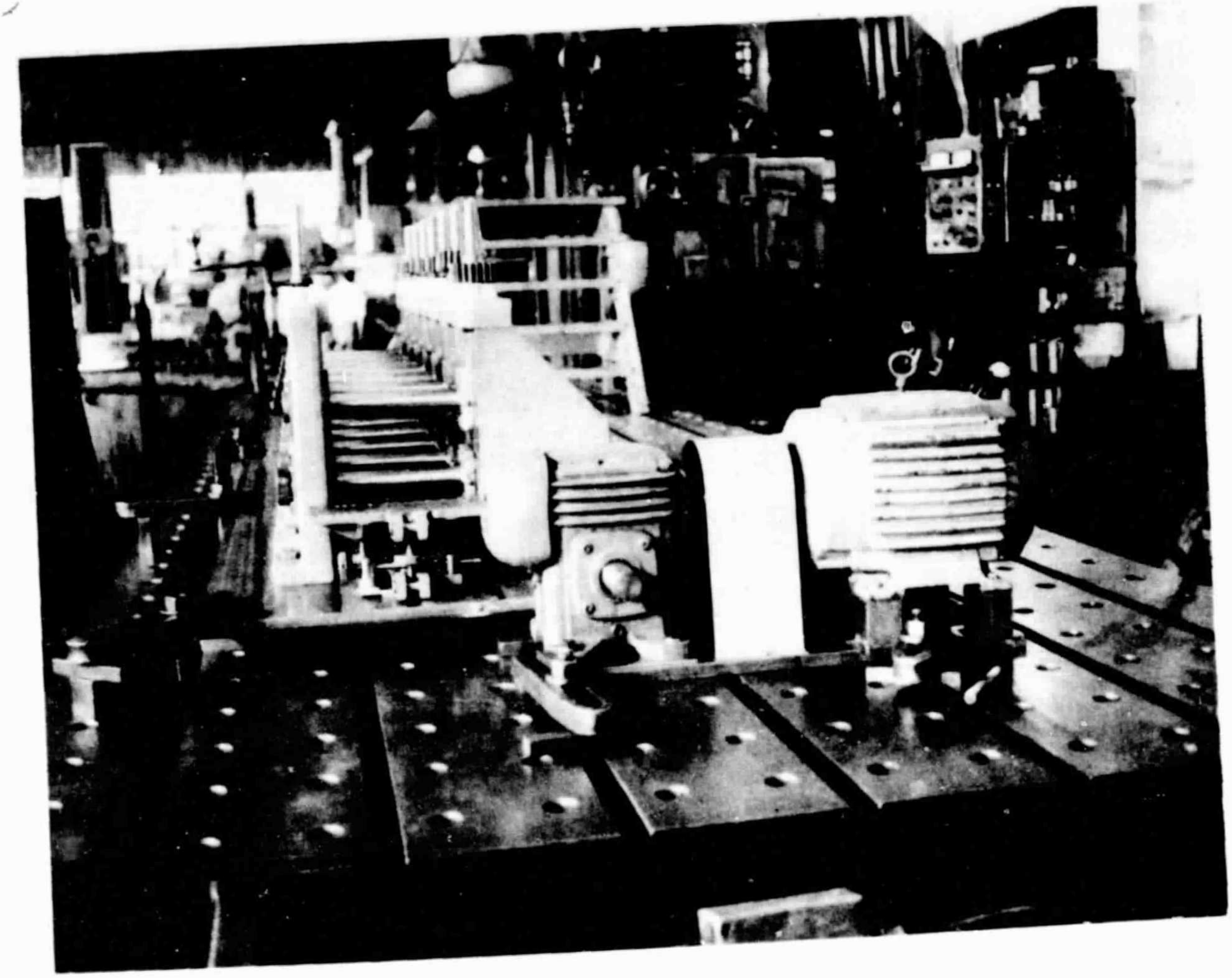


FIGURE 1 - SFDS Yoder Roll Forming Mill

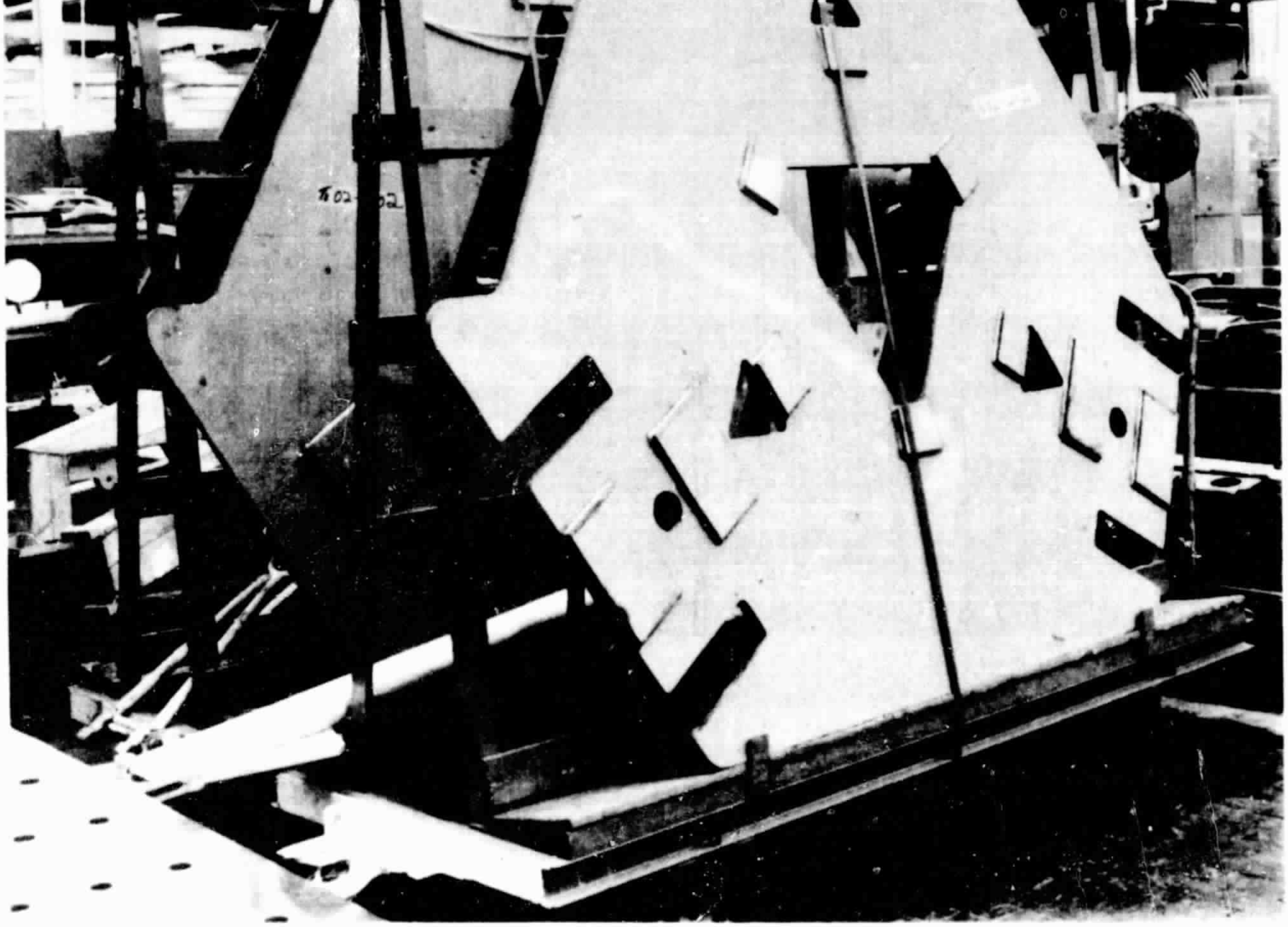


FIGURE 2 - SFDS Bulkhead Weldments

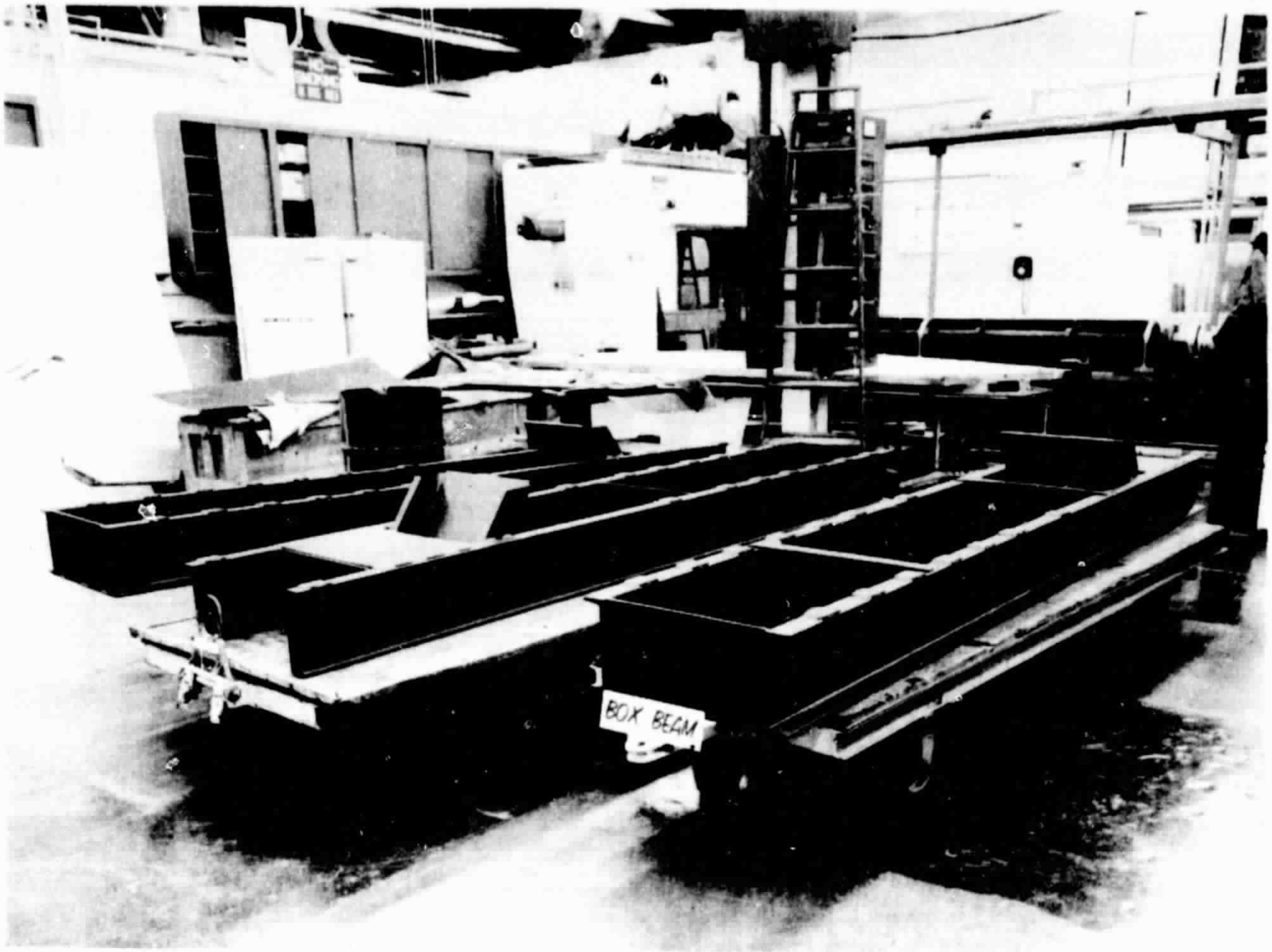


FIGURE 3 - SFDS Box Beam Weldments

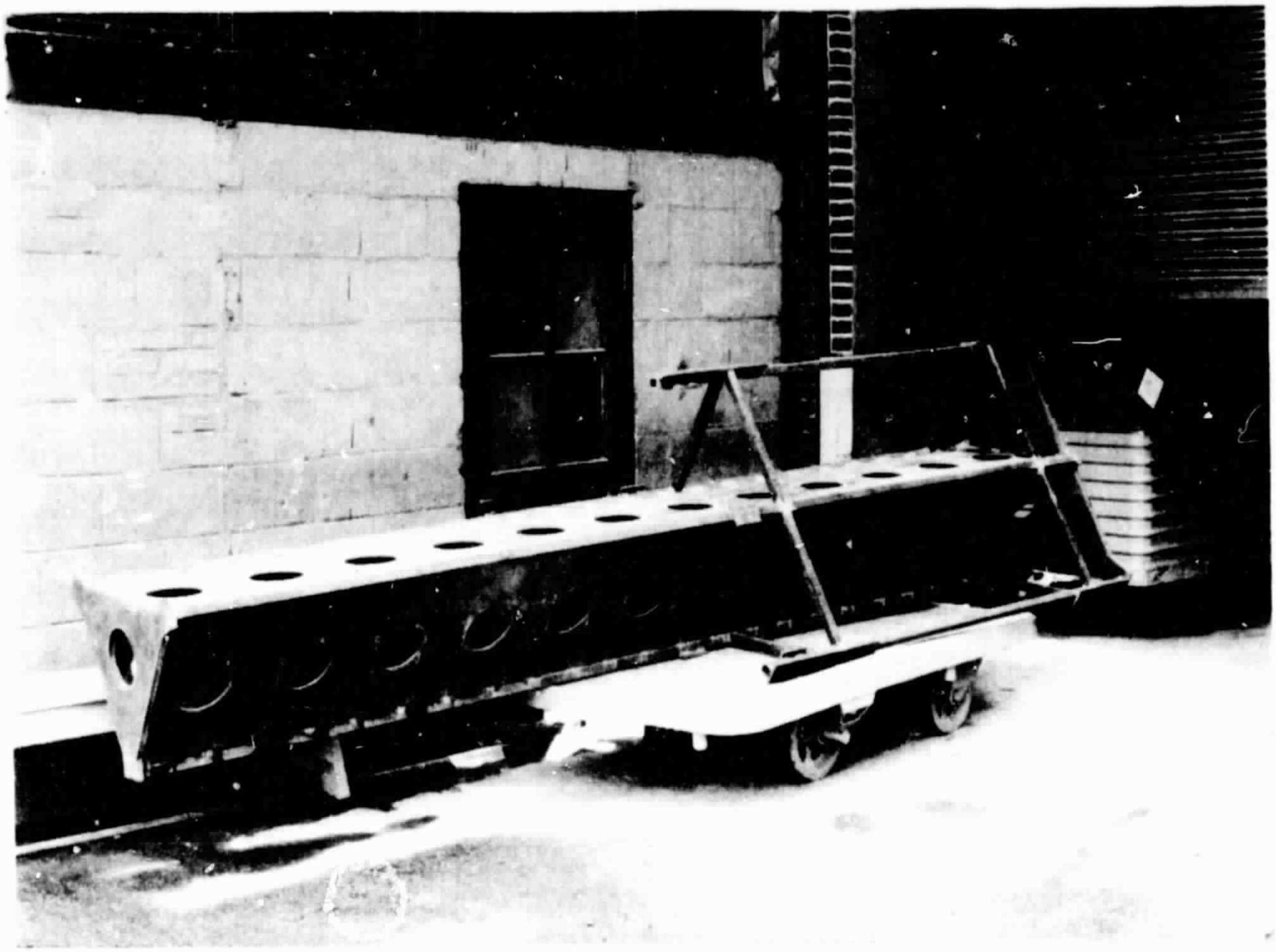


FIGURE 4 - SFDS Internal Support Structure

FIGURE 5 - SFDS Base Frame and Assembly Brackets

ORIGINAL PAGE IS
OF POOR QUALITY

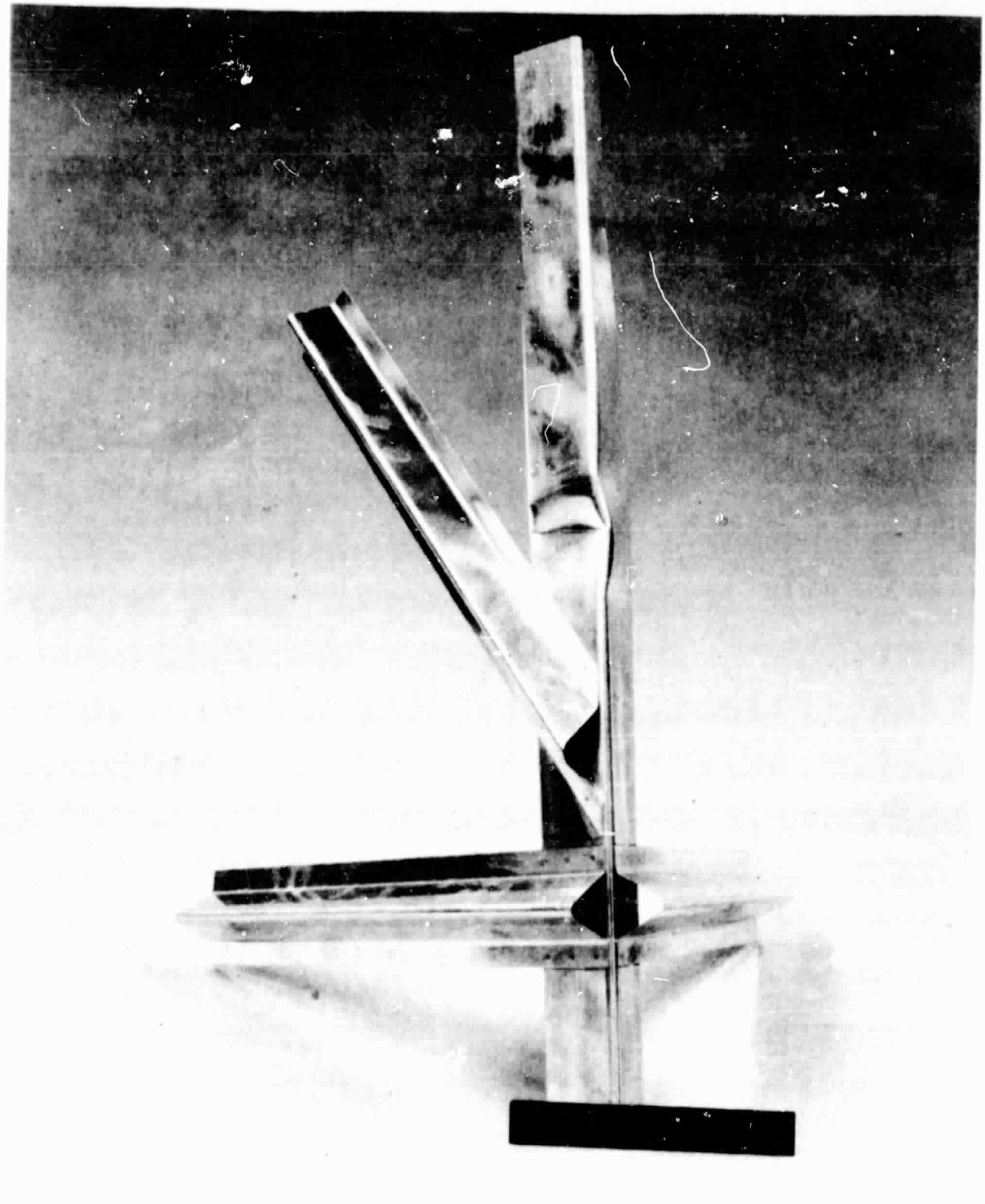


FIGURE 6 - Six Weld/Joint Test Specimen

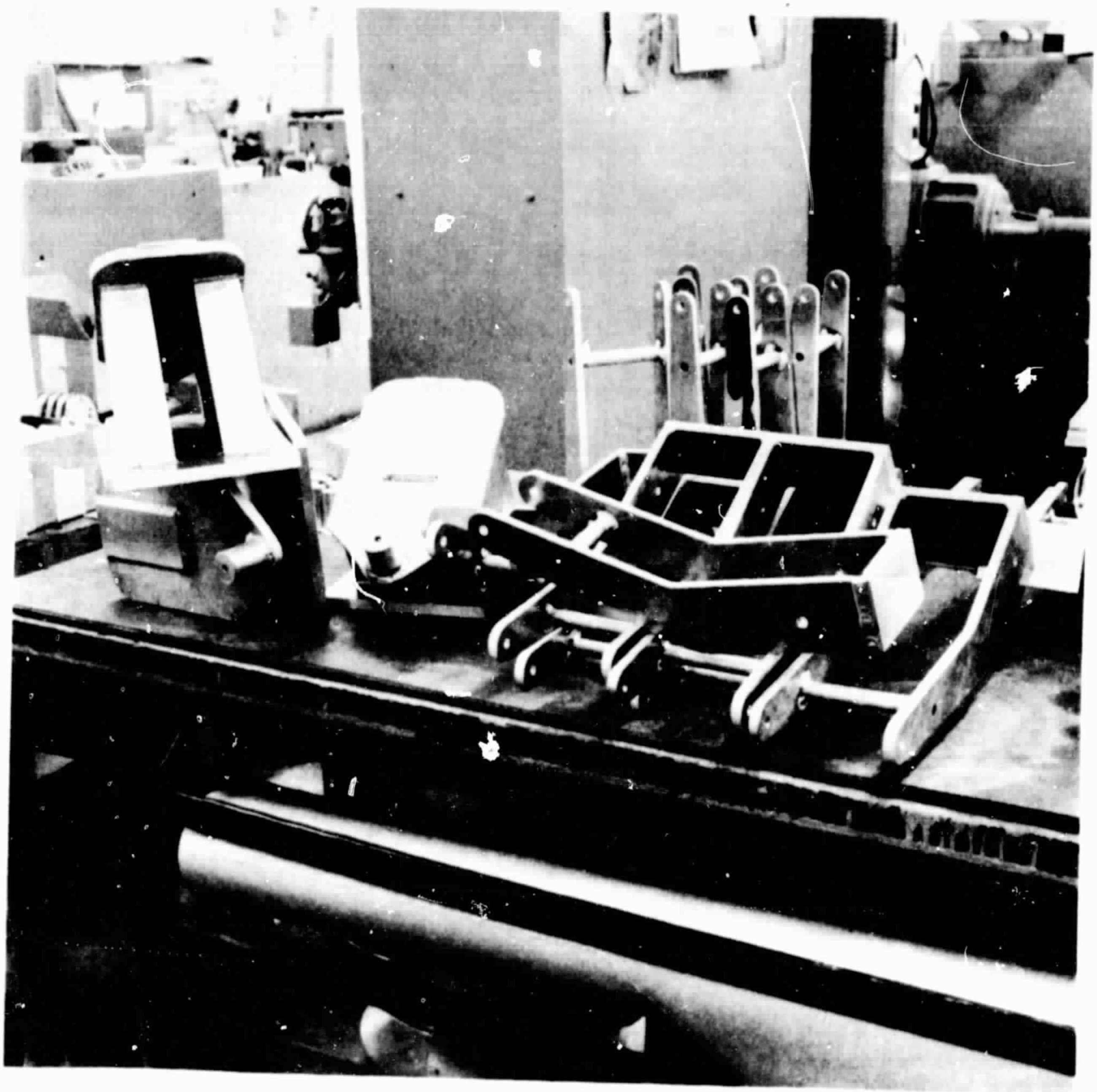
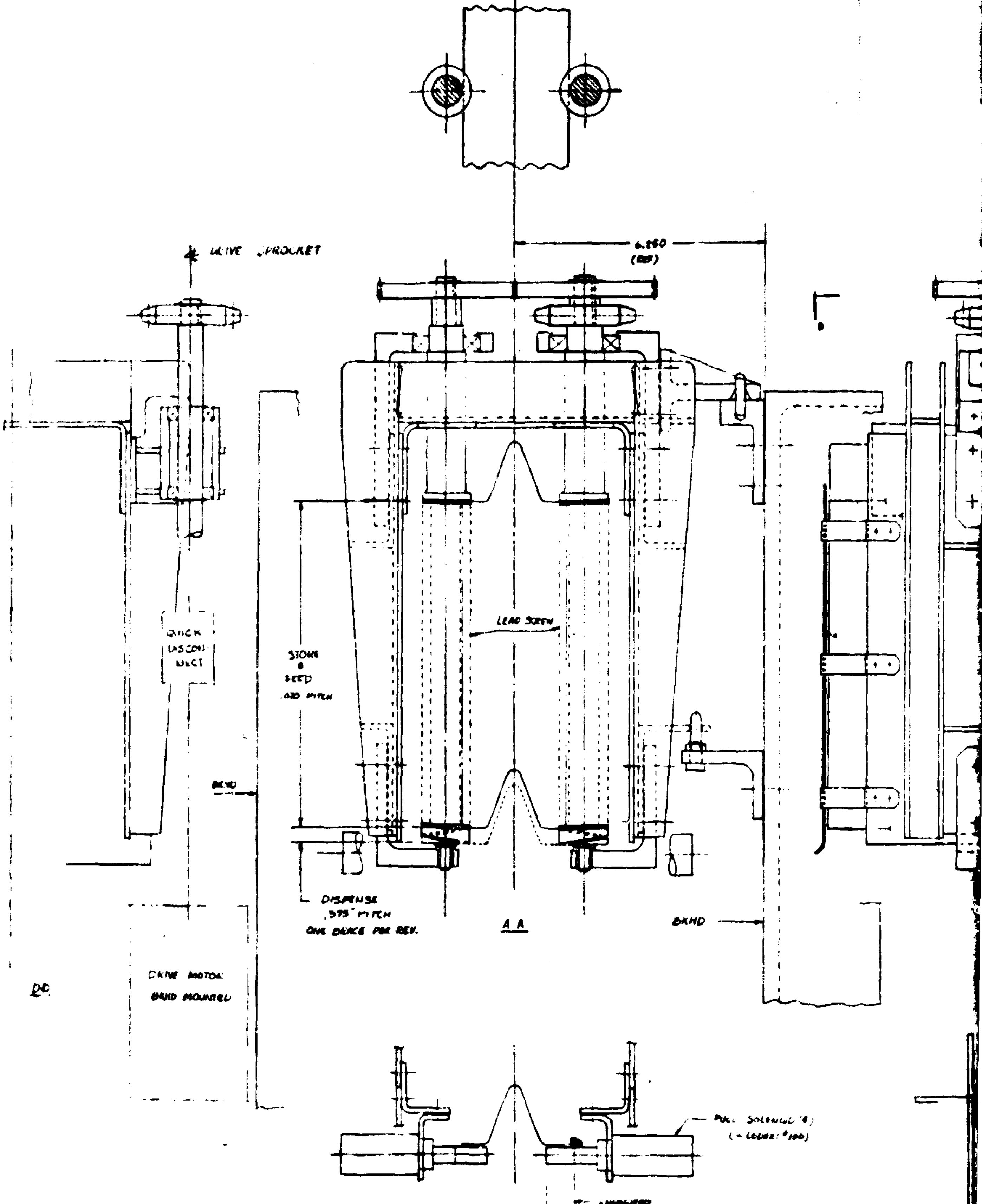
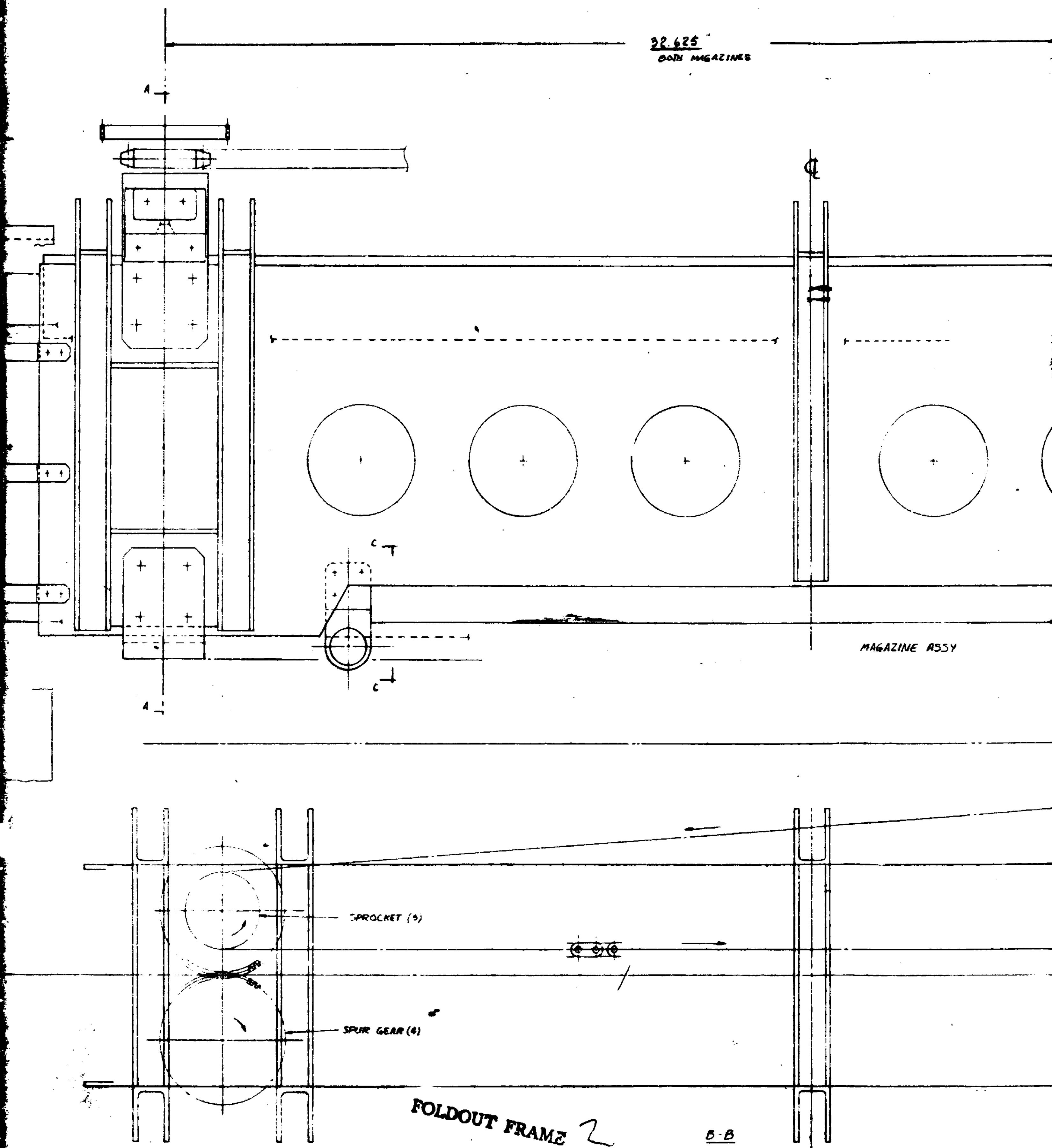


FIGURE 7 - SFDS Clamp/Weld Block Detail Parts

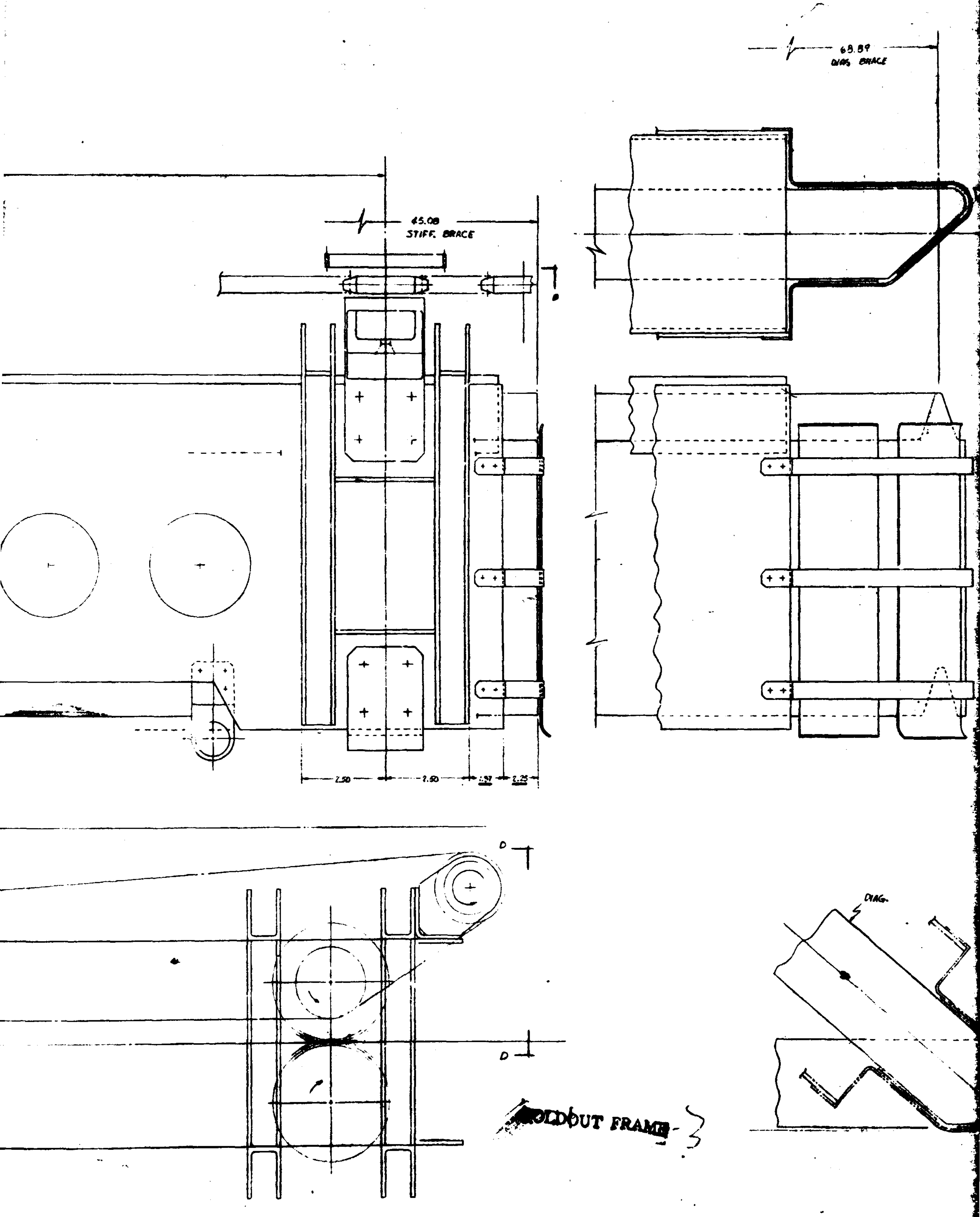
ORIGINAL PAGE IS
OF POOR QUALITY



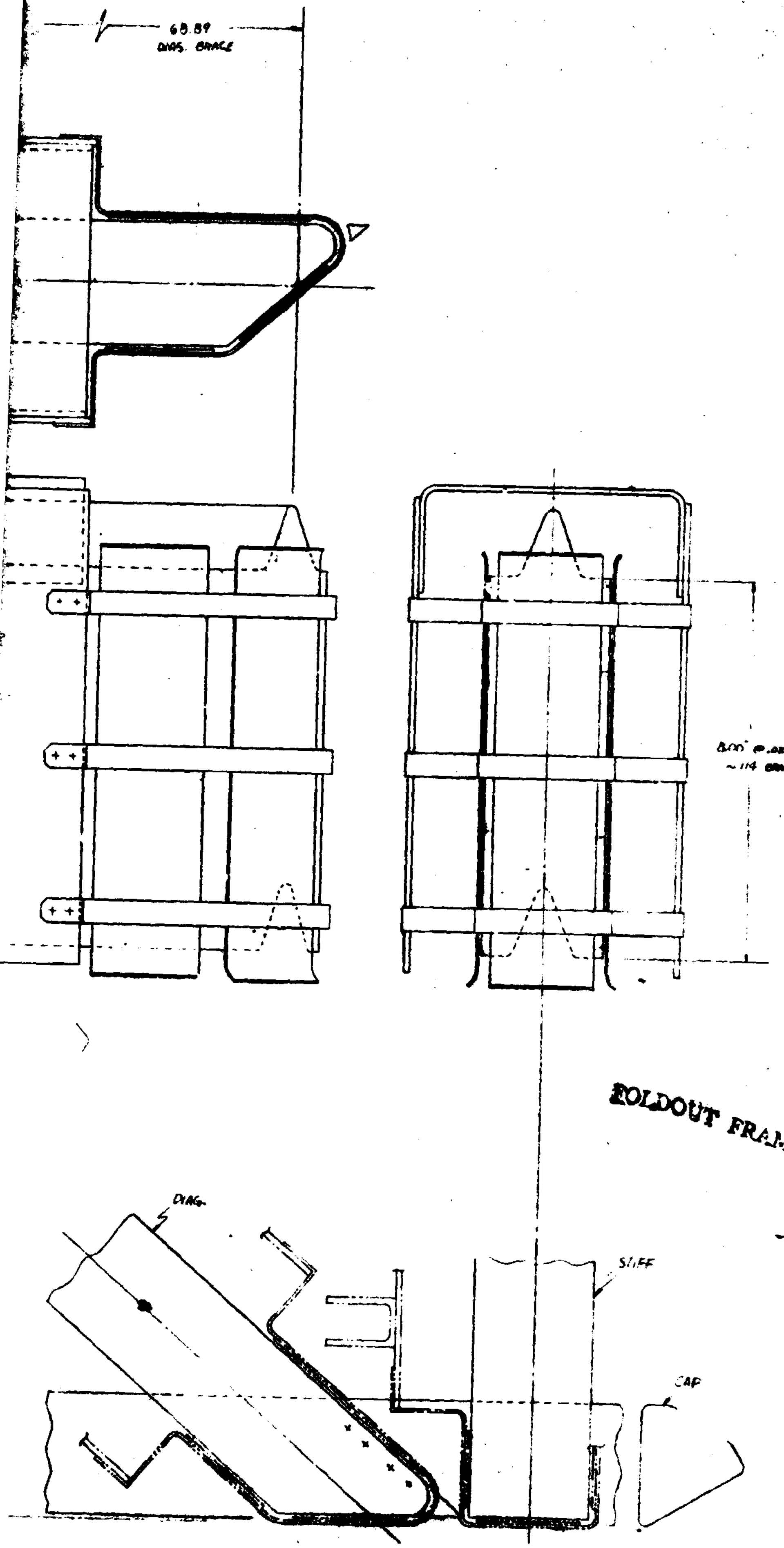
FOLDOUT FRAME



FOLDOUT FRAME 2



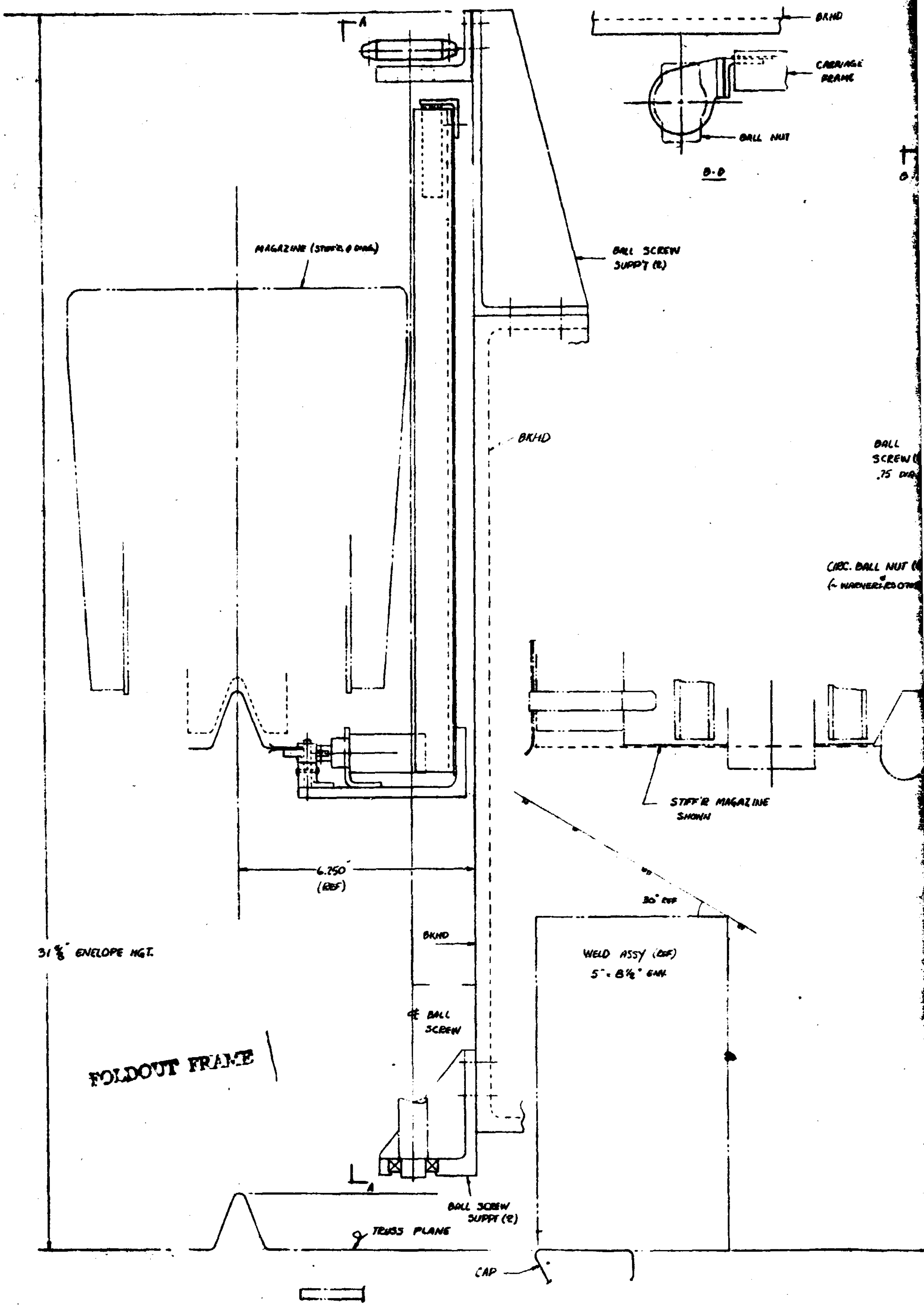
FOLDOUT FRAME - 3



FOLDOUT FRAME 4

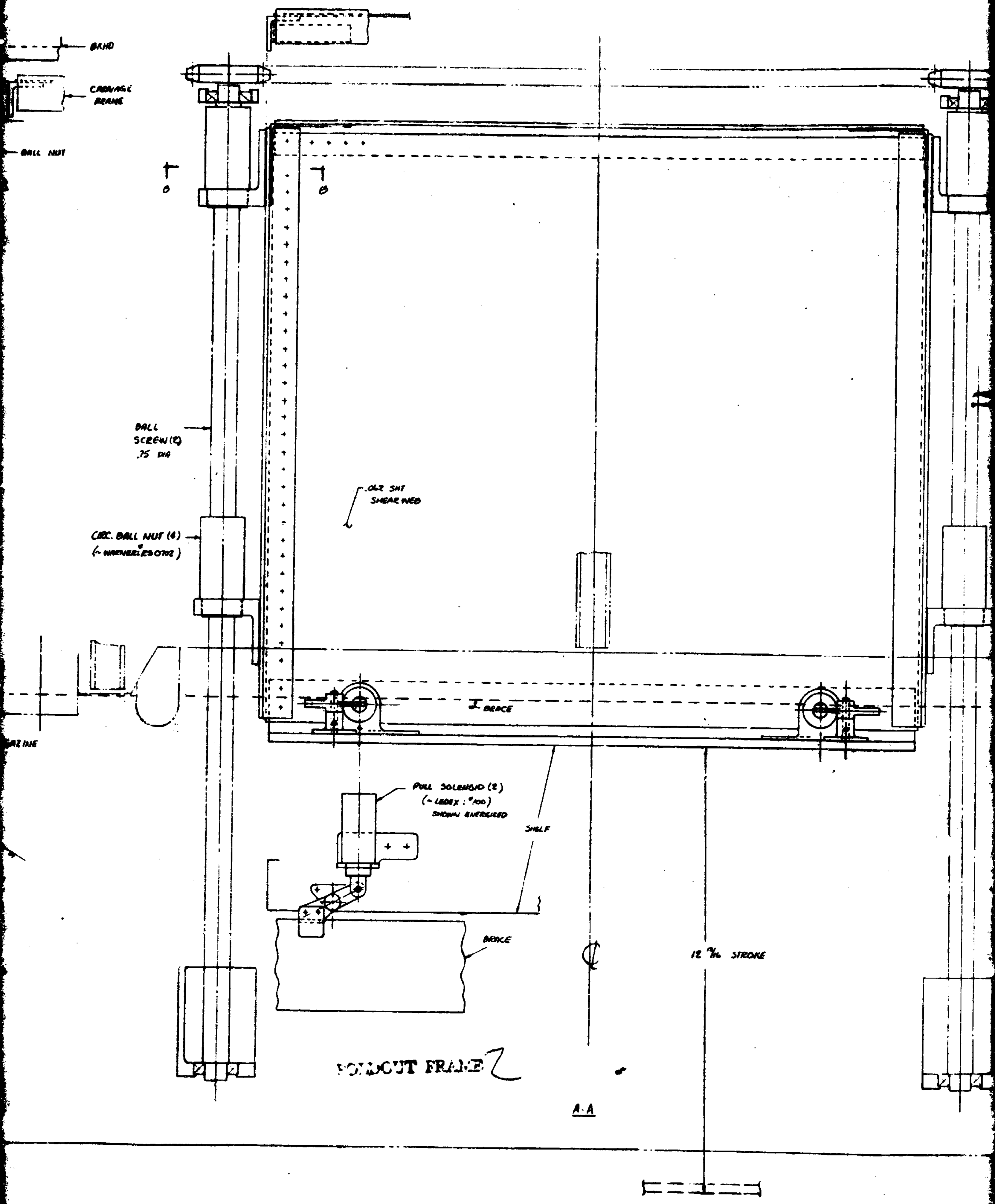
BRACE MAGAZINE

FIG. 10

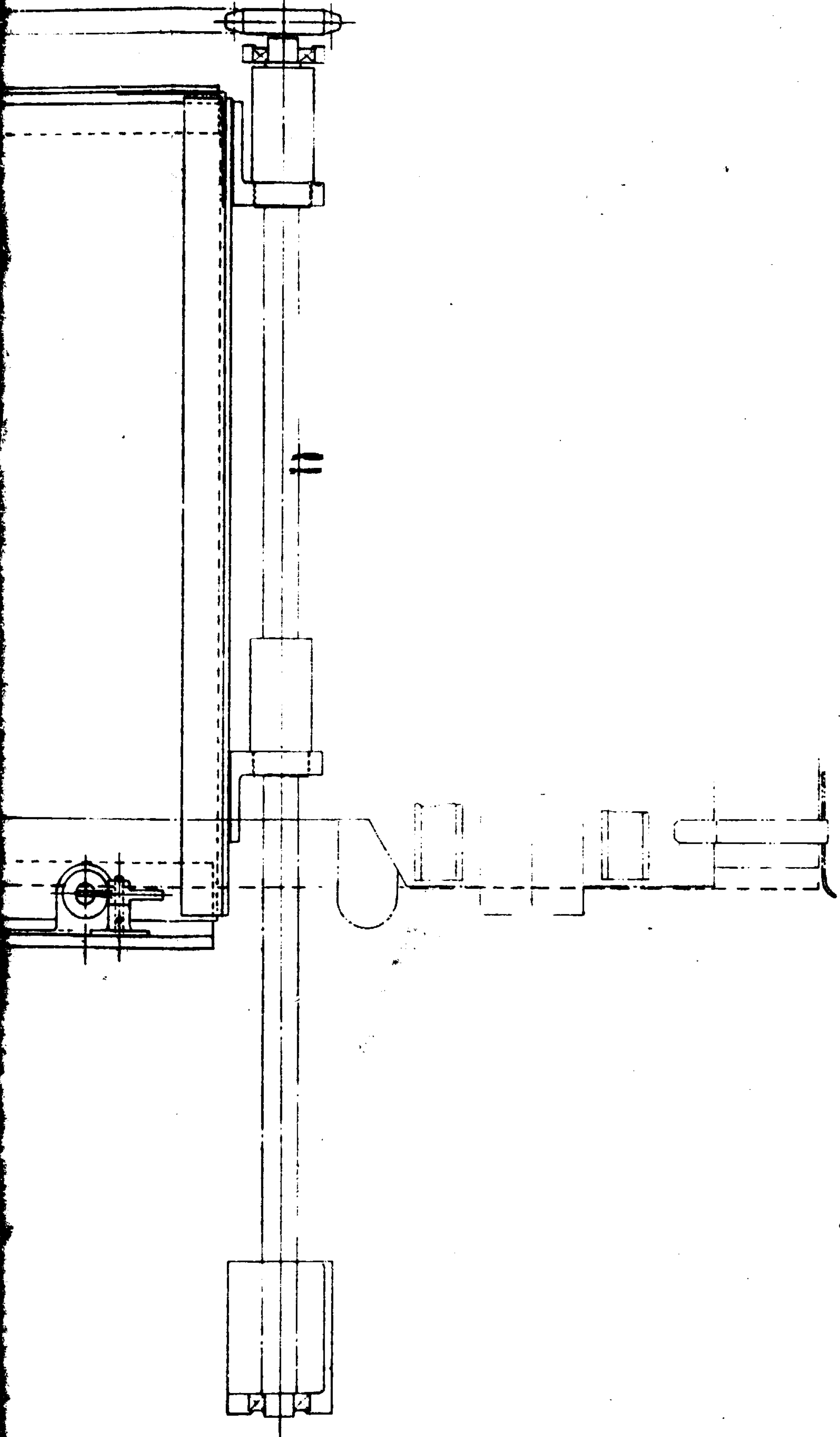


FOLDOUT FRAME

2-17



FOLDOUT FRAME 2



CARRIAGE

FIG. 11.

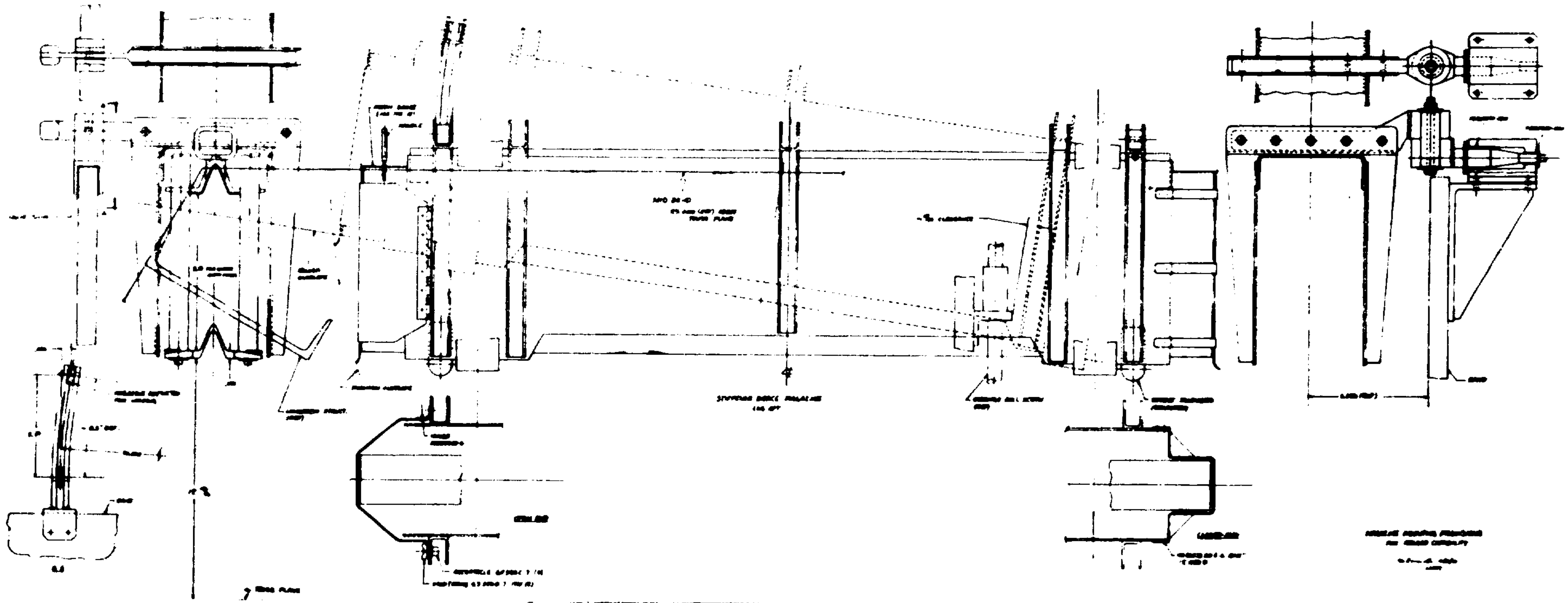


Figure 12 - SFDS Magazine Hinge Layout

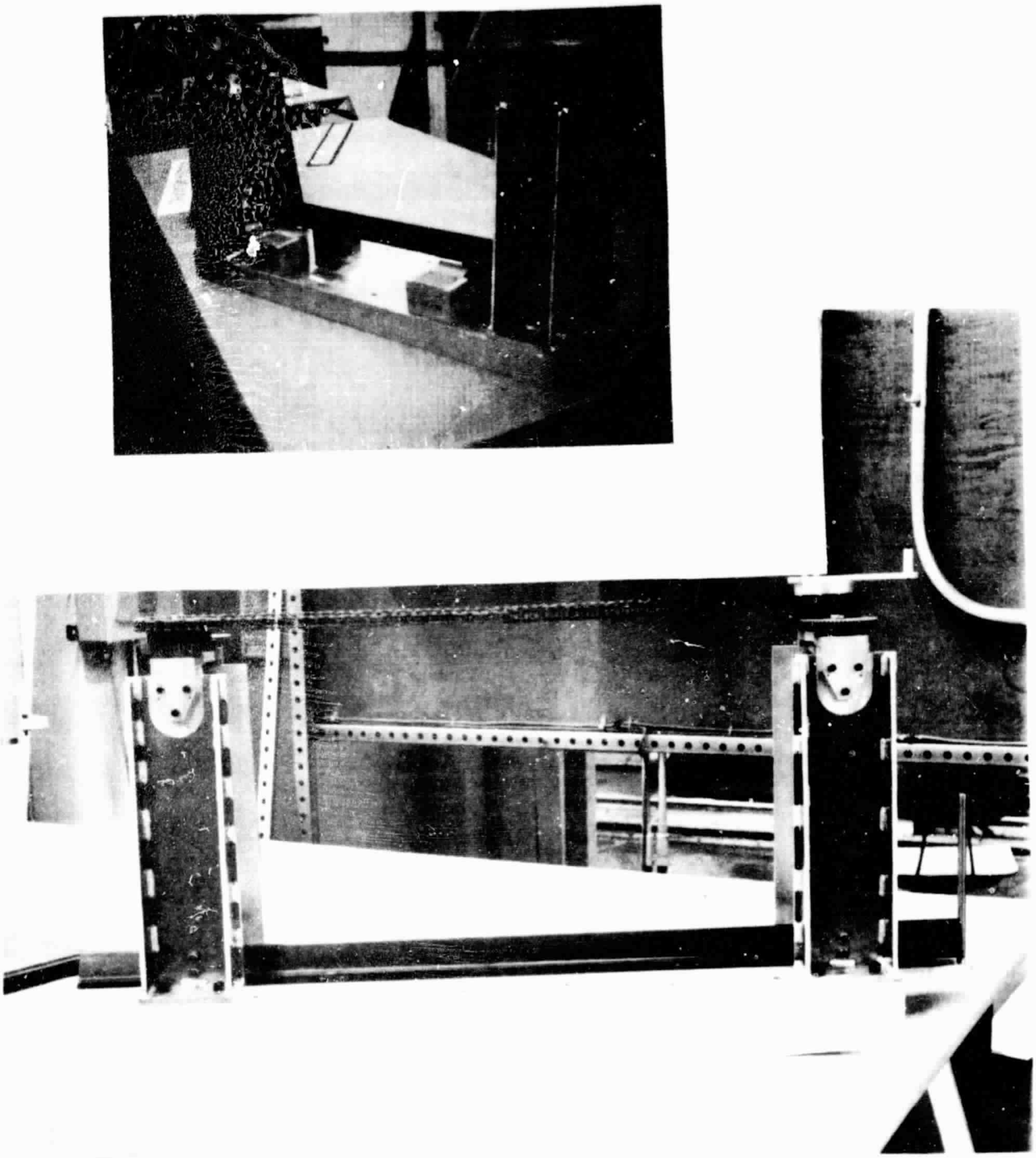


FIGURE 13 - SFDS Magazine/Dispenser Mockup

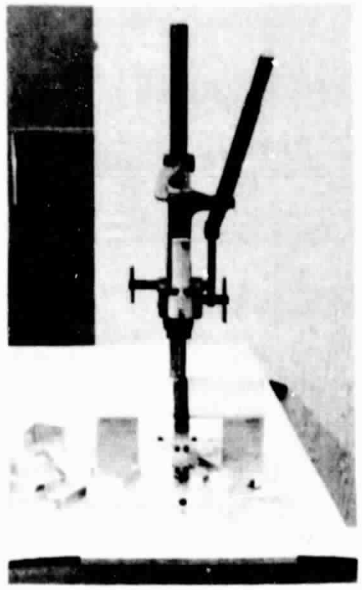


FIGURE 15 - SFDS Truss Cutoff Mockup

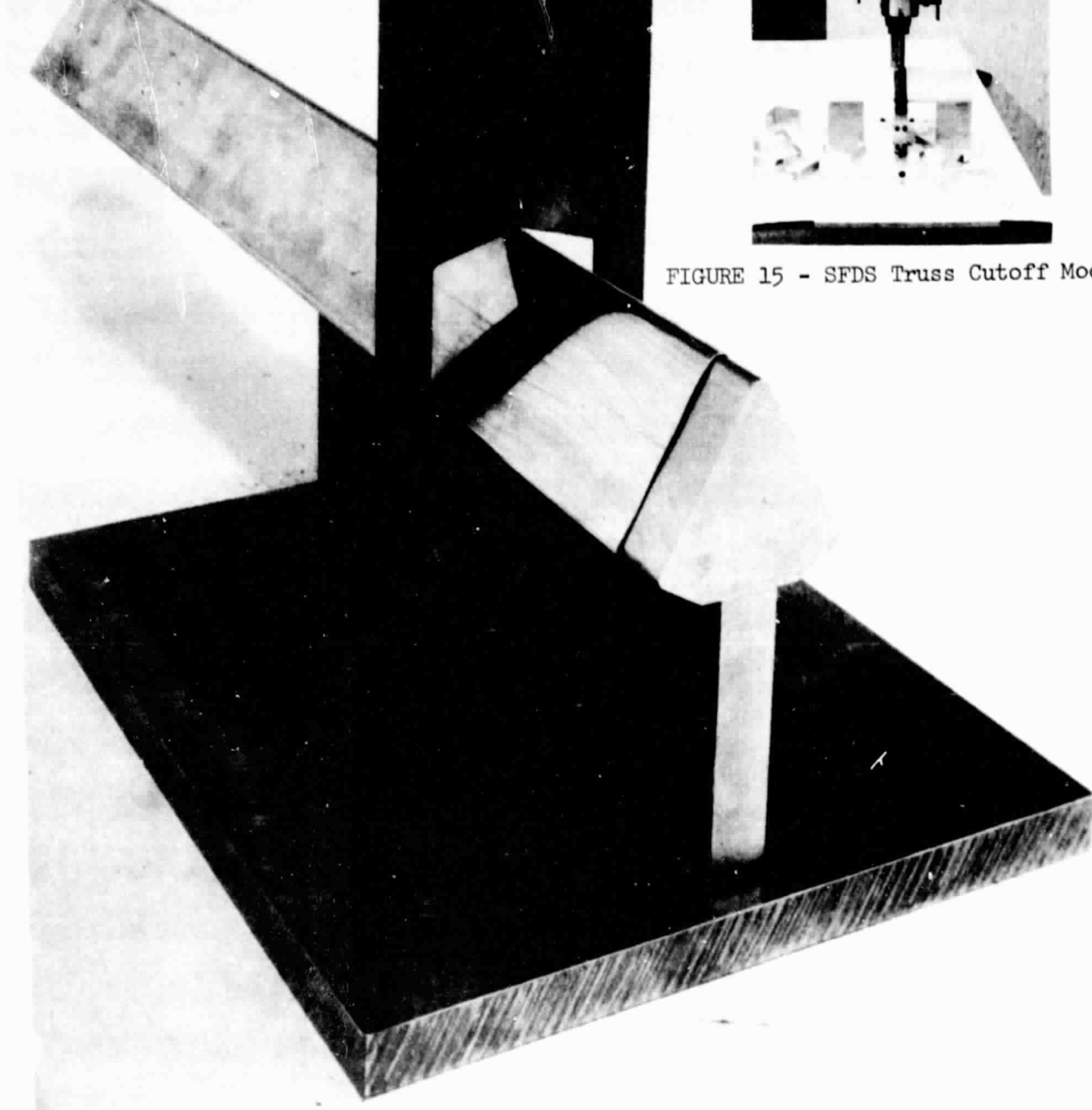


FIGURE 14 - SFDS Truss Cutoff

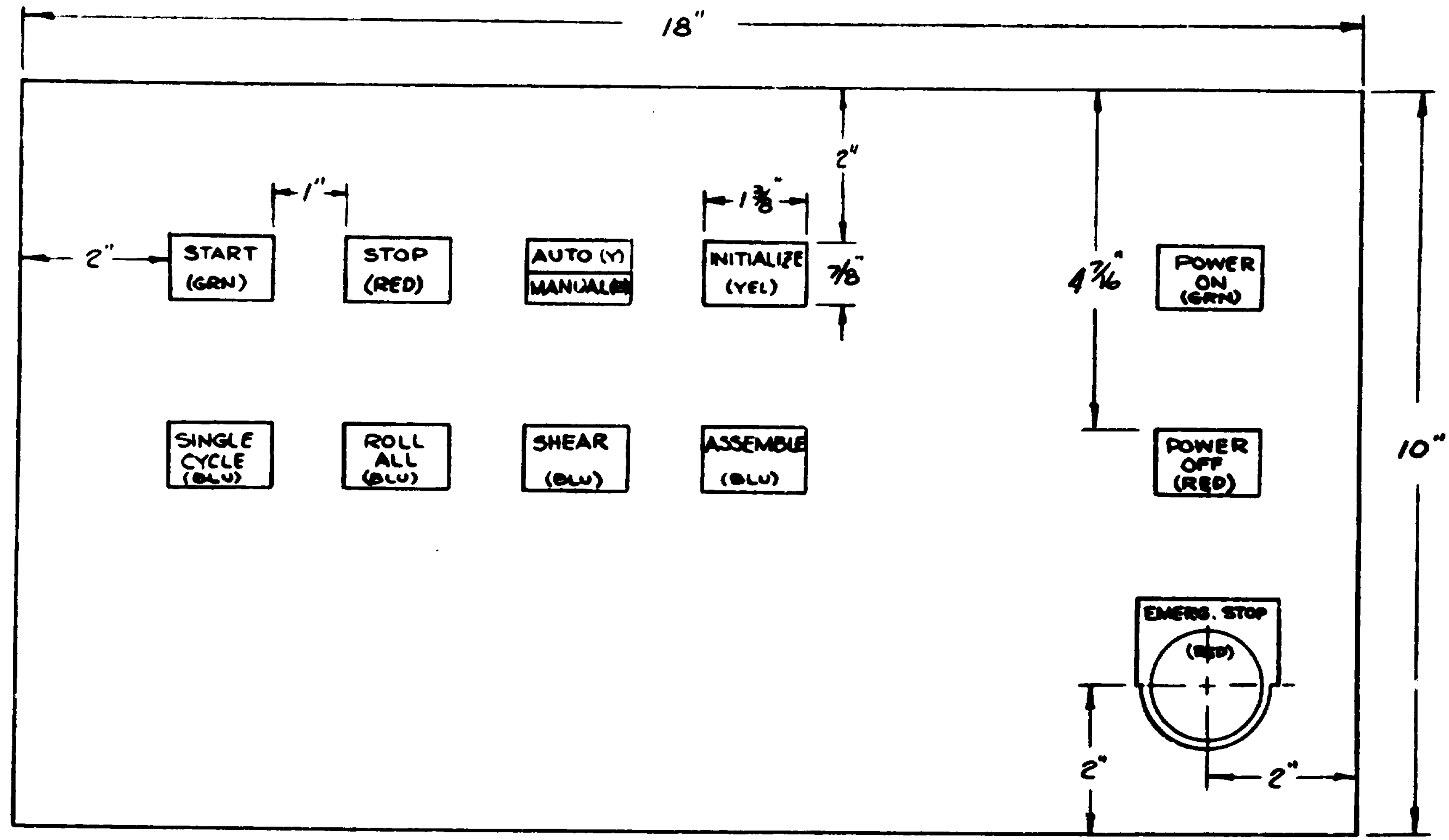


FIGURE 16 CONTROL PANEL LAYOUT

ASSEMBLY SUBSYSTEM SOFTWARE

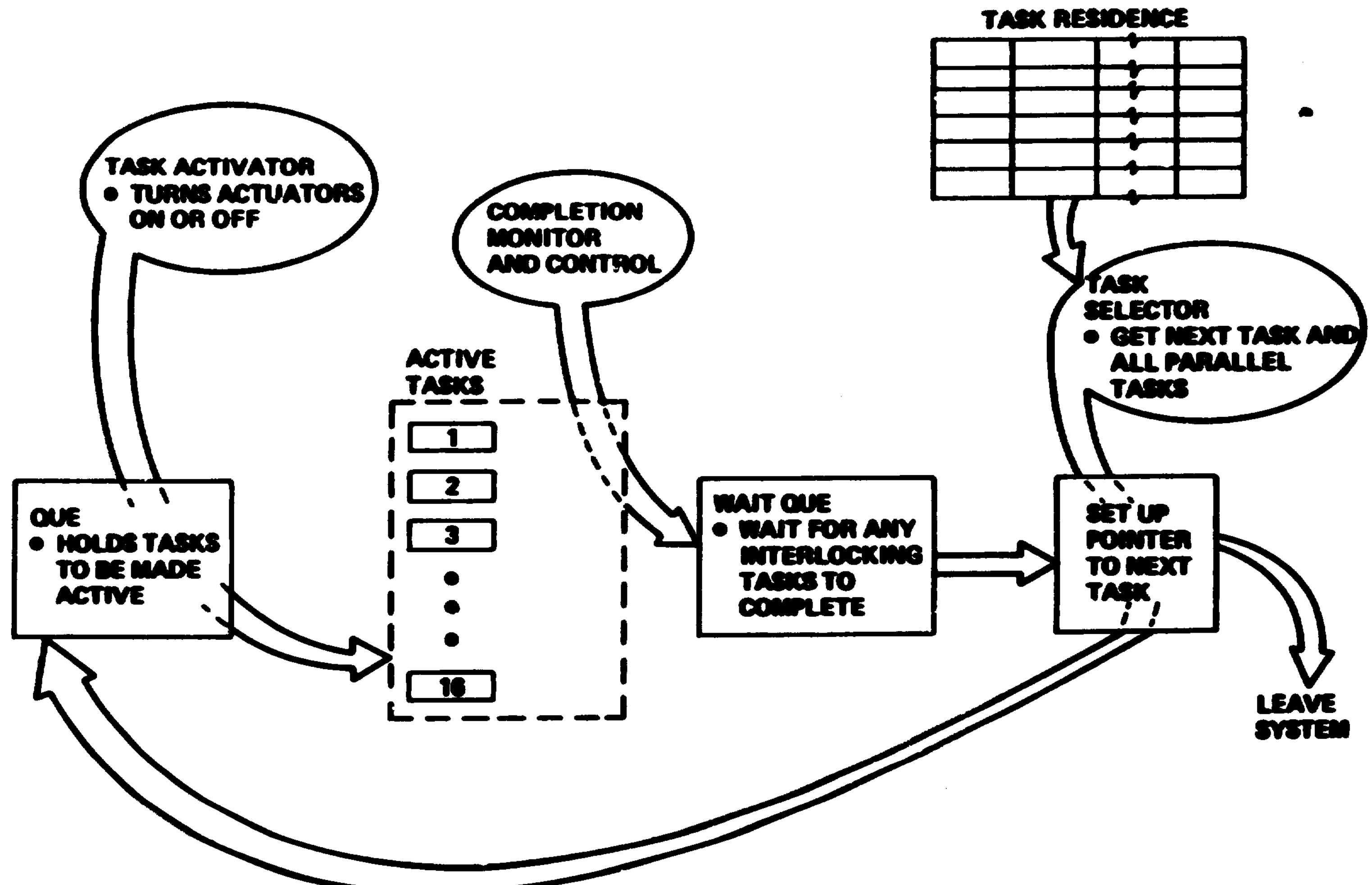


FIGURE 17

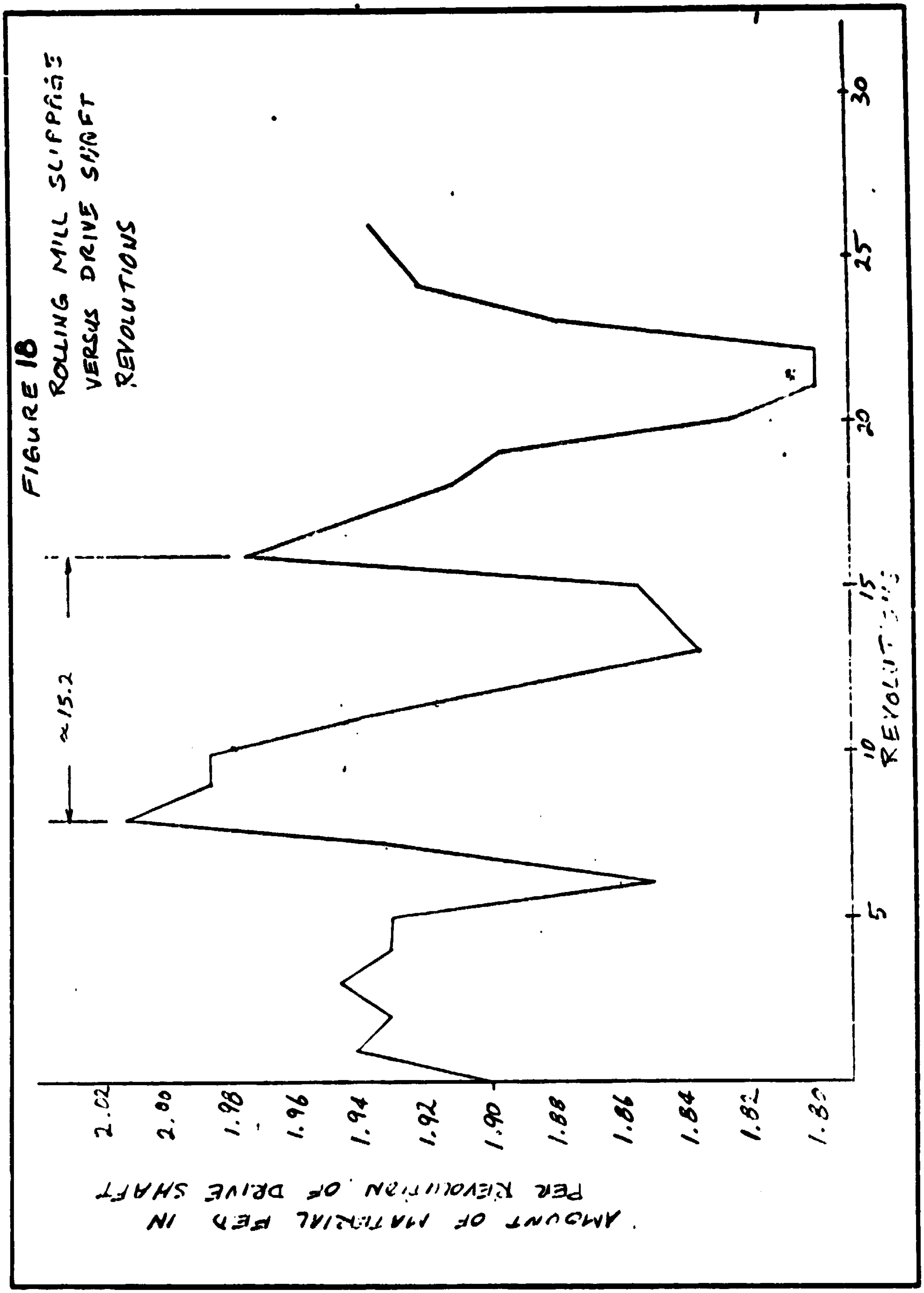


FIGURE 18
ROLLING MILL SLIPPAGE
VERSUS DRIVE SHAFT
REVOLUTIONS

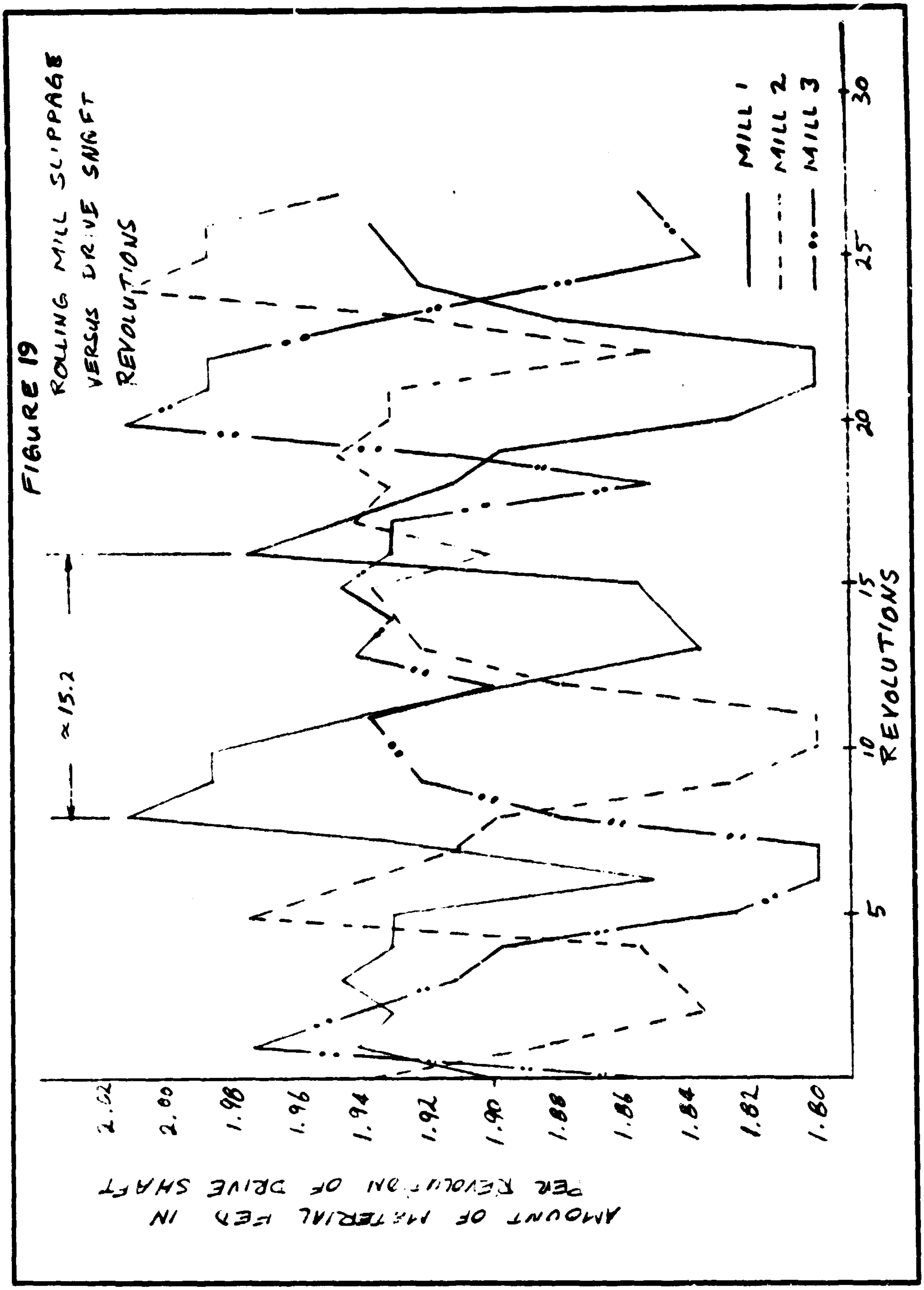


FIGURE 19
ROLLING MILL SLIPPAGE VERSUS DRIVE SHAFT REVOLUTIONS

APPENDIX A

MEMORANDUM

CHECK (✓) BOXES AS APPROPRIATE

ACTION .... ☐
INFO ONLY.... ..... ☐
REPLY REQUESTED... ☐

	NAME	GROUP NO. & NAME	PLANT NO.	COMPANY EXT.	
FROM:	R. Messler, Jr.	AMPD	A04/12	2244	DATE 7 October 1977
TO:	J. Huber/R. Witt	AMPD	A04/12	7363/2244	NO. MP-AMPD-MO-77-129

SUBJECT: **Static and Fatigue Characteristics of Spotwelded 2024-T3 Aluminum Joints**

As part of an effort to evaluate techniques for joining structural elements fabricated in space to form a truss, resistance spot-welded 2024-T3 aluminum alloy (0.016-inch thick) was tested for static and fatigue properties. Test specimens, consisting of single lap shear joints, were resistance spot-welded to each of four configurations shown in Figure 1. Welding was performed on a 100 kva welder using 300 lb. per spot electrode pressure. Single spot direct welding using one cycle of heat was employed to simulate the series resistance welding concept proposed for space fabrication. Three samples of each configuration (Figure 1) were statically tested. Results are shown in Figure 2.

Configuration "D" (four spots in-line) resulted in the highest total (700 lbs.) and per spot (175 lbs.) shear load carrying capacity and was therefore selected for fatigue testing. Twenty-six additional samples were welded. Twelve specimens were tested in constant amplitude tension-fatigue (R=0.05) in an unrestrained (free) manner and twelve restrained between oiled Micarta to prevent end curling or lifting in the lap joint area. The three remaining specimens were statically tested to determine the shear ultimate strength of the lot. Test results are tabulated in Figure 3 and plotted as an S-N curve in Figure 4.

Fatigue testing in the unrestrained condition resulted in a predominant failure mode consisting of spot pull-out, attributed to a tension component induced by sample curling or lifting in the lap joint area. Fatigue run-out (endurance limit) occurred for loads below 10% of the ultimate shear load. Restraining the fatigue specimen in the lap joint area prevented curling or lifting and resulted in a predominant failure mode consisting of fatigue failure through the aluminum, initiating at one of the end spot welds. Fatigue run-out occurred between 10 and 15% of the shear ultimate load.

In conclusion, spot welds which are representative of those which would be made in space (i.e. single spot direct welded) produced ultimate shear tension strengths of 700 lbs. using four spots in-line. Fatigue run-out averages 10-15% of shear ultimate load which is within the range of values obtained by other programs (e.g. Goodyear spot-welding studies).

✓cc: W. Marx
A. Alberi
W. Muench
D. Layton
A. Sinowitz

G1100 REV 6 6-74 250M

Type A
Single Spot
(3 Reqd)

Type B
3 in Transverse
Row
(3 Reqd)

Type C
2 Rows of 2
(3 Reqd)

Type D
4 In-Line
(3 Reqd)

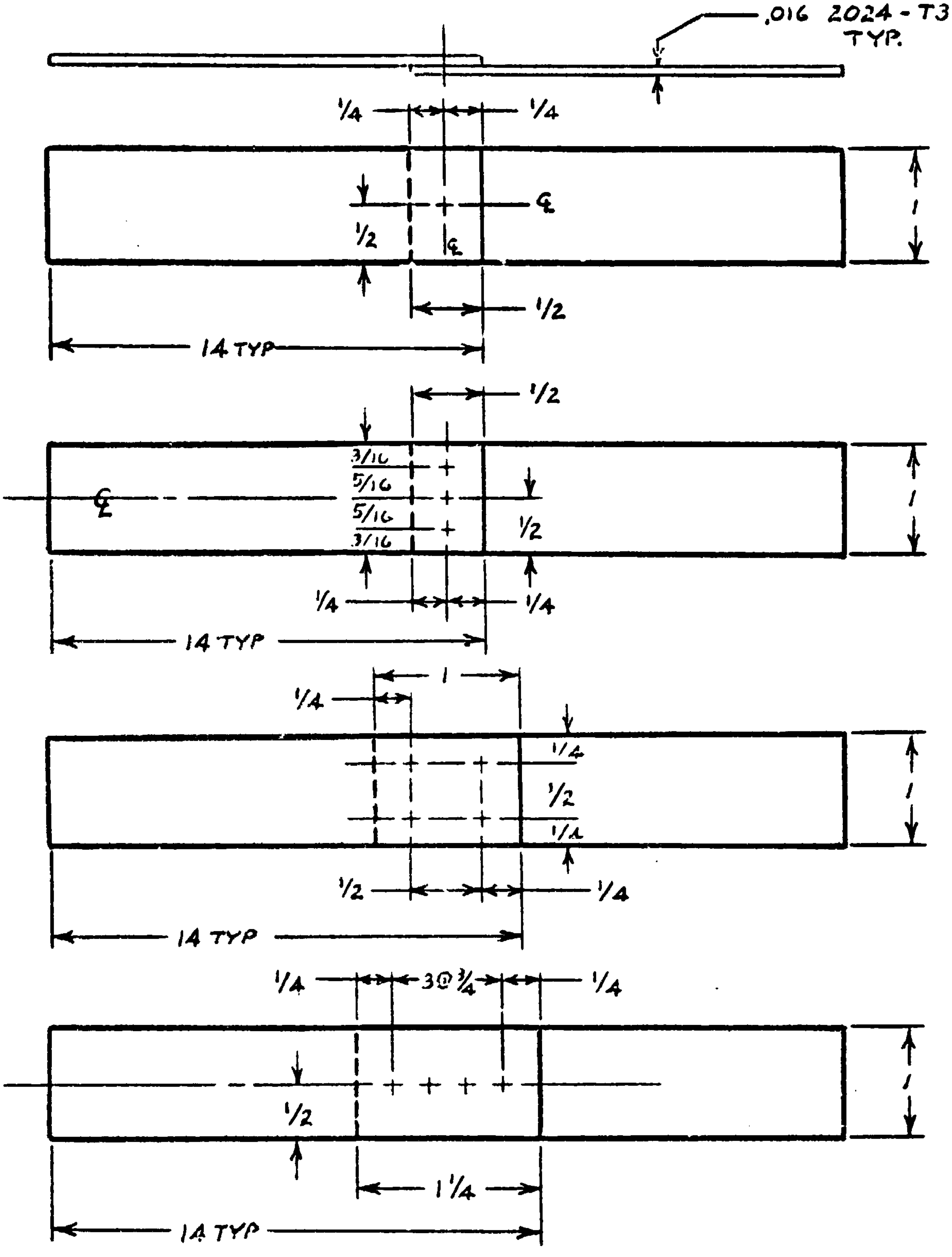


Figure 1. Spot Weld Evaluation Static and Fatigue
Test Specimen Configurations

Spec. No.	No. of Spots	Ultimate Failing Load (lbs)	Failing Load Per Spot (lbs)	Comment
A-1	1	170	170	
A-2	1	150	150	
A-3	1	191	191	
		170 Avg.	170 Avg.	
B-1	3	467	156	Considerable
B-2	3	479	159	Bending Extracted
B-3	3	473	158	Spots as "Plugs"
		473 Avg.	158 Avg.	
C-1	4 (2)	676	169	Slight
C-2	4 (Rows)	652	163	Bending
C-3	4 (of 2)	685	171	
		671 Avg.	168 Avg.	
D-1	4 (4)	715	179	Slight Bending
D-2	4 (Spots)	675	169	Selected for
D-3	4 (in)	709	177	Phase II
	(Line)			
		700 Avg.	175 Avg.	

Figure 2. Spot Weld Evaluation: Static Test Results

Spec. No.	Max. Load (lbs)	% Static Test Ultimate	Cycles to Failure	Mode of Failure
UNRESTRAINED JOINT				
1	350	55	6,000	Spot
2	210	33	106,000	Al
3	140	22	238,000	"
4	175	27.3	177,000	"
5	280	44	31,000	Spot
6	280	44	19,000	"
7	245	38.3	65,000	"
8	245	38.3	68,000	Al
9	227½	35.8	100,000	Spot
10	227½	35.8	100,000	"
11	140	22	255,000	Al
12	70	11	10,000,000	No Failure
12R	350	55	8,000	Spot
RESTRAINED JOINT				
13	210	33	109,000	Al
14	140	22	483,000	"
15	140	22	235,000	"
16	315	49.3	38,000	"
17	315	49.3	27,000	Spot
18	210	33	106,000	Al
19	140	22	510,000	"
20	105	16.4	2,560,000	"
21	70	11	10,000,000	No Failure
21R	245	38.3	63,000	Al
22	175	27.3	280,000	"
23	105	16.4	8,345,000	"

STATIC	ULT. LOAD (LBS)	LOAD PER SPOT (LBS)-4 SPOTS IN LINE
24	660	165
25	631	158
26	627	157
Ave.	639	160

Figure 3. Spot Weld Evaluation: Fatigue Test Results

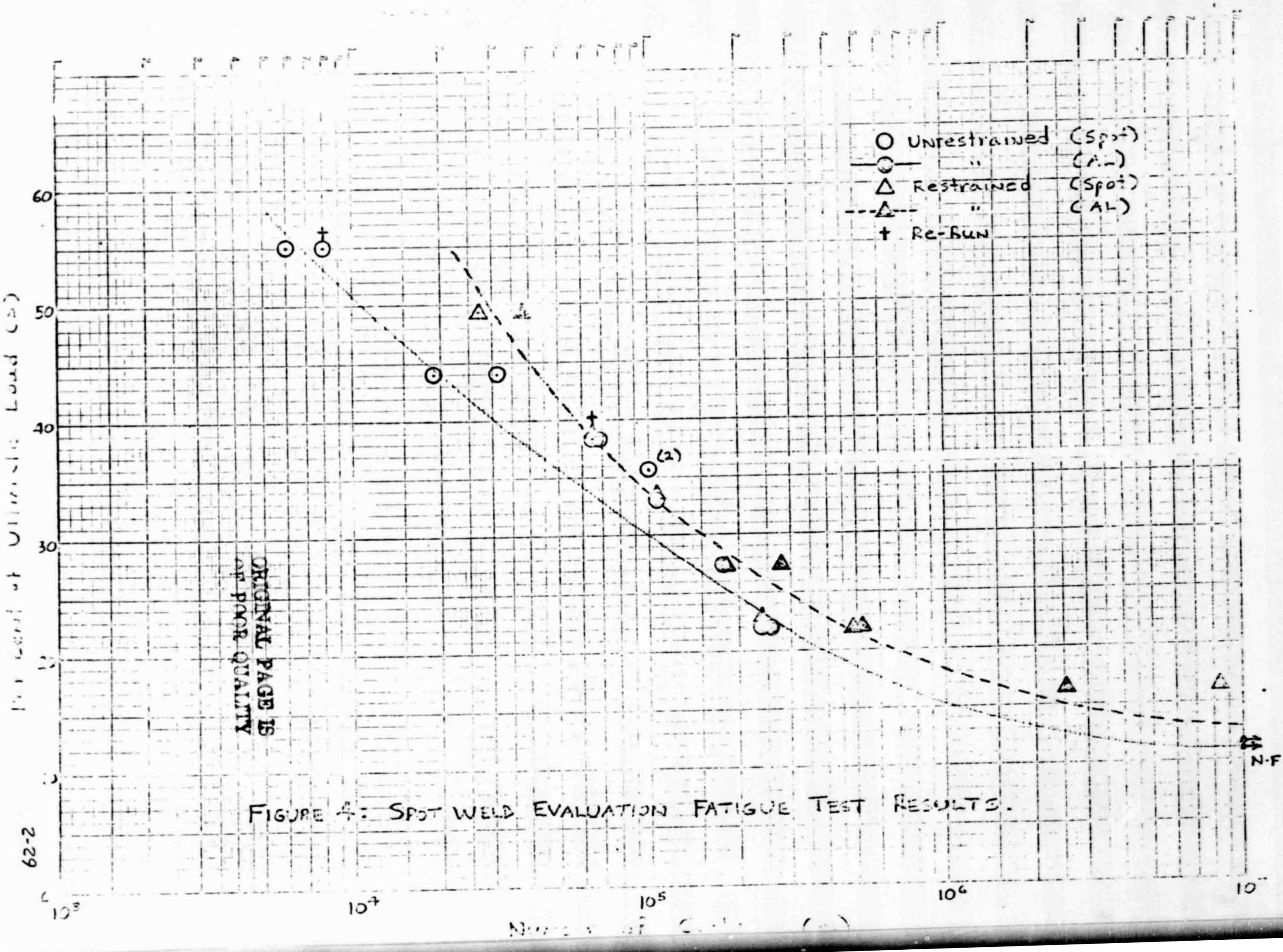


FIGURE 4: SPOT WELD EVALUATION FATIGUE TEST RESULTS.

APPENDIX B

MOTOR CROSS REFERENCE

MOTOR NUMBER	LOCATION	TYPE
	Vert Magazines	
M1	Right Vertical	
M2	Bottom Vertical	
M3	Left Vertical	
	Diagonal Magazines	
M4	Right Diagonal	
M5	Bottom Diagonal	
M6	Left Diagonal	
	Vert Carriage	
M7	Right Vertical	
M8	Bottom Vertical	
M9	Left Vertical	
	Diag Carriage	
M10	Right Diagonal	
M11	Bottom Diagonal	
M12	Left Diagonal	

ELECTRODE BLOCK CLAMP DEVICE
TRANSLATE

MOTOR NUMBER	LOCATION	TYPE
M13	Top Vertival	PMI U9 50:1 60 RPM
M14	Right Vertical	
M15	Left Vertical	
M16	Right Diagonal Aft	
M17	Right Diagonal Fwd	
M18	Bottom Diagonal Aft	
M19	Bottom Diagonal Fwd	
M20	Left Diagonal Aft	
M21	Left Diagonal Fwd	
	Scissors	
M22	Top Vertical	PMI U9FG 25:1 120 RPM
M23	Right Vertical	
M24	Left Vertical	
M25	Right Diagonal Aft	
M26	Right Diagonal Fwd	
M27	Bottom Diagonal Aft	
M28	Bottom Diagonal Fwd	
M29	Left Diagonal Aft	
M30	Left Diagonal Fwd	
	Cams	
M31	Right Vertical Top	PMI U9FG 50:1 Extended Shaft - Keyway
M32	Right Vertical Bottom	
M33	Bottom Vertical Right	
M34	Bottom Vertical Left	
M35	Left Vertical Top	
M36	Left Vertical Bottom	
M37	Right Diagonal Aft	
M38	Right Diagonal Fwd	
M39	Bottom Diagonal Aft	
M40	Bottom Diagonal Fwd	
M41	Left Diagonal Aft	
M42	Left Diagonal Fwd	
	Guillotines	PMZ U9FG 50:1
M43	Top Guillotine Upper	
M44	Top Guillotine Lower	
M45	Right Guillotine Upper	
M46	Right Guillotine Lower	
M47	Left Guillotine Upper	
M48	Left Guillotine Lower	

MOTOR CONTROL SIGNALS
(CONT'D)

NO.	MOTOR	FUNCTION
75	M41	cw
76	M41	ccw
77	M42	cw
78	M42	ccw
79	M43	Up
80	M43	Dn
81	M44	Up
82	M44	Dn
83	M45	Up
84	M45	Dn
85	M46	Up
86	M46	Dn
87	M47	Up
88	M47	Dn
89	M48	Up
90	M48	Dn

SOLENOID CONTROL SIGNALS

NO.	SOLENOID	FUNCTION
1	SOL 1, SOL 2, SOL 3, SOL 4,	Retract
2	SOL 5, SOL 6, SOL 7, SOL 8	Retract
3	SOL 9, SOL 10, SOL 11, SOL 12	Retract
4	SOL 13, SOL 14, SOL 15, SOL 16	Retract
5	SOL 17, SOL 18, SOL 19, SOL 20	Retract
6	SOL 21, SOL 22, SOL 23, SOL 24	Retract
7	SOL 25, SOL 26	Extend
8	SOL 27, SOL 28	Extend
9	SOL 29, SOL 30	Extend
10	SOL 31, SOL 32	Extend
11	SOL 33, SOL 34	Extend
12	SOL 35, SOL 36	Extend
13	SOL 37	Release
1	SOL 38	Release
15	SOL 39	Release
16	SOL 40	Release
17	SOL 41	Release
18	SOL 42	Release
19	SOL 43	Release
20	SOL 44	Release
21	SOL 45	Release
22	SOL 46	Release
23	SOL 47	Release
24	SOL 48	Release

SOLENOID CROSS REFERENCE

Vert Magazines

SOL 1	Right Vert A
SOL 2	Right Vert B
SOL 3	Right Vert C
SOL 4	Right Vert D
SOL 5	Bottom Vert A
SOL 6	Bottom Vert B
SOL 7	Bottom Vert C
SOL 8	Bottom Vert D
SOL 9	Left Vert A
SOL 10	Left Vert B
SOL 11	Left Vert C
SOL 12	Left Vert D

Diag Magazines

SOL 13	Right Diagonal A
SOL 14	Right Diagonal B
SOL 15	Right Diagonal C
SOL 16	Right Diagonal D
SOL 17	Bottom Liagonal A
SOL 18	Bottom Diagonal B
SOL 19	Bottom Diagonal C
SOL 20	Bottom Diagonal D
SOL 21	Left Diagonal A
SOL 22	Left Diagonal B
SOL 23	Left Diagonal C
SOL 24	Left Diagonal D

Vert Carriage

SOL 25	Right Vert A
SOL 26	Right Vert B
SOL 27	Bottom Vert A
SOL 28	Bottom Vert B
SOL 29	Left Vert A
SOL 30	Left Vert B

Diagonal Carriage

SOL 31	Right Diagonal A
SOL 32	Right Diagonal B
SOL 33	Bottom Diagonal A
SOL 34	Bottom Diagonal B
SOL 35	Left Diagonal A
SOL 36	Left Diagonal B

SOLENOID CROSS REFERENCE

Cams

SOL 37	Right Vert Top
SOL 38	Right Vert Bottom
SOL 39	Bottom Vert Right
SOL 40	Bottom Vert Left
SOL 41	Left Vert Top
SOL 42	Left Vert Bottom
SOL 43	Right Diagonal Aft
SOL 44	Right Diagonal Fwd
SOL 45	Bottom Diagonal Aft
SOL 46	Bottom Diagonal Fwd
SOL 47	Left Diagonal Aft
SOL 48	Left Diagonal Fwd

POSITION SWITCHES

SWITCH NUMBER	LOCATION
	Vert Magazines
LS1	Right Vert Home
LS2	Bottom Vert Home
LS3	Left Vert Home
LS4	Right Solenoid A Retract
LS5	Right Solenoid B Retract
LS6	Right Solenoid C Retract
LS7	Right Solenoid D Retract
LS8	Bottom Solenoid A Retract
LS9	Bottom Solenoid B Retract
LS10	Bottom Solenoic C Retract
LS11	Bottom Solenoid D Retract
LS12	Left Solenoid A Retract
LS13	Left Solenoid B Retract
LS14	Left Solenoid C Retract
LS15	Left Solenoid D Retract
	Diagonal Magazines
LS16	Right Diagonal Home
LS17	Bottom Diagonal Home
LS18	Left Diagonal Home
LS19	Right Solenoid A Retract
LS20	Right Solenoid B Retract
LS21	Right Solenoid C Retract
LS22	Right Solenoid D Retract
LS23	Bottom Solenoid A Retract
LS24	Bottom Solenoid B Retract
LS25	Bottom Solenoid C Retract
LS26	Bottom Solenoid D Retract
LS27	Left Solenoid A Retract
LS28	Left Solenoid B Retract
LS29	Left Solenoid C Retract
LS30	Left Solenoid C Retract
	Vertical Carriage
LS31	Right Vertical Home
LS32	Right Vertical Extend
LS33	Bottom Vertical Home
LS34	Bottom Vertical Extend
LS35	Left Vertical Home
LS36	Left Vertical Extend

POSITION SWITCHES (cont'd)

SWITCH NUMBER	LOCATION
	Vertical Carriage
LS37	Right Solenoid A Extend
LS38	Right Solenoid B Extend
LS39	Bottom Solenoid A Extend
LS40	Bottom Solenoid B Extend
LS41	Left Solenoid A Extend
LS42	Left Solenoid B Extend
	Diagonal Carriage
LS43	Right Diag Home
LS44	Right Diag Extend
LS45	Bottom Diag Home
LS46	Bottom Diag Extend
LS47	Left Diag Home
LS48	Left Diag Extend
LS49	Right Solenoid A Extend
LS50	Right Solenoid B Extend
LS51	Bottom Solenoid A Extend
LS52	Bottom Solenoid B Extend
LS53	Left Solenoid A Extend
LS54	Left Solenoid B Extend
	Electrode Flock Clamp Device Translate
LS55	Top Vertical Home
LS56	Top Vertical Extend
LS57	Right Vertical Home
LS58	Right Vertical Extend
LS59	Left Vertical Home
LS60	Left Vertical Extend
LS61	Right Diagonal Aft
LS62	Right Diagonal Aft Extend
LS63	Right Diagonal Fwd Home
LS64	Right Diagonal Fwd Extend
LS65	Bottom Diagonal Aft Home
LS66	Bottom Diagonal Aft Extend
LS67	Bottom Diagonal Fwd Home
LS68	Bottom Diagonal Fwd Extend

Electrode Block Clamp Device Translate

LS69	Left Diagonal Aft Home
LS70	Left Diagonal Aft Extend
LS71	Left Diagonal Fwd Home
LS72	Left Diagonal Fwd Extend

Scissors

LS73	Top Vertical Home
LS74	Top Vertical Contact
LS75	Right Vertical Home
LS76	Right Vertical Contact
LS77	Left Vertical Home
LS78	Left Vertical Contact
LS79	Right Diagonal Aft Home
LS80	Right Diagonal Aft Contact
LS81	Right Diagonal Fwd Home
LS82	Right Diagonal Fwd Contact
LS83	Bottom Diagonal Aft Home
LS84	Bottom Diagonal Aft Contact
LS85	Bottom Diagonal Fwd Home
LS86	Bottom Diagonal Fwd Contact
LS87	Left Diagonal Aft Home
LS88	Left Diagonal Aft Contact
LS89	Left Diagonal Fwd Home
LS90	Left Diagonal Fwd Contact

Cams

LS91	Right Vertical Top Home
LS92	Right Vertical Top Position A + B + C
LS93	Right Vertical Bottom Home
LS94	Right Vertical Bottom Position A + B + C
LS95	Bottom Vertical Right Home
LS96	Bottom Vertical Right Position A + B + C
LS97	Bottom Vertical Left Home
LS98	Bottom Vertical Left Position A + B + C
LS99	Left Vertical Top Home
LS100	Left Vertical Top Position A + B + C

POSITION SWITCHES (cont'd)

Cams

LS101 Left Vertical Bottom Home
LS102 Left Vertical Bottom Position A + B + C

LS103 Right Diagonal Aft Home
LS104 Right Diagonal Aft Position A + B + C

LS105 Right Diagonal Fwd Home
LS106 Right Diagonal Fwd Position A + B + C

LS107 Bottom Diagonal Aft Home
LS108 Bottom Diagonal Aft Position A + B + C

LS109 Bottom Diagonal Fwd Home
LS110 Bottom Diagonal Fwd Position A + B + C

LS111 Left Diagonal Aft Home
LS112 Left Diagonal Aft Position A + B + C

LS113 Left Diagonal Fwd Home
LS114 Left Diagonal Fwd Position A + B + C

Cam Solenoid

LS115 Right Vertical Top in Pos.
LS116 Right Vertical Bottom in Pos.

LS117 Bottom Vertical Right in Pos.
LS118 Bottom Vertical Left in Pos.

LS119 Left Vertical Top in Pos.
LS120 Left Vertical Bottom in Pos.

LS121 Right Diagonal Aft in Pos.
LS122 Right Diagonal Fwd in Pos.

LS123 Bottom Diagonal Aft in Pos.
LS124 Bottom Diagonal Fwd in Pos.

LS125 Left Diagonal Aft in Pos.
LS126 Left Diagonal Fwd in Pos.

Guillotine 211SM6-T

LS127 Top Guillotine Upper Home
LS128 Top Guillotine Cut Done
LS129 Top Guillotine Lower Home
LS130 Top Guillotine Lower Extended

LS131 Right Guillotine Upper Home
LS132 Right Guillotine Cut Done
LS133 Right Guillotine Lower Home
LS134 Right Guillotine Lower Extended

LS135 Left Guillotine Upper Home
LS136 Left Guillotine Cut Done
LS137 Left Guillotine Lower Home
LS138 Left Guillotine Lower Extended

POSITION SWITCHES (cont'd)

Scissors

LS139	Top Vertical	Pre Position
LS140	Right Vertical	Pre Position
LS141	Left Vertical	Pre Position
LS142	Right Diagonal Aft	Pre Position
LS143	Right Diagonal Fwd	Pre Position
LS144	Bottom Diagonal Aft	Pre Position
LS145	Bottom Diagonal Fwd	Pre Position
LS146	Left Diagonal Aft	Pre Position
LS147	Left Diagonal Fwd	Pre Position

FEEDBACK SIGNALS

SIGNAL NO.	FUNCTION	SWITCHES
	Vertical Magazines	
S-1	Right Vertical Home	LS1
S-2	Bottom Vertical Home	LS2
S-3	Left Vertical Home	LS3
S-4	Right Vertical Solenoids Retract	LS4.LS5.LS6. LS7
S-5	Bottom Vertical Solenoids Retract	LS8.LS9.LS10.LS11
S-6	Left Vertical Solenoids Retract	LS12.LS13.LS14.LS15
	Diagonal Magazines	
S-7	Right Diagonal Home	LS16
S-8	Bottom Diagonal Home	LS17
S-9	Left Diagonal Home	LS18
S-10	Right Diagonal Solenoids Retract	LS19.LS20.LS21.LS22
S-11	Bottom Diagonal Solenoids Retract	LS23.LS24.LS25.LS26
S-12	Left Diagonal Solenoids Retract	LS27.LS28.LS29.LS30
	Vertical Carriage	
S-13	Right Vertical In Position	LS31 + LS32
S-14	Bottom Vertical In Position	LS33 + LS34
S-15	Left Vertical In Position	LS35 + LS36
S-16	Right Vertical Solenoids Extend	LS37.LS38
S-17	Bottom Vertical Solenoids Extend	LS39.LS40
S-18	Left Vertical Solenoids Extend	LS41.LS42
	Diagonal Carriage	
S-19	Right Diagonal In Position	LS43 + LS44
S-20	Bottom Diagonal In Position	LS45 + LS46
S-21	Left Diagonal In Position	LS47 + LS48
S-22	Right Diagonal Solenoids Extend	LS49. LS50
S-23	Bottom Diagonal Solenoids Extend	LS51.LS52
S-24	Left Diagonal Solenoids Extend	LS53.LS54
	Electrode Block Clamp Devices	
S-25	Top Vertical In Position	LS55 + LS56
S-26	Right Vertical In Position	LS57 + LS58
S-27	Left Vertical In Position	LS59 + LS60
S-28	Right Diagonal Aft In Position	LS61 + LS62
S-29	Right Diagonal Fwd In Position	LS63 + LS64
S-30	Bottom Diagonal Aft In Position	LS65 + LS66
S-31	Bottom Diagonal Fwd In Position	LS67 + LS68
S-32	Left Diagonal Aft In Position	LS69 + LS70
S-33	Left Diagonal Aft In Position	LS71 + LS72

FEEDBACK SIGNALS (Cont'd)

SIGNAL NO.	FUNCTION	SWITCHES
	Scissors	
S-34	Top Vertical In Position	LS73 + LS74
S-35	Right Vertical In Position	LS75 + LS76
S-36	Left Vertical In Position	LS77 + LS78
S-37	Right Diagonal Aft In Position	LS79 + LS80
S-38	Right Diagonal Fwd In Position	LS81 + LS82
S-39	Bottom Diagonal Aft In Position	LS83 + LS84
S-40	Bottom Diagonal Fwd In Position	LS85 + LS86
S-41	Left Diagonal Aft In Position	LS87 + LS88
S-42	Left Diagonal Fwd In Position	LS89 + LS90
S-43	Right Vertical Top Home	LS91
S-44	Right Vertical Top In Position	LS92
S-45	Right Vertical Bottom Home	LS95
S-46	Right Vertical Bottom In Position	LS96
S-47	Bottom Vertical Right Home	LS95
S-48	Bottom Vertical Right In Position	LS96
S-49	Bottom Vertical Left Home	LS97
S-50	Bottom Vertical Left In Position	LS98
S-51	Left Vertical Top Home	LS99
S-52	Left Vertical Top In Position	LS100
S-53	Left Vertical Bottom Home	LS101
S-54	Left Vertical Bottom In Position	LS102
S-55	Right Diagonal Aft Home	LS103
S-56	Right Diagonal Aft In Position	LS104
S-57	Right Diagonal Fwd Home	LS105
S-58	Right Diagonal Fwd In Position	LS106
S-59	Bottom Diagonal Aft Home	LS107
S-60	Bottom Diagonal Aft In Position	LS108
S-61	Bottom Diagonal Fwd Home	LS109
S-62	Bottom Diagonal Fwd In Position	LS110
S-63	Left Diagonal Aft Home	LS111
S-64	Left Diagonal Aft In Position	LS112
S-65	Left Diagonal Fwd Home	LS113
S-66	Left Diagonal Fwd In Position	LS114
	Cam Solenoids	
S-67	Right Vertical Top In Position	LS115
S-68	Right Vertical Bottom In Position	LS116
S-69	Bottom Vertical Right In Position	LS117
S-70	Bottom Vertical Left In Position	LS118

FEEDBACK SIGNALS (CONT'd)

SIGNAL NO.	FUNCTION	SWITCHES
	Cam Solenoids	
S-71	Left Vertical Top In Position	LS119
S-72	Left Vertical Bottom In Position	LS120
S-73	Right Diagonal Aft In Position	LS121
S-74	Right Diagonal Fwd In Position	LS122
S-75	Bottom Diagonal Aft In Position	LS123
S-76	Bottom Diagonal Fwd In Position	LS124
S-77	Left Diagonal Aft In Position	LS125
S-78	Left Diagonal Fwd In Position	LS126
	Guillotine	
S-79	Top Guillotine Upper Home	LS127
S-80	Top Guillotine Cut Done	LS128
S-81	Top Guillotine Lower In Position	LS129 + LS130
S-82	Right Guillotine Upper Home	LS131
S-83	Right Guillotine Cut Done	LS132
S-84	Right Guillotine Lower In Position	LS133 + LS134
S-85	Left Guillotine Upper Home	LS135
S-86	Left Guillotine Cut Done	LS136
S-87	Left Guillotine Lower In Position	LS137 + LS138
	Scissors	
S-88	Top Vertical Pre Position	LS139
S-89	Right Vertical Pre Position	LS140
S-90	Left Vertical Pre Position	LS141
S-91	Right Diagonal Aft Pre Position	LS142
S-92	Right Diagonal Fwd Per Position	LS143
S-93	Bottom Diagonal Aft Per Position	LS144
S-94	Bottom Diagonal Fwd Per Position	LS145
S-95	Left Diagonal Aft Per Position	LS146
S-96	Left Diagonal Fwd Per Position	LS147

M1705 CARD #4A - Load Command IOT 6363

BIT	MOTOR	CONTROL	FUNCTION	
0	M37	1/0 - Off/cw	Cam Right Diag	Aft
1	M37	1/0 - Off/ccw	Cam Right Diag	Aft
2	M38	1/0 - Off/cw	Cam Right Diag	Fwd
3	M38	1/0 - Off/ccw	Cam Right Diag	Fwd
4	M39	1/0 - Off/cw	Cam Bottom Diag	Aft
5	M39	1/0 - Off/ccw	Cam Bottom Diag	Aft
6	M40	1/0 - Off/cw	Cam Bottom Diag	Fwd
7	M40	1/0 - Off/ccw	Cam Bottom Diag	Fwd
8	M41	1/0 - Off/cw	Cam Left Diag	Aft
9	M41	1/0 - Off/ccw	Cam Left Diag	Aft
10	M42	1/0 - Off/cw	Cam Left Diag	Fwd
11	M42	1/0 - Off/ccw	Cam Left Diag	Fwd

M1705 CARD #4B - Load Command IOT 6373

BIT	MOTOR	CONTROL	FUNCTION	
0	M43	1/0 - Off/Up	Guillotine Top	Upper
1	M43	1/0 - Off/Dn	Guillotine Top	Upper
2	M44	1/0 - Off/Up	Guillotine Top	Lower
3	M44	1/0 - Off/Dn	Guillotine Top	Lower
4	M45	1/0 - Off/Up	Guillotine Right	Upper
5	M45	1/0 - Off/Dn	Guillotine Right	Upper
6	M46	1/0 - Off/Up	Guillotine Right	Lower
7	M46	1/0 - Off/Dn	Guillotine Right	Lower
8	M47	1/0 - Off/Up	Guillotine Left	Upper
9	M47	1/0 - Off/Dn	Guillotine Left	Upper
10	M48	1/0 - Off/Up	Guillotine Left	Lower
11	M48	1/0 - Off/Dn	Guillotine Left	Lower

M1705 CARD #5A - Load Command IOT 6403

BIT	SOLENOID	CONTROL	FUNCTION
0	1,2,3,4	1/0 - Off/On	Right Vertical Magazine
1	5,6,7,8	1/0 - Off/On	Bottom Vertical Magazine
2	9,10,11,12	1/0 - Off/On	Left Vertical Magazine
3	13,14,15,16	1/0 - Off/On	Right Diagonal Magazine
4	17,18,19,20	1/0 - Off/On	Bottom Diagonal Magazine
5	21,22,23,24	1/0 - Off/On	Left Diagonal Magazine
6	25,26	1/0 - Off/On	Right Vertical Carriage
7	27,28	1/0 - Off/On	Bottom Vertical Carriage
8	29,30	1/0 - Off/On	Left Vertical Carriage
9	31,32	1/0 - Off/On	Right Diagonal Carriage
10	33,34	1/0 - Off/On	Bottom Diagonal Carriage
11	35,36	1/0 - Off/On	Left Diagonal Carriage

M1705 CARD #5B - Load Command 6413

BIT	SOLENOID	CONTROL	FUNCTION
0	37	1/0 - Off/On	Right Vertical Top Cam
1	38	1/0 - Off/On	Right Vertical Bottom Cam
2	39	1/0 - Off/On	Bottom Vertical Right Cam
3	40	1/0 - Off/On	Bottom Vertical Left Cam
4	41	1/0 - Off/On	Left Vertical Top Cam
5	42	1/0 - Off/On	Left Vertical Bottom Cam
6	43	1/0 - Off/On	Right Diagonal Aft Cam
7	44	1/0 - Off/On	Right Diagonal Fwd Cam
8	45	1/0 - Off/On	Bottom Diagonal Aft Cam
9	46	1/0 - Off/On	Bottom Diagonal Fwd Cam
10	47	1/0 - Off/On	Left Diagonal Aft Cam
11	48	1/0 - Off/On	Left Diagonal Fwd Cam

M1705 CARD #1A - Load Command IOT 6303

BIT	MOTOR	CONTROL	FUNCTION
0	M1	1/0 - Off/On	Right Vertical Magazine
1	M2	1/0 - Off/On	Bottom Vertical Magazine
2	M3	1/0 - Off/On	Left Vertical Magazine
3	M7	1/0 - Off/Up	Right Vertical Carriage
4	M7	1/0 - Off/Dn	Right Vertical Carriage
5	M8	1/0 - Off/Up	Bottom Vertical Carriage
6	M8	1/0 - Off/Dn	Bottom Vertical Carriage
7	M9	1/0 - Off/Up	Left Vertical Carriage
8	M9	1/0 - Off/Dn	Left Vertical Carriage
9			
10			
11			

M1705 CARD #1B - Load Command IOT 6313

BIT	MOTOR	CONTROL	FUNCTION
0	M4	1/0 - Off/On	Right Diagonal Magazine
1	M5	1/0 - Off/On	Bottom Diagonal Magazine
2	M6	1/0 - Off/On	Left Diagonal Magazine
3	M10	1/0 - Off/Up	Right Diagonal Carriage
4	M10	1/0 - Off/Dn	Right Diagonal Carriage
5	M11	1/0 - Off/Up	Bottom Diagonal Carriage
6	M11	1/0 - Off/Dn	Bottom Diagonal Carriage
7	M12	1/0 - Off/Up	Left Diagonal Carriage
8	M12	1/0 - Off/Dn	Left Diagonal Carriage
9			
10			
11			

M1705 CARD #2A - Load Command IOT 6323

BIT	MOTOR	CONTROL	FUNCTION
0	M13	1/0 - Off/Up	EBCD Top Vertical
1	M13	1/0 - Off/Dn	EBCD Top Vertical
2	M14	1/0 - Off/Up	EBCD Right Vertical
3	M14	1/0 - Off/Dn	EBCD Right Vertical
4	M15	1/0 - Off/Up	EBCD Left Vertical
5	M15	1/0 - Off/Dn	EBCD Left Vertical
6	M22	1/0 - Off/Close	Scissor Top Vertical
7	M22	1/0 - Off/Open	Scissor Top Vertical
8	M23	1/0 - Off/Close	Scissor Right Vertical
9	M23	1/0 - Off/Open	Scissor Right Vertical
10	M24	1/0 - Off/Close	Scissor Left Vertical
11	M24	1/0 - Off/Open	Scissor Left Vertical

M1705 CARD #2B - Load Command IOT 6333

BIT	MOTOR	CONTROL	FUNCTION
0	M16	1/0 - Off/Up	EBCD Right Diag Aft
1	M16	1/0 - Off/Dn	EBCE Right Diag Aft
2	M17	1/0 - Off/Up	EBCD Right Diag Fwd
3	M17	1/0 - Off/Dn	EBCD Right Diag Fwd
4	M18	1/0 - Off/Up	EBCD Bottom Diag Aft
5	M18	1/0 - Off/Dn	EBCD Bottom Diag Aft
6	M19	1/0 - Off/Up	EBCE Bottom Diag Fwd
7	M19	1/0 - Off/Dn	EBCD Bottom Diag Fwd
8	M20	1/0 - Off/Up	EBCD Left Diag Aft
9	M20	1/0 - Off/DN	EBCD Left Diag Aft
10	M21	1/0 - Off/Up	EBCD Left Diag Fwd
11	M21	1/0 - Off/DN	EBCD Left Diag Fwd

M1705 CARD #3A - Load Command IOT 6343

BIT	MOTOR	CONTROL	FUNCTION
0	M25	1/0 - Off/Close	Scissor Right Diag Aft
1	M25	1/0 - Off/Open	Scissor Right Diag Aft
2	M26	1/0 - Off/Close	Scissor Right Diag Fwd
3	M26	1/0 - Off/Open	Scissor Right Diag Fwd
4	M27	1/0 - Off/Close	Scissor Bottom Diag Aft
5	M27	1/0 - Off/Open	Scissor Bottom Diag Aft
6	M28	1/0 - Off/Close	Scissor Bottom Diag Fwd
7	M28	1/0 - Off/Open	Scissor Bottom Diag Fwd
8	M29	1/0 - Off/Close	Scissor Left Diag Aft
9	M29	1/0 - Off/Open	Scissor Left Diag Aft
10	M30	1/0 - Off/Close	Scissor Left Diag Fwd
11	M30	1/0 - Off/Open	Scissor Left Diag Fwd

M1705- CARD #3B - Load Command IOT 6353

BIT	MOTOR	CONTROL	FUNCTION
0	M31	1/0 - Off/cw	Cam Right Vert Top
1	M31	1/0 - Off/ccw	Cam Right Vert Top
2	M32	1/0 - Off/cw	Cam Right Vert Bottom
3	M32	1/0 - Off/ccw	Cam Right Vert Bottom
4	M33	1/0 - Off/cw	Cam Bottom Vert Right
5	M33	1/0 - Off/ccw	Cam Bottom Vert Right
6	M34	1/0 - Off/cw	Cam Bottom Vert Left
7	M34	1/0 - Off/ccw	Cam Bottom Vert Left
8	M35	1/0 - Off/cw	Cam Left Vert Top
9	M35	1/0 - Off/ccw	Cam Left Vert Top
10	M36	1/0 - Off cw	Cam Left Vert Bottom
11	M36	1/0 - Off/ccw	Cam Left Vert Bottom

FORTE CARD 2

MUX WORD #1 - Read Command IOT 6560

BIT	S#	FUNCTION
0	1	Right Vert Magazine Home
1	2	Bottom Vert Magazine Home
2	3	Left Vert Magazine Home
3	4	Right Vert Magazine Solenoid Retract
4	5	Bottom Vert Magazine Solenoid Retract
5	6	Left Vert Magazine Solenoid Retract
6	13	Right Vert Carriage in Position
7	14	Bottom Vert Carriage in Position
8	15	Left Vert Carriage in Position
9	16	Right Vert Carriage Solenoid Extend
10	17	Bottom Vert Carriage Solenoid Extend
11	18	Left Vert Carriage Solenoid Extend

FORTE CARD 2

MUX WORD #2 - Read Command IOT 6561

BIT	S#	FUNCTION
0	7	Right Diag Magazine Home
1	8	Bottom Diag Magazine Home
2	9	Left Diag Magazine Home
3	10	Right Diag Magazine Solenoid Retract
4	11	Bottom Diag Magazine Solenoid Retract
5	12	Left Diag Magazine Solenoid Retract
6	19	Right Diag Carriage in Position
7	20	Bottom Diag Carriage in Position
8	21	Left Diag Carriage in Position
9	22	Right Diag Carriage Solenoid Extend
10	23	Bottom Diag Carriage Solenoid Extend
11	24	Left Diag Carriage Solenoid Extend

FORTE CARD 2

MUX WORD #3 - Read Command IOT 6562

BIT	S#	FUNCTION
0	25	EBCD Top Vert in Position
1	26	EBCD Right Vert in Position
2	27	EBCD Left Vert in Position
3	28	EBCD Right Diag Aft in Position
4	29	EBCD Right Diag Fwd in Position
5	30	EBCD Bottom Diag Aft in Position
6	31	EBCD Bottom Diag Fwd in Position
7	32	EBCD Left Diag Aft in Position
8	33	EBCD Left Diag Fwd in Position
9		
10		
11		

FORTE CARD 2

MUX WORD #4 - Read Command IOT 6563

BIT	S#	FUNCTION
0	34	Scissors Top Vert in Position
1	35	Scissors Right Vert in Position
2	36	Scissors Left Vert in Position
3	37	Scissors Right Diag Aft in Position
4	38	Scissors Right Diag Fwd in Position
5	39	Scissors Bottom Diag Aft in Position
6	40	Scissors Bottom Diag Fwd in Position
7	41	Scissors Left Diag Aft in Position
8	42	Scissors Left Diag Fwd in Position
9		
10		
11		

FORTE CARD 2

MUX WORD #5 - Read Command IOT 6564

BIT	S#	FUNCTION
0	43	Right Vert Top Cam Home
1	44	Right Vert Top Cam In Position
2	67	Right Vert Top Cam Solenoid in Position
3	45	Right Vert Bottom Cam Home
4	46	Right Vert Bottom Cam in Position
5	68	Right Vert Bottom Cam Solenoid in Position
6	47	Bottom Vert Right Cam Home
7	48	Bottom Vert Right Cam in Position
8	69	Bottom Vert Right Cam Solenoid in Position
9	49	Bottom Vert Left Cam Home
10	50	Bottom Vert Left Cam in Position
11	70	Bottom Vert Left Cam solenoid in Position

FORTE CARD 2

MUX WORD #6 - Read Command IOT 6565

BIT	S#	FUNCTION
0	51	Left Vert Top Cam Home
1	52	Left Vert Top Cam in Position
2	71	Left Vert Top Cam Solenoid in Pos.
3	53	Left Vert Bottom Cam Home
4	54	Left Vert Bottom Cam in Position
5	72	Left Vert Bottom Cam Solenoid in position
6	55	Right Diag Aft Cam Home
7	56	Right Diag Aft Cam in Position
8	73	Right Diag Aft Cam Solenoid in Position
9	57	Right Diag Fwd Cam Home
10	58	Right Diag Fwd cam in Position
11	74	Right Diag Fwd Cam Solenoid in Position

FORTE CARD 2

MUX WORD #7 - READ COMMAND IOT 6566

BIT	S#	FUNCTION
0	59	Bottom Diag Aft Cam Home
1	60	Bottom Diag Aft Cam In Position
2	75	Bottom Diag Aft Cam Solenoid in Pos
3	61	Bottom Diag Fwd Cam Home
4	62	Bottom Diag Fwd Cam In Position
5	76	Bottom Diag Fwd Cam Solenoid in Pos
6	63	Left Diag Aft Cam Home
7	64	Left Diag Aft Cam Home
8	77	Left Diag Aft Cam Solenoid in Pos.
9	65	Left Diag Fwd Cam Home
10	66	Left Diag Fwd Cam In Position
11	78	Left Diag Fwd Cam Solenoid in Pos.

FORTE CARD 2

MUX WORK #8 - Read Command IOT 6567

BIT	S#	FUNCTION
0	79	Top Guillotine Upper Home
1	80	Top Guillotine Cut Done
2	81	Top Guillotine Lower in Position
3	82	Right Guillotine Upper Home
4	83	Right Guillotine Cut Done
5	84	Right Guillotine Lower in Position
6	85	Left Guillotine Upper Home
7	86	Left Guillotine Cut Done
8	87	Left Guillotine Lower in Position
9		
10		
11		

FORTE CARD 1

MUX WORD #1 - Read Command IOT 6520

BIT	S#	FUNCTION
0	88	Scissor Top Vert Preposition
1	89	Scissor Right Vert Preposition
2	90	Scissor Left Vert Preposition
3	91	Scossor Right Diag Preposition
4	92	Scissor Right Diag Preposition
5	93	Scossor Bottom Diag Preposition
6	94	Scissor Bottom Diag Preposition
7	95	Scissor Left Diag Preposition
8	96	Scissor Left Diag Preposition
9		

APPENDIX C - PROGRAM LISTING

```
SERVO: PROCEDURE OPTIONS (MAIN);
    DCL EMCD(3) FIXED DECIMAL(9,4) INIT(0,0,0);
    DCL FIFO(3,2) FIXED DECIMAL (3,0) INIT((6)0);
    DCL NEW_F(3) FIXED DECIMAL(9,5);
    DCL ERROR(3) FIXED DECIMAL(9,5) INIT(0,0,0);
    DCL HH FIXED DECIMAL (9,5) INIT (1.);
    DCL NPW FIXED DECIMAL (9,5) INIT (.00194);
    DCL TARGET FIXED DECIMAL (9,5) INIT (59.0);
    DCL MAX_LD FIXED DECIMAL (3,0) INIT (192);
    DCL MERGE BINARY FIXED INIT (0);
    DCL END_ERROR FIXED DECIMAL (9,5) INIT (0);
    DCL MAX_ERROR FIXED DECIMAL(9,5) INIT(0);
    DCL TEMP FIXED DECIMAL(9,5) INIT(0);
    DCL END_POS(3) FIXED DECIMAL(9,4);
    DCL PRE_ER(3) FIXED DECIMAL(9,5);
    DCL REM(3) FIXED DECIMAL(9,4);
    DCL PULSE(3) FIXED DECIMAL(9,1);
    DCL OUTPUT(3) FIXED DECIMAL(9,1);
    DCL T1 FIXED DECIMAL(9,1);
    DCL ER_PULSE(3) FIXED DECIMAL(4,1);
    DCL NEW_COUNT(3) FIXED DECIMAL(4,0);
    DCL NEW_COUNTA(3) FIXED DECIMAL(4,0);
    DCL FIFOA(3,2) FIXED DECIMAL(3,0);
START: /* START */
/* SIMULATE ENCODER READ, DETERMINATION OF NEW
   SLIPPAGE FACTORS (NEW_F) & COMPUTATION OF
   ENCODER MEASURED CUMULATIVE DISTANCE (EMCD)
*/
    GET SKIP DATA (NEW_F);
    IF NEW_F(1) < .2 THEN DO;
      CLOSE FILE(SYSIN);
      OPEN FILE(SYSIN);
      GO TO START;
    END;

    DO N=1 TO 3;
         EMCD(N)=EMCD(N)+(NPW)*(FIFO(N,1))*(NEW_F(N));

    END;
    FIFOA=FIFO;
/* COMPUTE POSITION VARIATION OF EACH CAP SECTION
   WITH RESPECT TO SLOWEST CAP SECTION
*/
    TEMP=MIN(EMCD(1), EMCD(2), EMCD(3));

    DO N=1 TO 3;
         ERROR(N)=EMCD(N)-TEMP;
         MAX_ERROR=MAX(MAX_ERROR,ERROR(N));

    END;
/* PREDICT CAP POSITION WHEN FIFO IS EMPTY
*/

    DO N=1 TO 3;
         END_POS(N)=EMCD(N)+NEW_F(N)*NPW*FIFO(N,2);

    END;
/* PREDICT VARIATION OF EACH CAP SECTION W.R.T.
   SLOWEST CAP WHEN FIFO IS EMPTY
*/
    TEMP=MIN(END_POS(1),END_POS(2),END_POS(3));

    DO N=1 TO 3;
         PRE_ER(N)=END_POS(N)-TEMP;
```

```
   END;
/* CALCULATE THE REMAINING PREDICTED DISTANCE TO
   MOVE WHEN FIFO IS EMPTY
*/

    DO N=1 TO 3;
         REM(N)=TARGET-END_POS(N);
         IF REM(N)<0 THEN REM(N)=0;
         IF MERGE=1 THEN
            DO WHILE ((MAX_LD>(REM(N)/(1.25*NPW)))
                     &(MAX_LD>2));
              MAX_LD=ROUND((.75*MAX_LD),0);
              MAX_LD=MAX(MAX_LD,2);
            END;

    END;
/*CALCULATE THE TOTAL REMAINING PULSES TO BE
   SENT OUT TO EACH MOTOR
*/

    DO N=1 TO 3;
         PULSE(N)=REM(N)/(NEW_F(N)*NPW);

    END;
/* COMPUTE PULSES TO BE SENT OUT AT NEXT LOAD OF
   FIFO WITH NO SLIPPAGE
*/
    T1= MAX(PULSE(1),PULSE(2),PULSE(3));

   IF T1>MAX_LD  THEN
    DO N=1 TO 3;
         OUTPUT(N)=(MAX_LD /T1)*PULSE(N);

    END;
   ELSE OUTPUT=PULSE;
/* COMPUTE PULSES REQUIRED TO MAKE UP POSITION
   VARIATION IN NEXT LOAD
*/

    DO N=1 TO 3;
         ER_PULSE(N)=PRE_ER(N)/(NPW)*(NEW_F(N));

    END;
/* CALCULATE THE NEW PULSE STREAM TO SEND OUT
*/

    DO N=1 TO 3;
         NEW_COUNTA(N)=ROUND((OUTPUT(N)-ER_PULSE(N)),0);
         IF NEW_COUNTA(N)<0 THEN NEW_COUNTA(N)=0;

    END;
/* RENORMALIZE
*/
     T1=MAX((PULSE(1)-ER_PULSE(1)),(PULSE(2)-ER_PULSE(2)),
           (PULSE(3)-ER_PULSE(3)));
     IF T1>MAX_LD THEN
       DO;
         T1=MAX(NEW_COUNTA(1),NEW_COUNTA(2),NEW_COUNTA(3));
         DO N=1 TO 3;
           NEW_COUNT(N)=(MAX_LD/T1)*NEW_COUNTA(N);
         END;
       END;
     ELSE NEW_COUNT=NEW_COUNTA;
/* SIMULATE FIFO LOAD
*/
```

```
DO N=1 TO 3;
     FIFO(N,1)=FIFO(N,2);
     FIFO(N,2)=NEW_COUNT(N);

END;
IF REM(1)<HH ^ REM(2)<HH ^ REM(3)<HH THEN
DO;
PUT SKIP (2) DATA (NEW_F);
PUT SKIP DATA (FIFOA(1,1),FIFOA(2,1),FIFOA(3,1));
PUT SKIP DATA (FIFOA(1,2),FIFOA(2,2),FIFOA(3,2));
PUT SKIP DATA(EMCD);
PUT SKIP DATA(ERROR);
PUT SKIP DATA(END_POS);
PUT SKIP DATA(PRE_ER);
PUT SKIP DATA(REM);
PUT SKIP DATA(PULSE);
PUT SKIP DATA(OUTPUT);
PUT SKIP DATA(ER_PULSE);
PUT SKIP DATA(NEW_COUNTA);
PUT SKIP DATA(NEW_COUNT);
PUT SKIP DATA (FIFO(1,1),FIFO(2,1),FIFO(3,1));
PUT SKIP DATA (FIFO(1,2),FIFO(2,2),FIFO(3,2));
END;
IF (FIFO(1,1)=0)&(FIFO(1,2)=0)&(FIFO(2,1)=0)&
   (FIFO(2,2)=0)&(FIFO(3,1)=0)&(FIFO(3,2)=0) THEN
  IF MERGE=0 THEN
    DO;
      TARGET=59.056;
      MERGE=1;
    END;
  ELSE
    DO;
      DO N=1 TO 3;
        END_ERROR=MAX(END_ERROR,ABS(59.055-EMCD(N)));
      END;
      PUT SKIP (5);
      PUT SKIP DATA (MAX_ERROR);
      PUT SKIP DATA (END_ERROR);
      STOP;
    END;
  GO TO START;
END SERVO;

R;
>TRANSFER COMPLETED
RENAME FILE (TEMPIN.PA) IF IT IS TO BE SAVED.
```

```
>P FILE SYSIN   APPENDIX A - INPUT FILE        C-3

 AA=1,BB=30,DD=59.055,PP=999,LL=.0,FF=100,GG=.004,TAG=0,HH=.1,MM=2;
NEW_F(1)=      0.84400   NEW_F(2)=      0.86200   NEW_F(3)=      0.82400;
NEW_F(1)=      0.84850   NEW_F(2)=      0.85595   NEW_F(3)=      0.83725;
NEW_F(1)=      0.85300   NEW_F(2)=      0.84990   NEW_F(3)=      0.85050;
NEW_F(1)=      0.85750   NEW_F(2)=      0.84385   NEW_F(3)=      0.86375;
NEW_F(1)=      0.86200   NEW_F(2)=      0.83780   NEW_F(3)=      0.87700;
NEW_F(1)=      0.86095   NEW_F(2)=      0.83225   NEW_F(3)=      0.87375;
NEW_F(1)=      0.85990   NEW_F(2)=      0.82670   NEW_F(3)=      0.87050;
NEW_F(1)=      0.85885   NEW_F(2)=      0.82115   NEW_F(3)=      0.86725;
NEW_F(1)=      0.85780   NEW_F(2)=      0.81560   NEW_F(3)=      0.86400;
NEW_F(1)=      0.85945   NEW_F(2)=      0.81670   NEW_F(3)=      0.86025;
NEW_F(1)=      0.86110   NEW_F(2)=      0.81780   NEW_F(3)=      0.85650;
NEW_F(1)=      0.86275   NEW_F(2)=      0.81890   NEW_F(3)=      0.85275;
NEW_F(1)=      0.86440   NEW_F(2)=      0.82000   NEW_F(3)=      0.84900;
NEW_F(1)=      0.86275   NEW_F(2)=      0.82100   NEW_F(3)=      0.84725;
NEW_F(1)=      0.36110   NEW_F(2)=      0.82200   NEW_F(3)=      0.84550;
NEW_F(1)=      0.85945   NEW_F(2)=      0.82300   NEW_F(3)=      0.84375;
NEW_F(1)=      0.85780   NEW_F(2)=      0.82400   NEW_F(3)=      0.84200;
NEW_F(1)=      0.84885   NEW_F(2)=      0.83725   NEW_F(3)=      0.83425;
NEW_F(1)=      0.83990   NEW_F(2)=      0.85050   NEW_F(3)=      0.82650;
NEW_F(1)=      0.83095   NEW_F(2)=      0.86375   NEW_F(3)=      0.81875;
NEW_F(1)=      0.82200   NEW_F(2)=      0.87700   NEW_F(3)=      0.81100;
NEW_F(1)=      0.82875   NEW_F(2)=      0.87375   NEW_F(3)=      0.80825;
NEW_F(1)=      0.83550   NEW_F(2)=      0.87050   NEW_F(3)=      0.80550;
NEW_F(1)=      0.84225   NEW_F(2)=      0.86725   NEW_F(3)=      0.80275;
NEW_F(1)=      0.84900   NEW_F(2)=      0.86400   NEW_F(3)=      0.80000;
NEW_F(1)=      0.86000   NEW_F(2)=      0.86025   NEW_F(3)=      0.80000;
NEW_F(1)=      0.87100   NEW_F(2)=      0.85650   NEW_F(3)=      0.80000;
NEW_F(1)=      0.88200   NEW_F(2)=      0.85275   NEW_F(3)=      0.80000;
NEW_F(1)=      0.89300   NEW_F(2)=      0.84900   NEW_F(3)=      0.80000;
NEW_F(1)=      0.89050   NEW_F(2)=      0.84725   NEW_F(3)=      0.80850;
NEW_F(1)=      0.88800   NEW_F(2)=      0.84550   NEW_F(3)=      0.81700;
NEW_F(1)=      0.88550   NEW_F(2)=      0.84375   NEW_F(3)=      0.82550;
NEW_F(1)=      0.88300   NEW_F(2)=      0.84200   NEW_F(3)=      0.83400;
NEW_F(1)=      0.88300   NEW_F(2)=      0.83425   NEW_F(3)=      0.83650;
NEW_F(1)=      0.88300   NEW_F(2)=      0.82650   NEW_F(3)=      0.83900;
NEW_F(1)=      0.88300   NEW_F(2)=      0.81875   NEW_F(3)=      0.84150;
NEW_F(1)=      0.88300   NEW_F(2)=      0.81100   NEW_F(3)=      0.84400;
NEW_F(1)=      0.87775   NEW_F(2)=      0.80825   NEW_F(3)=      0.84855;
NEW_F(1)=      0.87250   NEW_F(2)=      0.80550   NEW_F(3)=      0.85310;
NEW_F(1)=      0.86725   NEW_F(2)=      0.80275   NEW_F(3)=      0.85765;
NEW_F(1)=      0.86200   NEW_F(2)=      0.80000   NEW_F(3)=      0.86220;
NEW_F(1)=      0.85595   NEW_F(2)=      0.80000   NEW_F(3)=      0.86110;
NEW_F(1)=      0.84990   NEW_F(2)=      0.80000   NEW_F(3)=      0.86000;
NEW_F(1)=      0.84385   NEW_F(2)=      0.80000   NEW_F(3)=      0.85890;
NEW_F(1)=      0.83780   NEW_F(2)=      0.80000   NEW_F(3)=      0.85780;
NEW_F(1)=      0.83225   NEW_F(2)=      0.80850   NEW_F(3)=      0.85945;
NEW_F(1)=      0.82670   NEW_F(2)=      0.81700   NEW_F(3)=      0.86110;
NEW_F(1)=      0.82115   NEW_F(2)=      0.82550   NEW_F(3)=      0.86275;
NEW_F(1)=      0.81560   NEW_F(2)=      0.83400   NEW_F(3)=      0.86440;
NEW_F(1)=      0.81670   NEW_F(2)=      0.83650   NEW_F(3)=      0.86275;
NEW_F(1)=      0.81780   NEW_F(2)=      0.83900   NEW_F(3)=      0.86110;
NEW_F(1)=      0.81890   NEW_F(2)=      0.84150   NEW_F(3)=      0.85945;
NEW_F(1)=      0.82000   NEW_F(2)=      0.84400   NEW_F(3)=      0.85780;
NEW_F(1)=      0.82100   NEW_F(2)=      0.84855   NEW_F(3)=      0.85780;
NEW_F(1)=      0.82200   NEW_F(2)=      0.85310   NEW_F(3)=      0.85780;
NEW_F(1)=      0.82300   NEW_F(2)=      0.85765   NEW_F(3)=      0.85780;
NEW_F(1)=      0.82400   NEW_F(2)=      0.86220   NEW_F(3)=      0.85780;
NEW_F(1)=      0.83725   NEW_F(2)=      0.96110   NEW_F(3)=      0.84885;
NEW_F(1)=      0.85050   NEW_F(2)=      0.86000   NEW_F(3)=      0.83990;
NEW_F(1)=      0.86375   NEW_F(2)=      0.85890   NEW_F(3)=      0.83095;
NEW_F(1)=      0.87700   NEW_F(2)=      0.85780   NEW_F(3)=      0.82200;
NEW_F(1)=      0.87375   NEW_F(2)=      0.85945   NEW_F(3)=      0.82875;
NEW_F(1)=      [illegible]   NEW_F(2)=      [illegible]   NEW_F(3)=      [illegible];
```

```
NEW_F(1)=    0.86725   NEW_F(2)=    0.86275   NEW_F(3)=    0.84225;
NEW_F(1)=    0.86400   NEW_F(2)=    0.86440   NEW_F(3)=    0.84900;
NEW_F(1)=    0.86025   NEW_F(2)=    0.86275   NEW_F(3)=    0.86000;
NEW_F(1)=    0.85650   NEW_F(2)=    0.86110   NEW_F(3)=    0.87100;
NEW_F(1)=    0.85275   NEW_F(2)=    0.85945   NEW_F(3)=    0.88200;
NEW_F(1)=    0.84900   NEW_F(2)=    0.85780   NEW_F(3)=    0.89300;
NEW_F(1)=    0.84725   NEW_F(2)=    0.85780   NEW_F(3)=    0.89050;
NEW_F(1)=    0.84550   NEW_F(2)=    0.85780   NEW_F(3)=    0.88800;
NEW_F(1)=    0.84375   NEW_F(2)=    0.85780   NEW_F(3)=    0.88550;
NEW_F(1)=    0.84200   NEW_F(2)=    0.85780   NEW_F(3)=    0.88300;
NEW_F(1)=    0.83425   NEW_F(2)=    0.84885   NEW_F(3)=    0.88300;
NEW_F(1)=    0.82650   NEW_F(2)=    0.83990   NEW_F(3)=    0.88300;
NEW_F(1)=    0.81875   NEW_F(2)=    0.83095   NEW_F(3)=    0.88300;
NEW_F(1)=    0.81100   NEW_F(2)=    0.82200   NEW_F(3)=    0.88300;
NEW_F(1)=    0.80825   NEW_F(2)=    0.82875   NEW_F(3)=    0.87775;
NEW_F(1)=    0.80550   NEW_F(2)=    0.83550   NEW_F(3)=    0.87250;
NEW_F(1)=    0.80275   NEW_F(2)=    0.84225   NEW_F(3)=    0.86725;
NEW_F(1)=    0.80000   NEW_F(2)=    0.84900   NEW_F(3)=    0.86200;
NEW_F(1)=    0.80000   NEW_F(2)=    0.86000   NEW_F(3)=    0.85595;
NEW_F(1)=    0.80000   NEW_F(2)=    0.87100   NEW_F(3)=    0.84990;
NEW_F(1)=    0.80000   NEW_F(2)=    0.88200   NEW_F(3)=    0.84385;
NEW_F(1)=    0.80000   NEW_F(2)=    0.89300   NEW_F(3)=    0.83780;
NEW_F(1)=    0.80850   NEW_F(2)=    0.89050   NEW_F(3)=    0.83225;
NEW_F(1)=    0.81700   NEW_F(2)=    0.88800   NEW_F(3)=    0.82670;
NEW_F(1)=    0.82550   NEW_F(2)=    0.88550   NEW_F(3)=    0.82115;
NEW_F(1)=    0.83400   NEW_F(2)=    0.88300   NEW_F(3)=    0.81560;
NEW_F(1)= 0.1  NEW_F(2)= 0.1  NEW_F(3)= 0.1;
 ;

R;
>
```

```
LOAD SHORTY ( XEQ )
EXECUTION BEGINS...
**
```

APPENDIX A - SAMPLE OUTPUT

```
NEW_F(1)=       0.84885   NEW_F(2)=       0.83725   NEW_F(3)=       0.83425;
FIFOA(1,1)=     184       FIFOA(2,1)=     191       FIFOA(3,1)=     188;
FIFOA(1,2)=     185       FIFOA(2,2)=     191       FIFOA(3,2)=     188;
EMCD(1)=       57.9307    EMCD(2)=       57.9405    EMCD(3)=       57.9312;
ERROR(1)=       0.00000   ERROR(2)=       0.00980   ERROR(3)=       0.00050;
END_POS(1)=       58.2353 END_POS(2)=       58.2507 END_POS(3)=       58.2354
;
PRE_ER(1)=        0.00000 PRE_ER(2)=        0.01540 PRE_ER(3)=        0.00010;
REM(1)=        0.7647     REM(2)=        0.7493     REM(3)=        0.7646;
PULSE(1)=         464.0   PULSE(2)=         461.0   PULSE(3)=         472.0;
OUTPUT(1)=          188.7 OUTPUT(2)=          187.5 OUTPUT(3)=          191.9;
ER_PULSE(1)=      0.0     ER_PULSE(2)=      6.6     ER_PULSE(3)=      0.0;
NEW_COUNTA(1)=      189   NEW_COUNTA(2)=      181   NEW_COUNTA(3)=      192;
NEW_COUNT(1)=       189   NEW_COUNT(2)=       181   NEW_COUNT(3)=       192;
FIFO(1,1)=     185        FIFO(2,1)=     191        FIFO(3,1)=     188;
FIFO(1,2)=     189        FIFO(2,2)=     181        FIFO(3,2)=     192;

NEW_F(1)=       0.83990   NEW_F(2)=       0.85050   NEW_F(3)=       0.82650;
FIFOA(1,1)=     185       FIFOA(2,1)=     191       FIFOA(3,1)=     188;
FIFOA(1,2)=     189       FIFOA(2,2)=     181       FIFOA(3,2)=     192;
EMCD(1)=       58.2321    EMCD(2)=       58.2556    EMCD(3)=       58.2326;
ERROR(1)=       0.00000   ERROR(2)=       0.02350   ERROR(3)=       0.00050;
END_POS(1)=       58.5400 END_POS(2)=       58.5542 END_POS(3)=       58.5404
;
PRE_ER(1)=        0.00000 PRE_ER(2)=        0.01420 PRE_ER(3)=        0.00040;
REM(1)=        0.4600     REM(2)=        0.4458     REM(3)=        0.4596;
PULSE(1)=         282.0   PULSE(2)=         270.0   PULSE(3)=         286.0;
OUTPUT(1)=          189.3 OUTPUT(2)=          181.2 OUTPUT(3)=          191.9;
ER_PULSE(1)=      0.0     ER_PULSE(2)=      6.2     ER_PULSE(3)=      0.1;
NEW_COUNTA(1)=      189   NEW_COUNTA(2)=      175   NEW_COUNTA(3)=      192;
NEW_COUNT(1)=       189   NEW_COUNT(2)=       175   NEW_COUNT(3)=       192;
FIFO(1,1)=     189        FIFO(2,1)=     181        FIFO(3,1)=     192;
FIFO(1,2)=     189        FIFO(2,2)=     175        FIFO(3,2)=     192;

NEW_F(1)=       0.83095   NEW_F(2)=       0.86375   NEW_F(3)=       0.81875;
FIFOA(1,1)=     189       FIFOA(2,1)=     181       FIFOA(3,1)=     192;
FIFOA(1,2)=     189       FIFOA(2,2)=     175       FIFOA(3,2)=     192;
EMCD(1)=       58.5367    EMCD(2)=       58.5588    EMCD(3)=       58.5375;
ERROR(1)=       0.00000   ERROR(2)=       0.02210   ERROR(3)=       0.00080;
END_POS(1)=       58.8413 END_POS(2)=       58.8520 END_POS(3)=       58.8424
;
PRE_ER(1)=        0.00000 PRE_ER(2)=        0.01070 PRE_ER(3)=        0.00110;
REM(1)=        0.1587     REM(2)=        0.1480     REM(3)=        0.1576;
PULSE(1)=          98.0   PULSE(2)=          88.0   PULSE(3)=          99.0;
OUTPUT(1)=           98.0 OUTPUT(2)=           88.0 OUTPUT(3)=           99.0;
ER_PULSE(1)=      0.0     ER_PULSE(2)=      4.7     ER_PULSE(3)=      0.4;
NEW_COUNTA(1)=       98   NEW_COUNTA(2)=       83   NEW_COUNTA(3)=       99;
NEW_COUNT(1)=        98   NEW_COUNT(2)=        83   NEW_COUNT(3)=        99;
FIFO(1,1)=     189        FIFO(2,1)=     175        FIFO(3,1)=     192;
FIFO(1,2)=     98         FIFO(2,2)=     83         FIFO(3,2)=     99;

NEW_F(1)=       0.82200   NEW_F(2)=       0.87700   NEW_F(3)=       0.81100;
FIFOA(1,1)=     189       FIFOA(2,1)=     175       FIFOA(3,1)=     192;
FIFOA(1,2)=     98        FIFOA(2,2)=     83        FIFOA(3,2)=     99;
EMCD(1)=       58.8380    EMCD(2)=       58.8565    EMCD(3)=       58.8395;
ERROR(1)=       0.00000   ERROR(2)=       0.01850   ERROR(3)=       0.00150;
END_POS(1)=       58.9942 END_POS(2)=       58.9977 END_POS(3)=       58.9952
;
PRE_ER(1)=        0.00000 PRE_ER(2)=        0.00350 PRE_ER(3)=        0.00100;
REM(1)=        0.0058     REM(2)=        0.0023     REM(3)=        0.0048;
PULSE(1)=           3.0   PULSE(2)=           1.0   PULSE(3)=           3.0;
```

```
OUTPUT(1)=          3.0 OUTPUT(2)=          1.0 OUTPUT(3)=          3.0;

ER_PULSE(1)=      0.0   ER_PULSE(2)=      1.5   ER_PULSE(3)=      0.4;
NEW_COUNTA(1)=      3   NEW_COUNTA(2)=      0   NEW_COUNTA(3)=      3;
NEW_COUNT(1)=       3   NEW_COUNT(2)=       0   NEW_COUNT(3)=       3;
FIFO(1,1)=     98       FIFO(2,1)=     83       FIFO(3,1)=     99;
FIFO(1,2)=      3       FIFO(2,2)=      0       FIFO(3,2)=      3;

NEW_F(1)=      0.82875  NEW_F(2)=      0.87375  NEW_F(3)=      0.80825;
FIFOA(1,1)=    98       FIFOA(2,1)=    83       FIFOA(3,1)=    99;
FIFOA(1,2)=     3       FIFOA(2,2)=     0       FIFOA(3,2)=     3;
EMCD(1)=     58.9955    EMCD(2)=     58.9971    EMCD(3)=     58.9947;
ERROR(1)=      0.00080  ERROR(2)=      0.00240  ERROR(3)=      0.00000;
END_POS(1)=      59.0003 END_POS(2)=     58.9971 END_POS(3)=      58.9994"
;
PRE_ER(1)=      0.00320 PRE_ER(2)=      0.00000 PRE_ER(3)=      0.00230;
REM(1)=      0.0000     REM(2)=      0.0029     REM(3)=      0.0006;
PULSE(1)=           0.0 PULSE(2)=           1.0 PULSE(3)=           0.0;
OUTPUT(1)=          0.0 OUTPUT(2)=          1.0 OUTPUT(3)=          0.0;
ER_PULSE(1)=      1.3   ER_PULSE(2)=      0.0   ER_PULSE(3)=      0.9;
NEW_COUNTA(1)=      0   NEW_COUNTA(2)=      1   NEW_COUNTA(3)=      0;
NEW_COUNT(1)=       0   NEW_COUNT(2)=       1   NEW_COUNT(3)=       0;
FIFO(1,1)=      3       FIFO(2,1)=      0       FIFO(3,1)=      3;
FIFO(1,2)=      0       FIFO(2,2)=      1       FIFO(3,2)=      0;

NEW_F(1)=      0.83550  NEW_F(2)=      0.87050  NEW_F(3)=      0.80550;
FIFOA(1,1)=     3       FIFOA(2,1)=     0       FIFOA(3,1)=     3;
FIFOA(1,2)=     0       FIFOA(2,2)=     1       FIFOA(3,2)=     0;
EMCD(1)=     59.0003    EMCD(2)=     58.9971    EMCD(3)=     58.9993;
ERROR(1)=      0.00320  ERROR(2)=      0.00000  ERROR(3)=      0.00220;
END_POS(1)=      59.0003 END_POS(2)=     58.9987 END_POS(3)=      58.9993"
;
PRE_ER(1)=      0.00160 PRE_ER(2)=      0.00000 PRE_ER(3)=      0.00060;
REM(1)=      0.0000     REM(2)=      0.0013     REM(3)=      0.0007;
PULSE(1)=           0.0 PULSE(2)=           0.0 PULSE(3)=           0.0;
OUTPUT(1)=          0.0 OUTPUT(2)=          0.0 OUTPUT(3)=          0.0;
ER_PULSE(1)=      0.6   ER_PULSE(2)=      0.0   ER_PULSE(3)=      0.2;
NEW_COUNTA(1)=      0   NEW_COUNTA(2)=      0   NEW_COUNTA(3)=      0;
NEW_COUNT(1)=       0   NEW_COUNT(2)=       0   NEW_COUNT(3)=       0;
FIFO(1,1)=      0       FIFO(2,1)=      1       FIFO(3,1)=      0;
FIFO(1,2)=      0       FIFO(2,2)=      0       FIFO(3,2)=      0;

NEW_F(1)=      0.84225  NEW_F(2)=      0.86725  NEW_F(3)=      0.80275;
FIFOA(1,1)=     0       FIFOA(2,1)=     1       FIFOA(3,1)=     0;
FIFOA(1,2)=     0       FIFOA(2,2)=     0       FIFOA(3,2)=     0;
EMCD(1)=     59.0003    EMCD(2)=     58.9987    EMCD(3)=     58.9993;
ERROR(1)=      0.00160  ERROR(2)=      0.00000  ERROR(3)=      0.00060;
END_POS(1)=      59.0003 END_POS(2)=     58.9987 END_POS(3)=      58.9993"
;
PRE_ER(1)=      0.00160 PRE_ER(2)=      0.00000 PRE_ER(3)=      0.00060;
REM(1)=      0.0000     REM(2)=      0.0013     REM(3)=      0.0007;
PULSE(1)=           0.0 PULSE(2)=           0.0 PULSE(3)=           0.0;
OUTPUT(1)=          0.0 OUTPUT(2)=          0.0 OUTPUT(3)=          0.0;
ER_PULSE(1)=      0.6   ER_PULSE(2)=      0.0   ER_PULSE(3)=      0.2;
NEW_COUNTA(1)=      0   NEW_COUNTA(2)=      0   NEW_COUNTA(3)=      0;
NEW_COUNT(1)=       0   NEW_COUNT(2)=       0   NEW_COUNT(3)=       0;
FIFO(1,1)=      0       FIFO(2,1)=      0       FIFO(3,1)=      0;
FIFO(1,2)=      0       FIFO(2,2)=      0       FIFO(3,2)=      0;

NEW_F(1)=      0.84900  NEW_F(2)=      0.86400  NEW_F(3)=      0.80000;
FIFOA(1,1)=     0       FIFOA(2,1)=     0       FIFOA(3,1)=     0;
FIFOA(1,2)=     0       FIFOA(2,2)=     0       FIFOA(3,2)=     0;
EMCD(1)=     59.0003    EMCD(2)=     58.9987    EMCD(3)=     58.9993;
ERROR(1)=      0.00160  ERROR(2)=      0.00000  ERROR(3)=      0.00060;
END_POS(1)=      59.0003 END_POS(2)=     58.9987 END_POS(3)=      58.9993"
;
```

```
PRE_ER(1)=      0.00160  PRE_ER(2)=      0.00000  PRE_ER(3)=      0.00060;
REM(1)=      0.0557      REM(2)=      0.0573      REM(3)=      0.0567;
PULSE(1)=          33.0  PULSE(2)=          34.0  PULSE(3)=          36.0;
OUTPUT(1)=         18.3  OUTPUT(2)=         18.8  OUTPUT(3)=         19.9;
ER_PULSE(1)=    0.7      ER_PULSE(2)=    0.0      ER_PULSE(3)=    0.2;
NEW_COUNTA(1)=      18   NEW_COUNTA(2)=      19   NEW_COUNTA(3)=      20;
NEW_COUNT(1)=      18    NEW_COUNT(2)=      19    NEW_COUNT(3)=      20;
FIFO(1,1)=     0         FIFO(2,1)=     0         FIFO(3,1)=     0;
FIFO(1,2)=    18         FIFO(2,2)=    19         FIFO(3,2)=    20;

NEW_F(1)=       0.86000  NEW_F(2)=       0.86025  NEW_F(3)=       0.80000;
FIFOA(1,1)=     0        FIFOA(2,1)=     0        FIFOA(3,1)=     0;
FIFOA(1,2)=    18        FIFOA(2,2)=    19        FIFOA(3,2)=    20;
EMCD(1)=     59.0003     EMCD(2)=     58.9987     EMCD(3)=     58.9993;
ERROR(1)=       0.00160  ERROR(2)=       0.00000  ERROR(3)=       0.00060;
END_POS(1)=       59.0303 END_POS(2)=       59.0304 END_POS(3)=       59.0303
;
PRE_ER(1)=      0.00000  PRE_ER(2)=      0.00010  PRE_ER(3)=      0.00000;
REM(1)=      0.0257      REM(2)=      0.0256      REM(3)=      0.0257;
PULSE(1)=          15.0  PULSE(2)=          15.0  PULSE(3)=          16.0;
OUTPUT(1)=          7.5  OUTPUT(2)=          7.5  OUTPUT(3)=          8.0;
ER_PULSE(1)=    0.0      ER_PULSE(2)=    0.0      ER_PULSE(3)=    0.0;
NEW_COUNTA(1)=       8   NEW_COUNTA(2)=       8   NEW_COUNTA(3)=       8;
NEW_COUNT(1)=       8    NEW_COUNT(2)=       8    NEW_COUNT(3)=       8;
FIFO(1,1)=    18         FIFO(2,1)=    19         FIFO(3,1)=    20;
FIFO(1,2)=     8         FIFO(2,2)=     8         FIFO(3,2)=     8;

NEW_F(1)=       0.87100  NEW_F(2)=       0.85650  NEW_F(3)=       0.80000;
FIFOA(1,1)=    18        FIFOA(2,1)=    19        FIFOA(3,1)=    20;
FIFOA(1,2)=     8        FIFOA(2,2)=     8        FIFOA(3,2)=     8;
EMCD(1)=     59.0307     EMCD(2)=     59.0302     EMCD(3)=     59.0303;
ERROR(1)=       0.00050  ERROR(2)=       0.00000  ERROR(3)=       0.00010;
END_POS(1)=       59.0442 END_POS(2)=       59.0434 END_POS(3)=       59.0427
;
PRE_ER(1)=      0.00150  PRE_ER(2)=      0.00070  PRE_ER(3)=      0.00000;
REM(1)=      0.0118      REM(2)=      0.0126      REM(3)=      0.0133;
PULSE(1)=           6.0  PULSE(2)=           7.0  PULSE(3)=           8.0;
OUTPUT(1)=          3.0  OUTPUT(2)=          3.5  OUTPUT(3)=          4.0;
ER_PULSE(1)=    0.6      ER_PULSE(2)=    0.3      ER_PULSE(3)=    0.0;
NEW_COUNTA(1)=       2   NEW_COUNTA(2)=       3   NEW_COUNTA(3)=       4;
NEW_COUNT(1)=       2    NEW_COUNT(2)=       3    NEW_COUNT(3)=       4;
FIFO(1,1)=     8         FIFO(2,1)=     8         FIFO(3,1)=     8;
FIFO(1,2)=     2         FIFO(2,2)=     3         FIFO(3,2)=     4;

NEW_F(1)=       0.88200  NEW_F(2)=       0.85275  NEW_F(3)=       0.80000;
FIFOA(1,1)=     8        FIFOA(2,1)=     8        FIFOA(3,1)=     8;
FIFOA(1,2)=     2        FIFOA(2,2)=     3        FIFOA(3,2)=     4;
EMCD(1)=     59.0443     EMCD(2)=     59.0434     EMCD(3)=     59.0427;
ERROR(1)=       0.00160  ERROR(2)=       0.00070  ERROR(3)=       0.00000;
END_POS(1)=       59.0477 END_POS(2)=       59.0483 END_POS(3)=       59.0489
;
PRE_ER(1)=      0.00000  PRE_ER(2)=      0.00060  PRE_ER(3)=      0.00120;
REM(1)=      0.0083      REM(2)=      0.0077      REM(3)=      0.0071;
PULSE(1)=           4.0  PULSE(2)=           4.0  PULSE(3)=           4.0;
OUTPUT(1)=          2.0  OUTPUT(2)=          2.0  OUTPUT(3)=          2.0;
ER_PULSE(1)=    0.0      ER_PULSE(2)=    0.2      ER_PULSE(3)=    0.4;
NEW_COUNTA(1)=       2   NEW_COUNTA(2)=       2   NEW_COUNTA(3)=       2;
NEW_COUNT(1)=       2    NEW_COUNT(2)=       2    NEW_COUNT(3)=       2;
FIFO(1,1)=     2         FIFO(2,1)=     3         FIFO(3,1)=     4;
FIFO(1,2)=     2         FIFO(2,2)=     2         FIFO(3,2)=     2;

NEW_F(1)=       0.89300  NEW_F(2)=       0.84900  NEW_F(3)=       0.80000;
FIFOA(1,1)=     2        FIFOA(2,1)=     3        FIFOA(3,1)=     4;
FIFOA(1,2)=     2        FIFOA(2,2)=     2        FIFOA(3,2)=     2;
```

```
EMCD(1)=      59.0477    EMCD(2)=      59.0483    EMCD(3)=      59.0489;
ERROR(1)=      0.00000   ERROR(2)=      0.00060   ERROR(3)=      0.00120;
END_POS(1)=       59.0511 END_POS(2)=       59.0515 END_POS(3)=       59.0520^
;
PRE_ER(1)=      0.00000  PRE_ER(2)=      0.00040  PRE_ER(3)=      0.00090;
REM(1)=      0.0049      REM(2)=      0.0045      REM(3)=      0.0040;
PULSE(1)=           2.0  PULSE(2)=           2.0  PULSE(3)=           2.0;
OUTPUT(1)=           2.0 OUTPUT(2)=           2.0 OUTPUT(3)=           2.0;
ER_PULSE(1)=     0.0     ER_PULSE(2)=     0.1     ER_PULSE(3)=     0.3;
NEW_COUNTA(1)=        2  NEW_COUNTA(2)=        2  NEW_COUNTA(3)=        2;
NEW_COUNT(1)=        2   NEW_COUNT(2)=        2   NEW_COUNT(3)=        2;
FIFO(1,1)=      2        FIFO(2,1)=      2        FIFO(3,1)=      2;
FIFO(1,2)=      2        FIFO(2,2)=      2        FIFO(3,2)=      2;

NEW_F(1)=      0.89050   NEW_F(2)=      0.84725   NEW_F(3)=      0.80850;
FIFOA(1,1)=      2       FIFOA(2,1)=      2       FIFOA(3,1)=      2;
FIFOA(1,2)=      2       FIFOA(2,2)=      2       FIFOA(3,2)=      2;
EMCD(1)=      59.0511    EMCD(2)=      59.0515    EMCD(3)=      59.0520;
ERROR(1)=      0.00000   ERROR(2)=      0.00040   ERROR(3)=      0.00090;
END_POS(1)=       59.0545 END_POS(2)=       59.0547 END_POS(3)=       59.0551^
;
PRE_ER(1)=      0.00000  PRE_ER(2)=      0.00020  PRE_ER(3)=      0.00060;
REM(1)=      0.0015      REM(2)=      0.0013      REM(3)=      0.0009;
PULSE(1)=           0.0  PULSE(2)=           0.0  PULSE(3)=           0.0;
OUTPUT(1)=           0.0 OUTPUT(2)=           0.0 OUTPUT(3)=           0.0;
ER_PULSE(1)=     0.0     ER_PULSE(2)=     0.0     ER_PULSE(3)=     0.2;
NEW_COUNTA(1)=        0  NEW_COUNTA(2)=        0  NEW_COUNTA(3)=        0;
NEW_COUNT(1)=        0   NEW_COUNT(2)=        0   NEW_COUNT(3)=        0;
FIFO(1,1)=      2        FIFO(2,1)=      2        FIFO(3,1)=      2;
FIFO(1,2)=      0        FIFO(2,2)=      0        FIFO(3,2)=      0;

NEW_F(1)=      0.88800   NEW_F(2)=      0.84550   NEW_F(3)=      0.81700;
FIFOA(1,1)=      2       FIFOA(2,1)=      2       FIFOA(3,1)=      2;
FIFOA(1,2)=      0       FIFOA(2,2)=      0       FIFOA(3,2)=      0;
EMCD(1)=      59.0545    EMCD(2)=      59.0547    EMCD(3)=      59.0551;
ERROR(1)=      0.00000   ERROR(2)=      0.00020   ERROR(3)=      0.00060;
END_POS(1)=       59.0545 END_POS(2)=       59.0547 END_POS(3)=       59.0551^
;
PRE_ER(1)=      0.00000  PRE_ER(2)=      0.00020  PRE_ER(3)=      0.00060;
REM(1)=      0.0015      REM(2)=      0.0013      REM(3)=      0.0009;
PULSE(1)=           0.0  PULSE(2)=           0.0  PULSE(3)=           0.0;
OUTPUT(1)=           0.0 OUTPUT(2)=           0.0 OUTPUT(3)=           0.0;
ER_PULSE(1)=     0.0     ER_PULSE(2)=     0.0     ER_PULSE(3)=     0.2;
NEW_COUNTA(1)=        0  NEW_COUNTA(2)=        0  NEW_COUNTA(3)=        0;
NEW_COUNT(1)=        0   NEW_COUNT(2)=        0   NEW_COUNT(3)=        0;
FIFO(1,1)=      0        FIFO(2,1)=      0        FIFO(3,1)=      0;
FIFO(1,2)=      0        FIFO(2,2)=      0        FIFO(3,2)=      0;


MAX_ERROR=      0.04180;
END_ERROR=      0.00050;
 !!! E(01000) !!!
R;
>
```