

Issued 1965-01
Revised 2000-06
Reaffirmed 2006-03

Superseding AIR860

Aircraft Electrical Heating Systems

FOREWORD

Changes in this revision are format/editorial only.

INTRODUCTION

The modern air transport utilizing main propulsion engines of the turbo-prop or turbo-jet types generally provides speed characteristics suitable for the generation of large quantities of electrical power. Proper speed characteristics may be inherent in the main engine design or may be provided through constant speed devices. The electrical load of modern aircraft is generally large, requiring sufficient generating capacity to meet all normal and emergency electrical demands. The use of electrical heating may be attractive since the generating capacity designed into the system to meet the cooling cycle and other non-continuous electrical loads becomes available for heating when cooling is not required.

TABLE OF CONTENTS

INTRODUCTION	1
1. SCOPE	4
1.1 Purpose	4
2. REFERENCES	4
3. GENERAL INFORMATION	4
3.1 General Design Considerations	4
3.1.1 Electrical Power Availability	4
3.1.2 Ground Power Sources	4
3.1.3 Reliability and Flexibility	4
3.1.4 Weight	4
3.1.5 Location	4
3.1.6 Control of Heating Elements	4

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SAE AIR860 Revision A

TABLE OF CONTENTS (Continued)

3.1.7	Heating System Integration.....	5
3.18	Heat Transmission	5
APPENDIX A	AIRCRAFT "A"	6
FIGURE A1		6
TABLE A1	Flight Station Duct Heater Functional Test.....	15
TABLE A2	Cabin Duct Heater Functional Test	16
FIGURE A2	Cabin Wall and Floor Radiant Panels	17
FIGURE A3	Radiant Heating Panels.....	18
FIGURE A3A	Cabin Wall and Floor Radiant Panels - Sect. View	19
FIGURE A3B	Wall Panel - Upper	20
FIGURE A4	Cabin Floor Radiant Panel Assembly.....	21
FIGURE A4A	Radiant Heat Panels Control.....	22
FIGURE A5	Section - Terminal Block - Floor Panel Installation.....	23
FIGURE A6	Section of Cabin Floor Radiant Panel Installation.....	24
FIGURE A7	Spacer - Screw - Radiant Panel	25
FIGURE A8	Terminal Block Details.....	26
FIGURE A9	Cargo Compartment Floor and Radiant Panel Installation.....	27
FIGURE A10	Cargo Compartment Radiant Panel (Typ).....	28
FIGURE A10A	Cargo Compartment Heating Circuit	29
FIGURE A11	Schematic of Air Conditioning System	30
FIGURE A12	Flight Station Duct Heater and Recirculation Fan Circuits	31
FIGURE A13	Flight Station Duct Heater Details	32
FIGURE A14	Flight Station Duct Heater Functional Test Setup	33
FIGURE A15	Cabin Duct Heater Details.....	34
FIGURE A16	Cabin Duct Heater Electrical Circuit.....	35
FIGURE A17	Cabin Duct Heater Functional Test Setup.....	36
APPENDIX B	MATERIAL SPECIFICATION.....	37
B.1	SCOPE	37
B.2	CLASSIFICATION	37
B.3	APPLICABLE DOCUMENTS.....	37
B.4	REQUIREMENTS	38
B.4.1	Materials	38
B.4.2	Conductor	38
B.4.3	Insulation.....	38
B.4.4	Jacket.....	38
B.4.5	Cable Dimensions and Weight.....	38
B.4.6	Dielectric Strength.....	39

SAE AIR860 Revision A

TABLE OF CONTENTS (Continued)

B.4.7 High Temperature	39
B.4.8 Aging	39
B.4.9 Bending	39
B.4.10 Jacket Strength	39
B.4.11 Type Identification	39
B.4.12 Workmanship	40
B.5 QUALITY ASSURANCE PROVISIONS	40
B.5.1 Reports	40
B.5.2 Approval	40
B.6 PREPARATION FOR DELIVERY	40
B.6.1 Shipping Reels	40
TABLE B1 Cable, Resistance Heating, Aluminum Jacket	37

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1. SCOPE:

It is intended that the scope of this information report be limited to electrical heating of passenger, crew, and cargo compartments only.

No attempt has been made to develop the complete electrical circuitry associated with the electrical heating components; however, the electrical circuitry required for heating component operation, safety, and monitoring will be included as available.

Specific design information is given for various modern aircraft utilizing electrical heating. Each aircraft discussed will be identified by alphabetical letter designation and included in the appropriate appendix.

1.1 Purpose:

This report is intended to furnish the aerospace industry with brief design information and data on cabin and cargo space electrical heating. The design information and data contained herein are applicable to modern aircraft utilizing main propulsion systems such as turbo-jet, turbo-fan, and turbo-prop.

2. REFERENCES:

There are no referenced publications specified herein.

3. GENERAL INFORMATION:

3.1 General Design Considerations:

3.1.1 Electrical Power Availability: Electrical heating may be used to compliment other heating sources or used as a sole heating source, depending upon flight and ground operating mode, degree of system integration, control, and economic considerations of heat and power generation devices.

3.1.2 Ground Power Sources: Ground power sources capable of supplying sufficient electrical power are available, thus permitting electrical heating of the aircraft on the ground without requiring main engine operation.

3.1.3 Reliability and Flexibility: A high degree of reliability and flexibility may be attained in the use of electrical heating.

3.1.4 Weight: The weight penalty incurred by using electrical heating may be small compared to other heat generating sources provided generator capacity is available as a requirement of meeting other electrical loads.

3.1.5 Location: The use of electrical heating may be more suitable when compared to other methods when the area or location of the area to be heated presents unusual heating design problems.

3.1.6 Control of Heating Elements: Control of electrical heating elements is simple.

- 3.1.7 Heating System Integration: Integration of electrical heating system with other heat sources can be accomplished. Proper integration and control can provide maximum passenger and crew comfort by the elimination of cold surfaces adjacent to passengers and the elimination of circulating air at uncomfortable air temperature gradients.
- 3.1.8 Heat Transmission: Heat may be transferred between various heat sources and heat sinks by one of the following, or a combination of the following, processes: convection, radiation, and conduction. In an aircraft cabin, heat transfer may take place in the following ways:
- a. Convection between the boundary layer and cabin outer skin.
 - b. Convection between the cabin interior surface and cabin air.
 - c. Convection between cabin air and passengers or equipment.
 - d. Convection and radiation from internal heat sources, such as electrical and electronic equipment, internal surfaces, and passengers.
 - e. Conduction through structural members and cabin walls.

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SAE AIR860 Revision A

APPENDIX A

AIRCRAFT "A"

Section 1

GENERAL AIRCRAFT INFORMATION

TYPE	ENGINES		ALTITUDE	CABIN DIFF. PR.	FUSELAGE		
	Type	No.			Mat.	Max. Breadth Outside Inside	Press. Vol.
Transport	Turbo- prop	4	S. L. to 30,000 ft	6.5 psig	Al.	136 in. 128 in.	8500 cu. ft.

FUSELAGE (continued)							
Pr. Vol. Cargo Compt.		Pass. & Crew Compt.		Insulation			
Fwd.	Rear	Pr. Volume		Mat.	Density	Walls	Floor
254 cu. ft.	263 cu. ft.	8000 cu. ft. (app.)		Fiber- glass	0.60 lb/cu.ft	1-1/2 in. to 3 in.	3-1/2 in.

FUSELAGE (Continued)		CABIN PRESS. AIR SOURCES	CABIN COOLING	
Insulation	Air Supply		Air Cycle	Vapor Cycle
Cargo Fl.	Ducts	Engine Driven Compressor (EDC) 2 Used	2 Used	2 Used
1-1/2 in.	Insulation			
	1-1/2 in. Fiber- glass - Mylar			

CABIN HEATING METHODS					CREW COMPARTMENT HEATING METHODS		
EDC Heat of Comp.	Elec. Rad. Floor Panels	Elec. Resist. Duct Heaters	Elec. Radiant Wall Panels	Elec. Radiant Window Panels	EDC Heat of Comp.	Elec. Resist. Duct Heaters	

FIGURE A1

SAE AIR860 Revision A

CARGO COMPARTMENT HEATING	TEMPERATURE REQMTS. A/C SYSTEM					
METHODS	HEATING					
Elec. Resist. Panels, Floor	In Flight			Ground Operation		
	Amb.	Occ. Area	Cargo	Amb.	Cab & Flt.	Cargo
	-60°F.	75°F.	35°F. or more	-5°F.	75°F.	35°F. or more

STEADY STATE HEATING PERFORMANCE

Auto. Temp. Cont. Tolerance	Flight Cond.	Comp't.	Amb. Temp.	Comp't. Temp.	Req'd Elec. Cap.	Total Available Elec. Cap.
Less than $\pm 2^{\circ}\text{F.}$ at any one point	Ground (Full Rec. Air.)	Flt. Sta. Cabin	-5°F.	75°F.	3.9 KW	10 KW (Duct Heater)
			-5°F.	75°F.	5.9 KW	11.3 KW (Radiant Panels)
	Ground 15 lb Fresh Air 50 lb Fresh Air	Flt. Sta. Cabin	-5°F.	75°F.	9.0 KW	10 KW (Duct Heater)
			-5°F.	75°F.	23.0 KW	30 KW (Radiant Pan- els plus duct heater)
	30,000 ft Cruise with 8000 Ft. Cabin	Flt. Sta. Cabin	-60°F.	75°F.	5.6 KW	10.0 KW (Duct Heater)
			-60°F.	75°F.	7.6 KW	9.7 KW (Radiant Panels)

FIGURE A1 (Continued)

SAE AIR860 Revision A

Section 2

SPECIFIC DESIGN AND OPERATION INFORMATION

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS

FLOOR PANELS

FLOOR PANELS					
LOCATION	TYPES USED			DETAILS - HONEYCOMB HEATED	
See Fig. A2 and Fig. A3	Plywood (Not heated) 3/8 in. thick	Honey- comb (Not heated) 3/8 in. thick	Honey- comb Heated 3/8 in. (approx.) thick 25 panels (Fig. 2)	CONSTRUCTION	
				Material and Size	
				Core	Plates
				Al. Al. 5052H Foil Spec. MIL-C-7438 Cell Size 1/8 in. Hex Thickness = .001 in. Cell Depth = .341 ± .003	<u>Top Cover Plate</u> Alclad 7075T6 Spec. QQ-A-287 .016 in thickness <u>Bottom Cover Plate</u> Alclad 7075T6 Spec. QQ-A-287 .012 in. thick- ness
				See Figures A4 & A6	

FLOOR PANELS

DETAILS - HONEYCOMB HEATED

CONSTRUCTION					INSTALLATION	
BONDING	ELECTRICAL RESIST. CABLE		ELEC. TERMINAL	MOUNTING SPACERS	METHOD	
	Install. & Mat.	Capacity			SCREWS	
MIL-A-5090 Adhesive System	<u>Installation</u> See Fig. A4 Install in crushed groove <u>Material</u> See App. B	20 watts per sq. ft. <u>Power</u> 115/208 VAC 3 phase 400 cycle	See Fig. A8 Install per Fig. A5	See Fig. A7 See Fig. A6	No. 10 Flat Head	

FIGURE A1 (Continued)

SAE AIR860 Revision A

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS (Continued)

FLOOR PANELS

DETAILS - HONEYCOMB HEATED

FUNCTIONAL TEST

DIELECTRIC TEST - HEATING ELEMENT TERMINALS

TEST EQUIPMENT	TEST CONNECTIONS	VOLTAGE	TIME	CRITERIA OF FAILURE	PANEL MARKING	
Insulation Breakdown Tester	1. Either term. 2. Ground (on panel)	1250 AC 60 cycle	1 sec.	No indication of Insul. Breakdown	Mark Panel as having been "Dielectric tested OK"	

DIELECTRIC TEST - TEMPERATURE SENSOR TERMINALS

TEST EQUIPMENT	TEST CONNECTIONS	VOLTAGE	TIME	CRITERIA OF FAILURE	PANEL MARKING	
(Same as for heating element test above)	1. <u>One</u> sensor term. 2. Ground (to panel)	200 AC 60 cycle	1 sec.	No indication of Insul. Breakdown	Mark Panel as having been "Dielectric tested OK"	

RESISTANCE TEST - HEATING ELEMENT

TEST EQUIPMENT	TEST CONNECTIONS	TEST REQUIREMENT	TEST TOLERANCE
1. Wheatstone Bridge 2. Detail Panel Dwg.	Both heating element terminals	Detail panel drawing to specify resistance cable length and resistance value per foot of length Total resist. = L' x R/ft	+ 10% from Resist. per detail drawing

FIGURE A1 (Continued)

SAE AIR860 Revision A

WALL AND WINDOW HEATING PANELS				
LOCATION	TYPES USED	DETAILS, PANELS, WALL AND WINDOW		
See Figs. 3A and 3B	Honeycomb Heated	CONSTRUCTION		
	1/4 in. thick	MATERIAL AND SIZE		BONDING
		Core	Plates	MIL-A-5090 Adhesive System
		Al. Al. 5052H Foil Spec. MIL-C-7438 Cell size 1/4 in. Hex. Thickness .001 Cell Depth 1/4 in.	<u>Inboard Cover Plate</u> Al. Al. .004 in. thick <u>Outboard Cover Plate</u> Al. Al. .004 in. thick	
	32 Sidewall Panels			
	37 Windows			
CONSTRUCTION (continued)				
Edging	Trim	Trim Padding	Elec. Resistance Cable	
Hardwood inserts on 4 edges	<u>Cabin Side</u> "Naugahyde" or "Duratrim" vinyl coated fabrics. Cemented or stapled to panels	<u>Cabin Side</u> 1/2 in. Fiberglass 0.6 lbs. per cu. ft. Install between trim and panel	<u>Install. & Mat.</u> <u>Installation</u> See Fig. A2 Similar to Floor Panel Fig. A4 <u>Material</u> See App. B	<u>Capacity</u> 20 watts per sq ft. Power 115/208 VAC 3 phase 400 cycle
CONSTRUCTION (Continued)				
Elec. Terminals	Installation	Functional Test		
See Fig. A8	See Figs. A2, A3, A3A, A3B	Check Elec. & Dielectric Tests		
Elec. Bonding per Fig. A3B	Special Extrusions and clips			

FIGURE A1 (Continued)

FUNCTIONAL TEST		
Dielectric Test Heating Elements	Dielectric Test Temp. Sensors	Resistance Test. Heating Elements

← Same as for floor panels →

FIGURE A1 (Continued)

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SAE AIR860 Revision A

SPECIFIC DESIGN AND OPERATION INFORMATION

CARGO COMPARTMENT - ELECTRIC RADIANT PANELS

CARGO HEATING PANELS

LOCATION	TYPE USED	CONSTRUCTION		
See Fig. A9 Below cargo structural floor. No. per comp't 42 panels fwd. 43 panels aft	See Fig. A10 Laminated - one layer of Al. alloy sheet, bonded to a layer of fiberglass, with heating element wires between the two layers.	Material and Size		
		<u>Al. Alloy</u> .008 in. thick 5052-0 Spec. QQ-A-318	<u>Fiberglass Cloth</u> .010 thick Phenolic impregnated Spec. "Conolon 506-B-181" "Narmco" or "AF104#120" by 3M Co.	<u>Bonding</u> MIL-A-5090 Bonding System Liq. Adhesive Type III Tape Adhesive Type I Cure at 350°F for 45 min. with bag press. of 10 to 25 psig

CONSTRUCTION (continued)

BUMPERS SPACERS	ELECTRICAL RESIST. CABLE		ELEC. TERMINAL & CIRCUITS	INSTALLATION
Plastic Foam, Cellulose Acetate Rod	<u>Install. & Mat.</u>	<u>Capacity</u>	See Fig. A8	See Figs. A9 & A10
	<u>Installation</u> See Fig. A10 <u>Material</u> See Appendix B	<u>Power</u> 61 watts per sq. ft. 115/208 VAC 3 phase 400 cycle	See Fig. A10A	

FUNCTIONAL TEST

Dielectric Test	Resistance Test
Heating Element & Terminals	Heating Element
Same as floor panels	Same as for floor panels

FIGURE A1 (Continued)

SPECIFIC DESIGN AND OPERATION INFORMATION

FLIGHT STATION - ELECTRIC DUCT HEATER

LOCATION	TYPE AND CONSTRUCTION	ELECTRICAL
See Fig. A11 Located in flight station air supply duct	See Fig. A13	See Fig. A12 Total op. current 29 to 35 amps Capacity, 10 KW Power 115/208 VAC, 400 cycle, 3 phase Control Power, 26 VDC

FLIGHT STATION - ELECTRIC DUCT HEATER

FUNCTIONAL TEST	PERFORMANCE	
See Fig. A14 for Test Setup	At Sea Level	At 8000' Press. Alt.
1. Continuity test	Air Flow 30#/min.	22#/min.
	Air "In" Temp. 70°F	70°F.
2. Airflow distribution across face of heater must be uniform	Max. Temp. Rise 79°F	108°F.
	Max Pr. Drop .50 in. H ₂ O	.40 in. H ₂ O
	Max. Surface Temp. 300°F	350°F.
3. Electrical sequence per Table A1.	Normal Surface Temp. 200 to 250°F.	200 to 250°F.
4. Overheat test - no airflow - Thermal protector to operate within 90 seconds.		

FIGURE A1 (Continued)

SPECIAL DESIGN AND OPERATION INFORMATION

CABIN - ELECTRICAL DUCT HEATER		
LOCATION	TYPE AND CONSTRUCTION	ELECTRICAL
See Fig. A11 located in cabin air supply duct	See Figure A15	See Figure A16 Total operating current 37 to 58 AMPS Power - 115/208 VAC, 400 cycle Capacity, 18 KW Control Power 26 VDC

CABIN - ELECTRICAL DUCT HEATER

FUNCTIONAL TEST	PERFORMANCE	
	At Sea Level	At 8000' Press. Alt.
See Fig. A17 for test setup		
1. Continuity test	Air Flow 151#/min.	116#/min.
	Air "In" Temp. 70°F.	70°F.
2. Airflow distribution across face of heater	Max. Temp. Rise 28°F.	36°F.
	Max. Pr. Drop .35" H ₂ O	.30 in. H ₂ O
	Max. Surface Temp. 300°F.	350°F.
3. Electrical sequence test per Table A2	Normal Surface Temp. 150 to 200°F.	150 to 200°F.
4. Overheat test - no airflow - thermal protector to operate within 90 seconds		

FIGURE A1 (Continued)

TABLE A1 - Flight Station Duct Heater Functional Test

TEST INFORMATION					
Energizing Sequence Steps	Close Circuit Breaker	Current (amp)			
		Group 1	Group 2	Group 3	Group 4
1	CB1	2.9-3.5			
2	CB2		5.8-7.0		
3	CB3			8.7-10.5	
4	CB4				11.6-14.0
5	CB1, CB4	2.6-3.2*			11.3-13.7
6	CB2, CB4		5.5-6.7		11.3-13.7
7	CB3, CB4			8.1-9.9	11.0-13.4
8	CB1, CB3, CB4	2.6-3.2		8.1-9.9	10.7-13.1
9	CB2, CB3, CB4		5.2-6.4	7.8-9.6	10.7-13.1
10	CB1, CB2 CB3, CB4	2.6-3.2	5.2-6.4	7.8-9.6	10.4-12.8
* Determine current value for each group in group combination by opening one circuit breaker at a time and noting current drop.					

TABLE A2 - Cabin Duct Heater Functional Test

Energizing Sequence Steps	TEST INFORMATION			
	Close Circuit Breaker	CURRENT (Amp)		
		Group 1	Group 2	Group 3
1	CB1	7.8 to 9.6		
2	CB2		15.6 to 19.2	
3	CB3			23.4 to 28.8
4	CB1, CB3	7.4 to 9.1		22.2 to 27.4
5	CB2, CB3		14.8 to 18.2	22.2 to 27.4
6	CB1, CB2, CB3	7.4 to 9.1	14 to 17.3	21 to 26

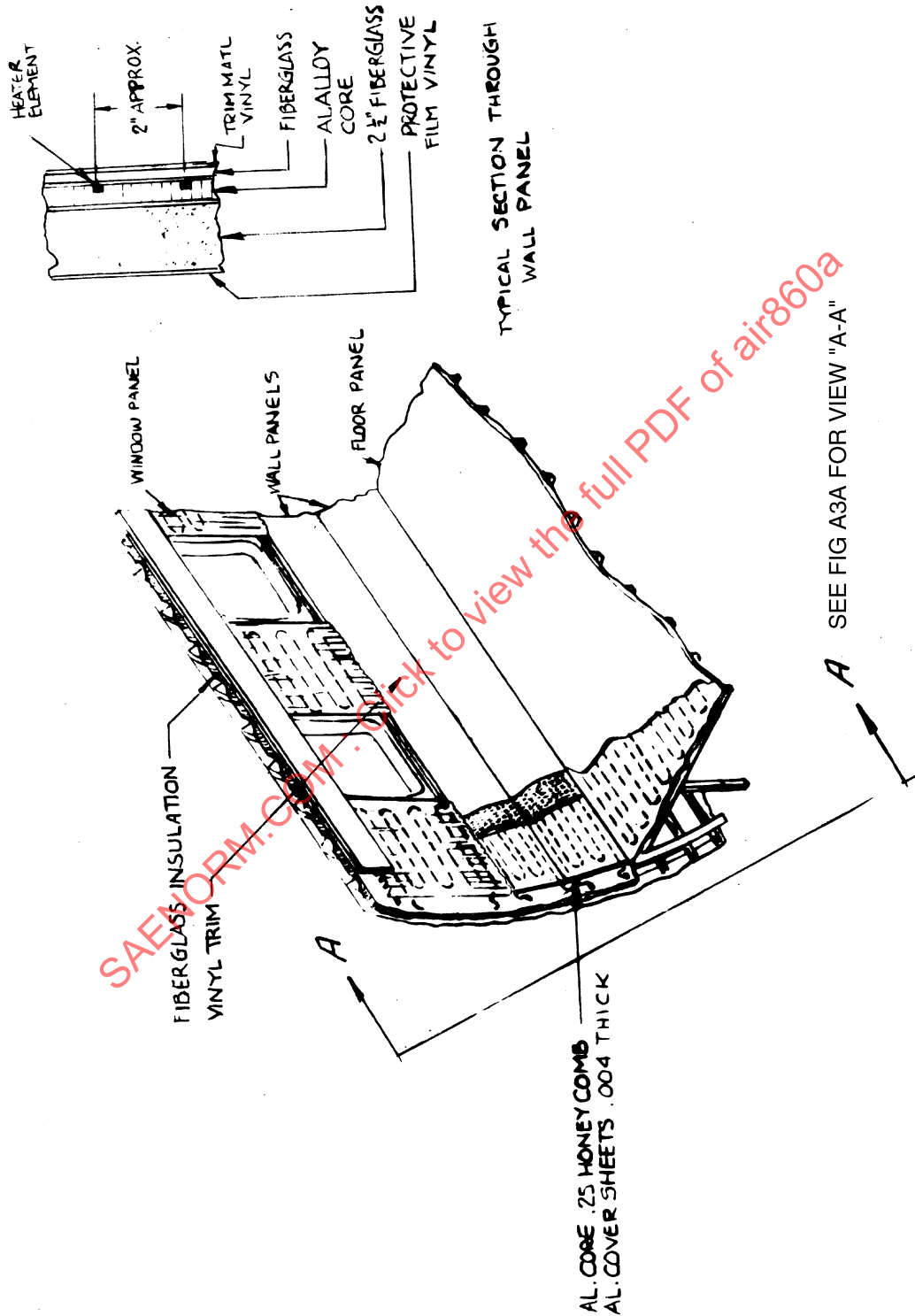


FIGURE A2 - Cabin Wall and Floor Radiant Panels

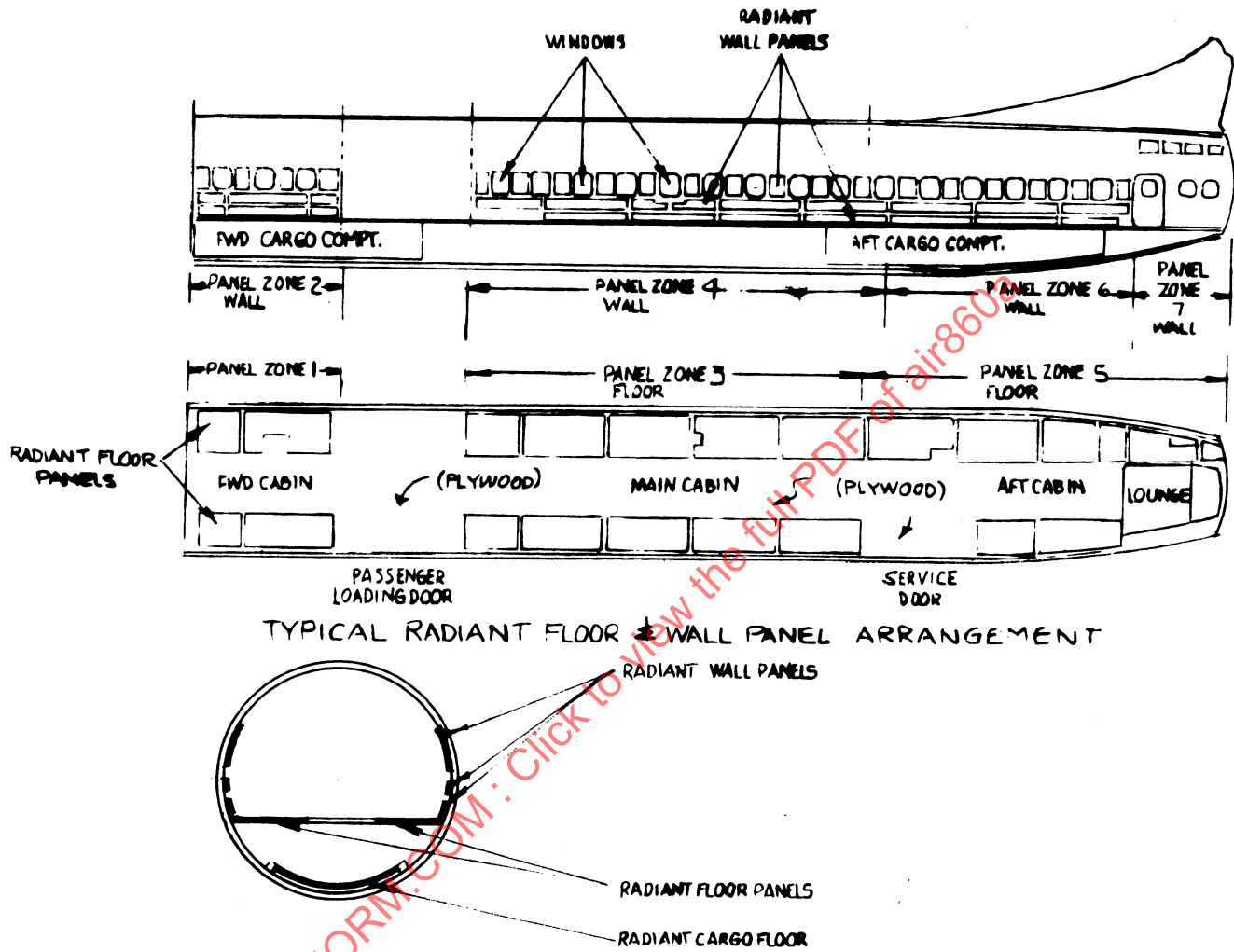


FIGURE A3 - Radiant Heating Panels

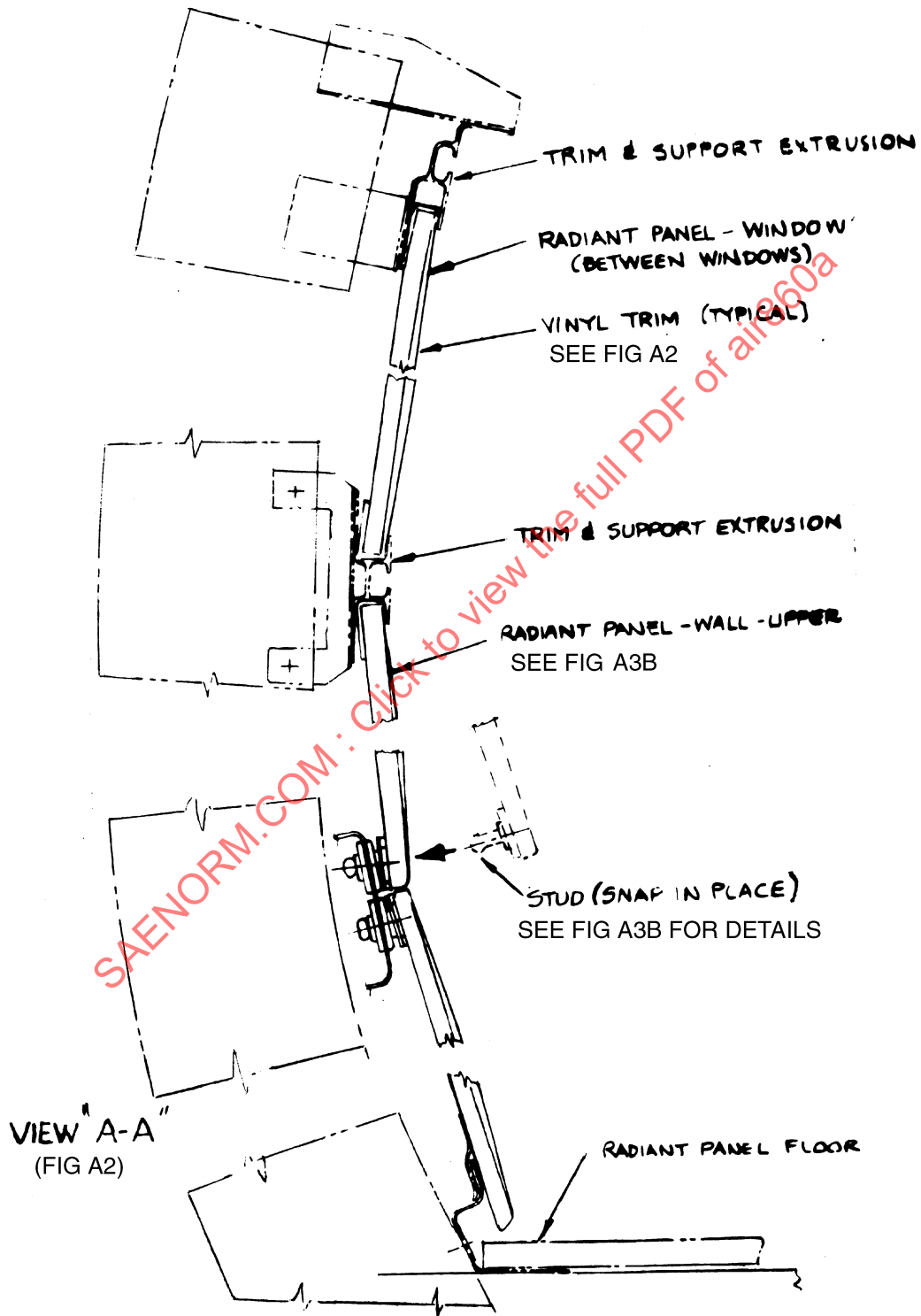


FIGURE A3A - Cabin Wall and Floor Radiant Panels - Sect. View

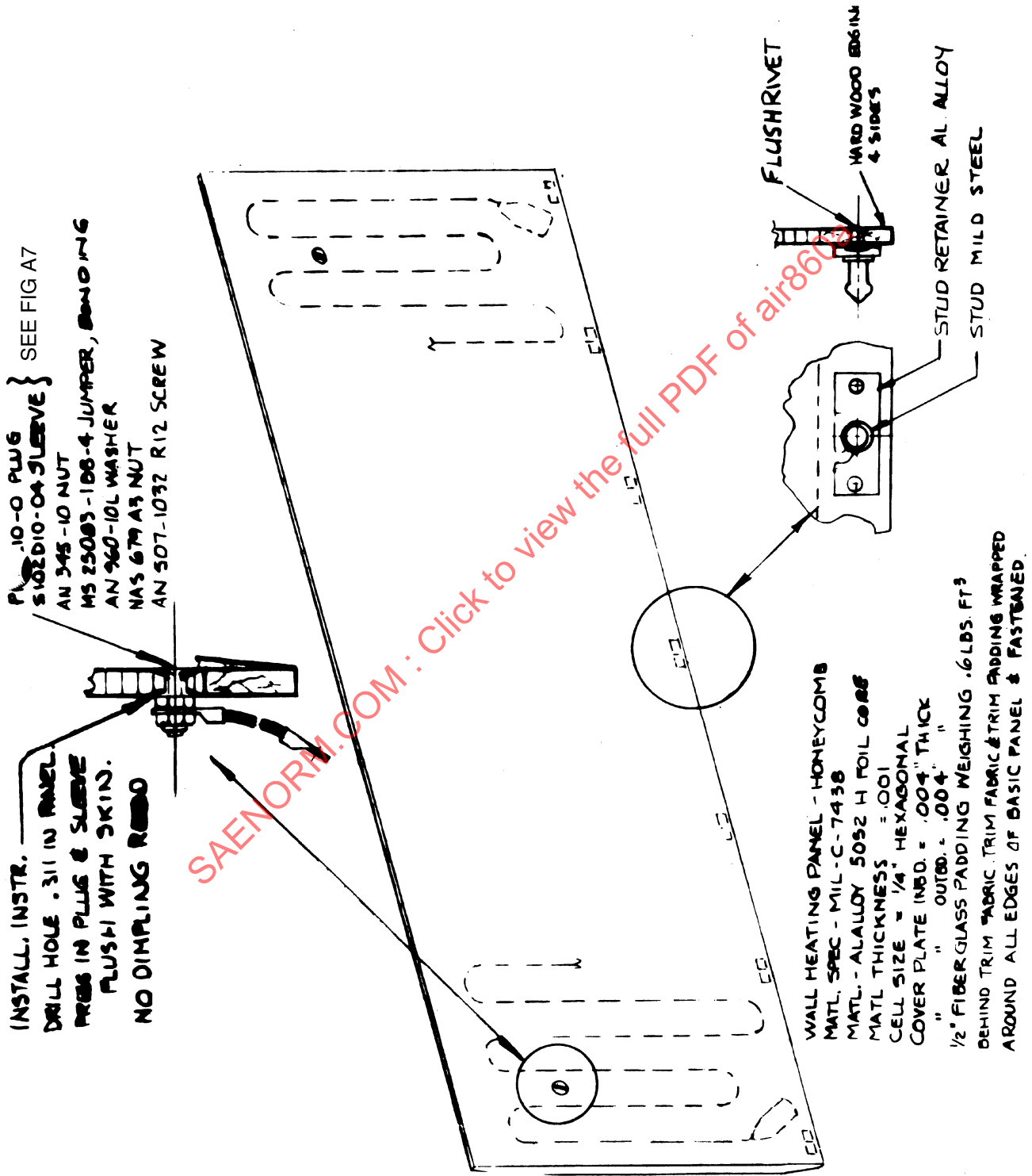


FIGURE A3B - Wall Panel - Upper

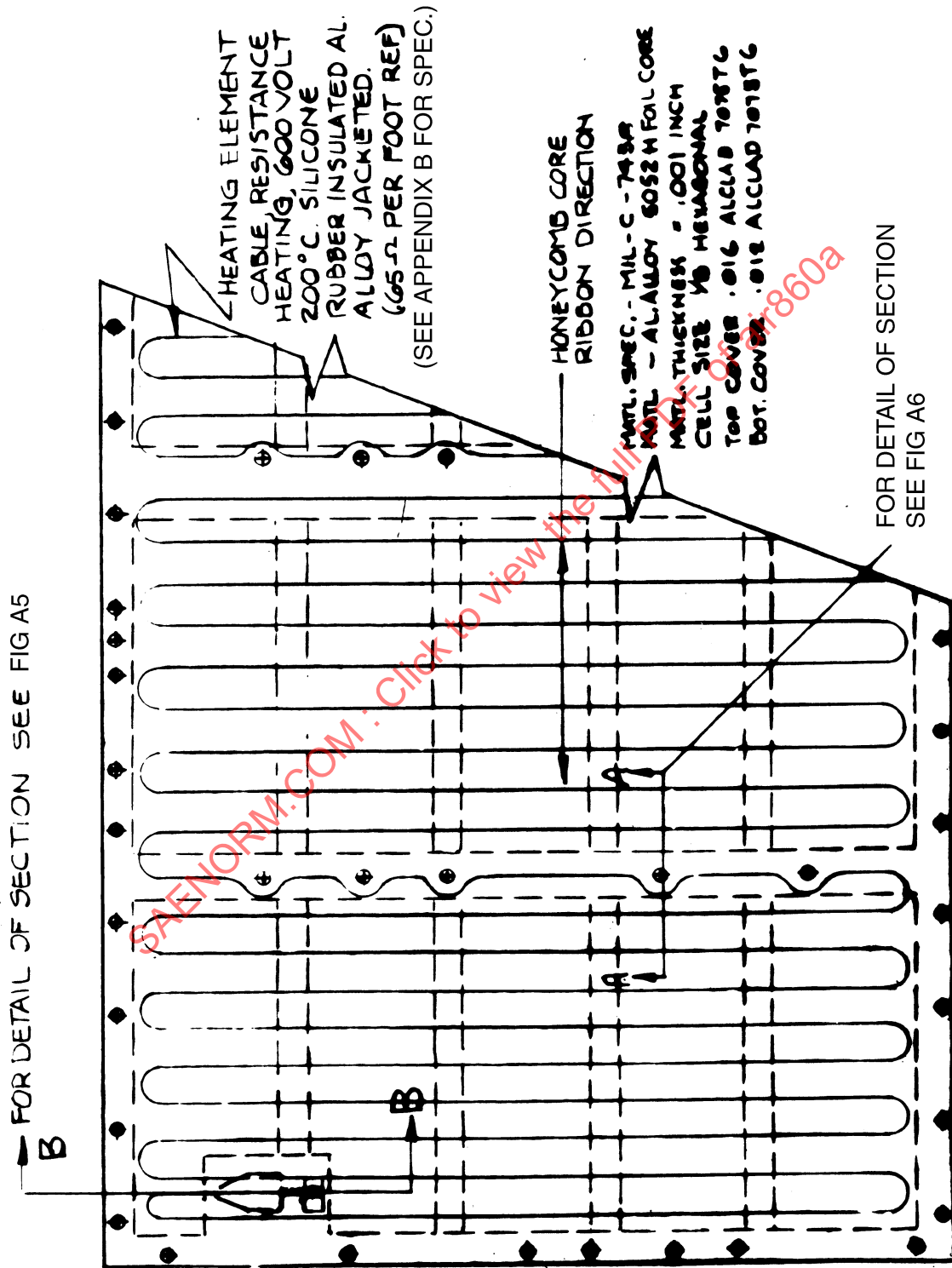


FIGURE A4 - Cabin Floor Radiant Panel Assembly

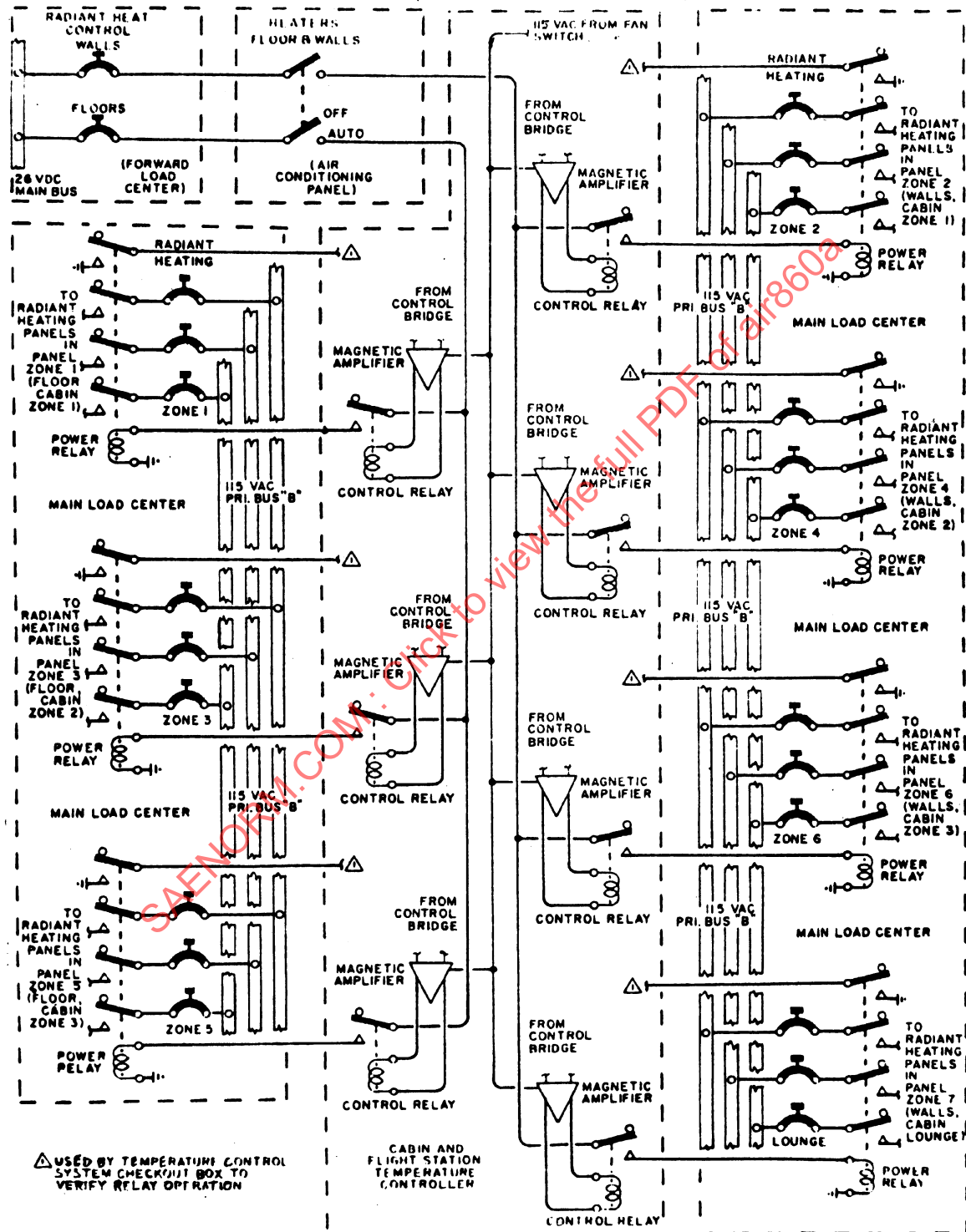


FIGURE A4A - Radiant Heat Panels Control

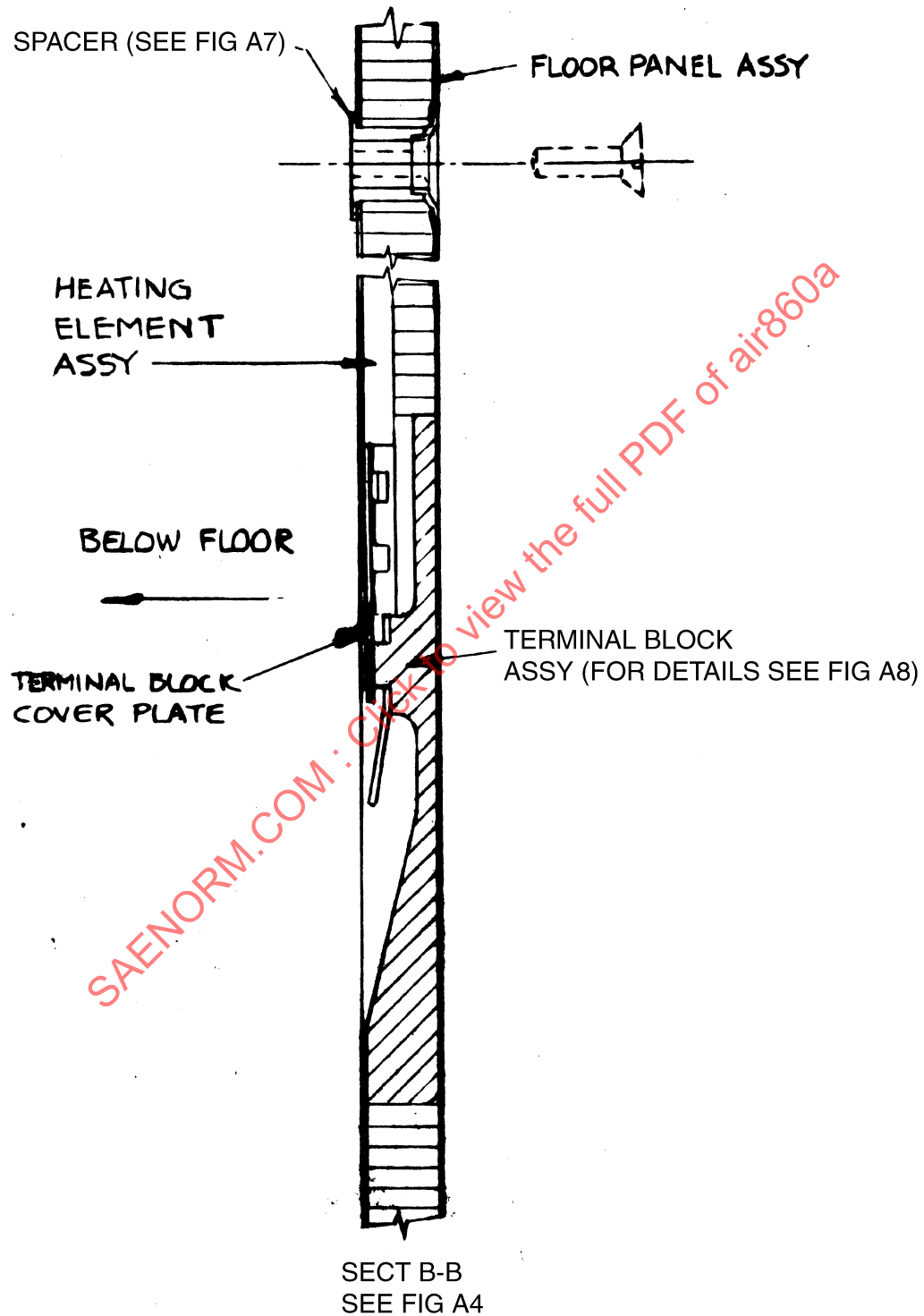


FIGURE A5 - Section - Terminal Block - Floor Panel Installation

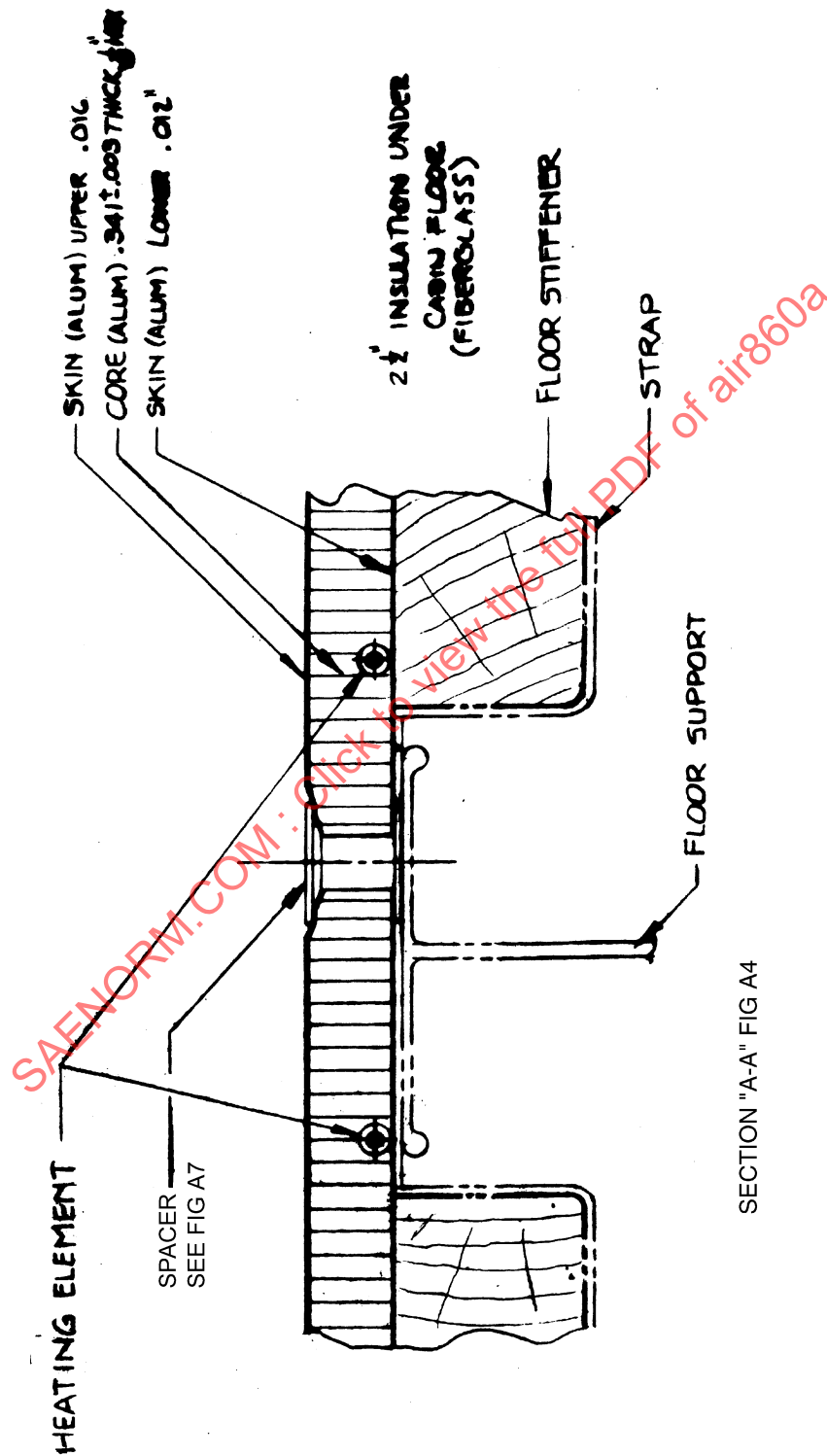
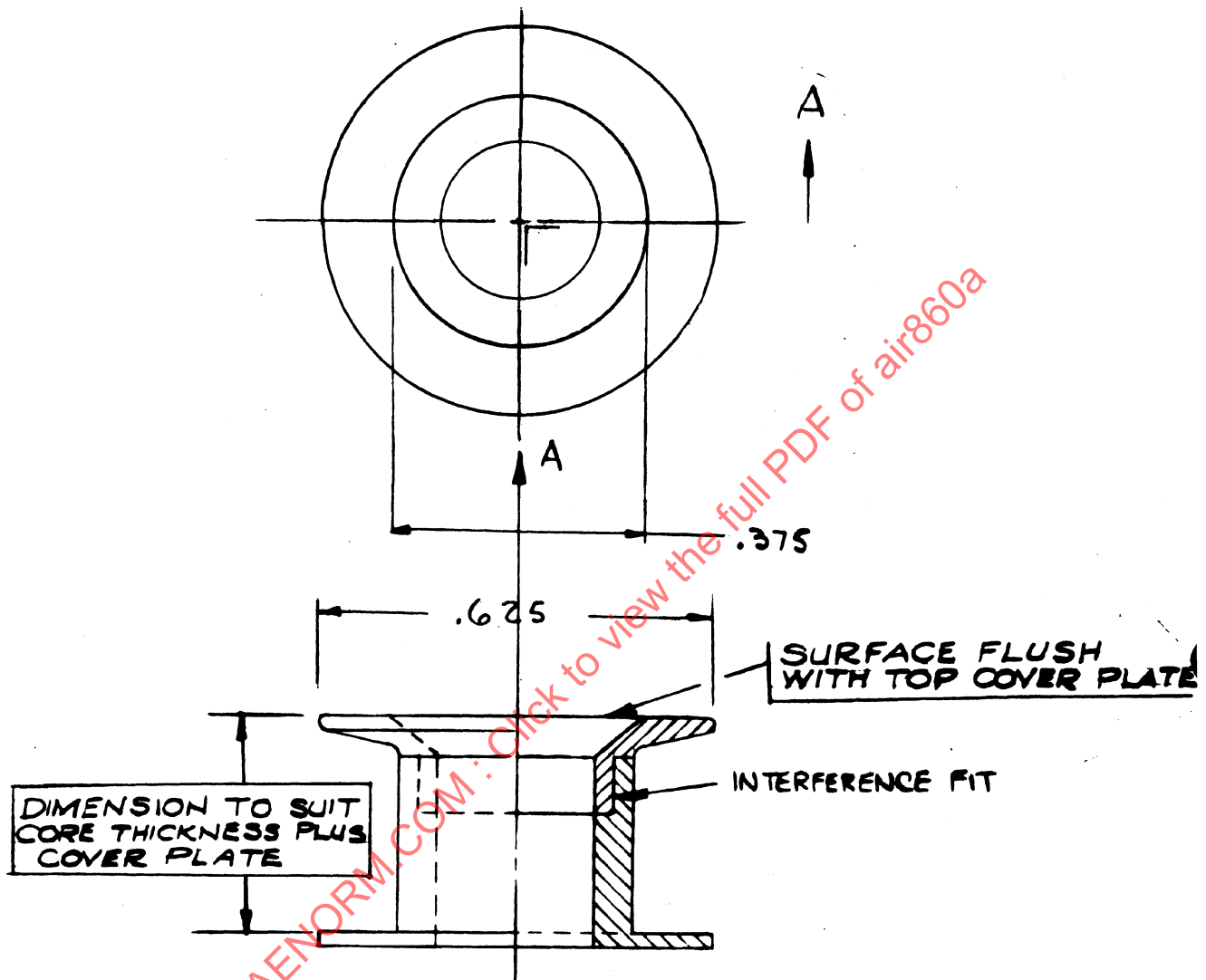


FIGURE A6 - Section of Cabin Floor Radiant Panel Installation



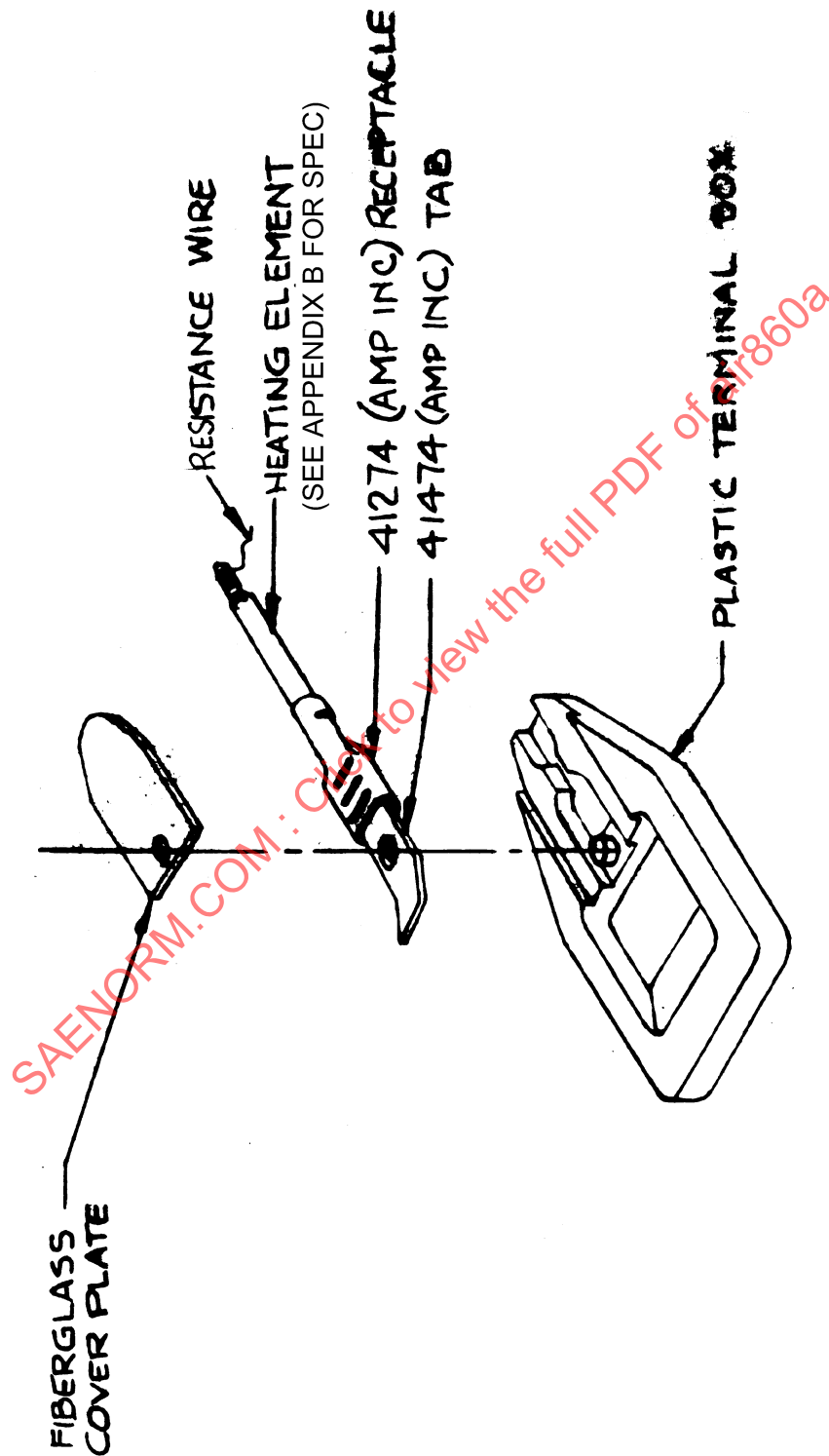


FIGURE A8 - Terminal Block Details

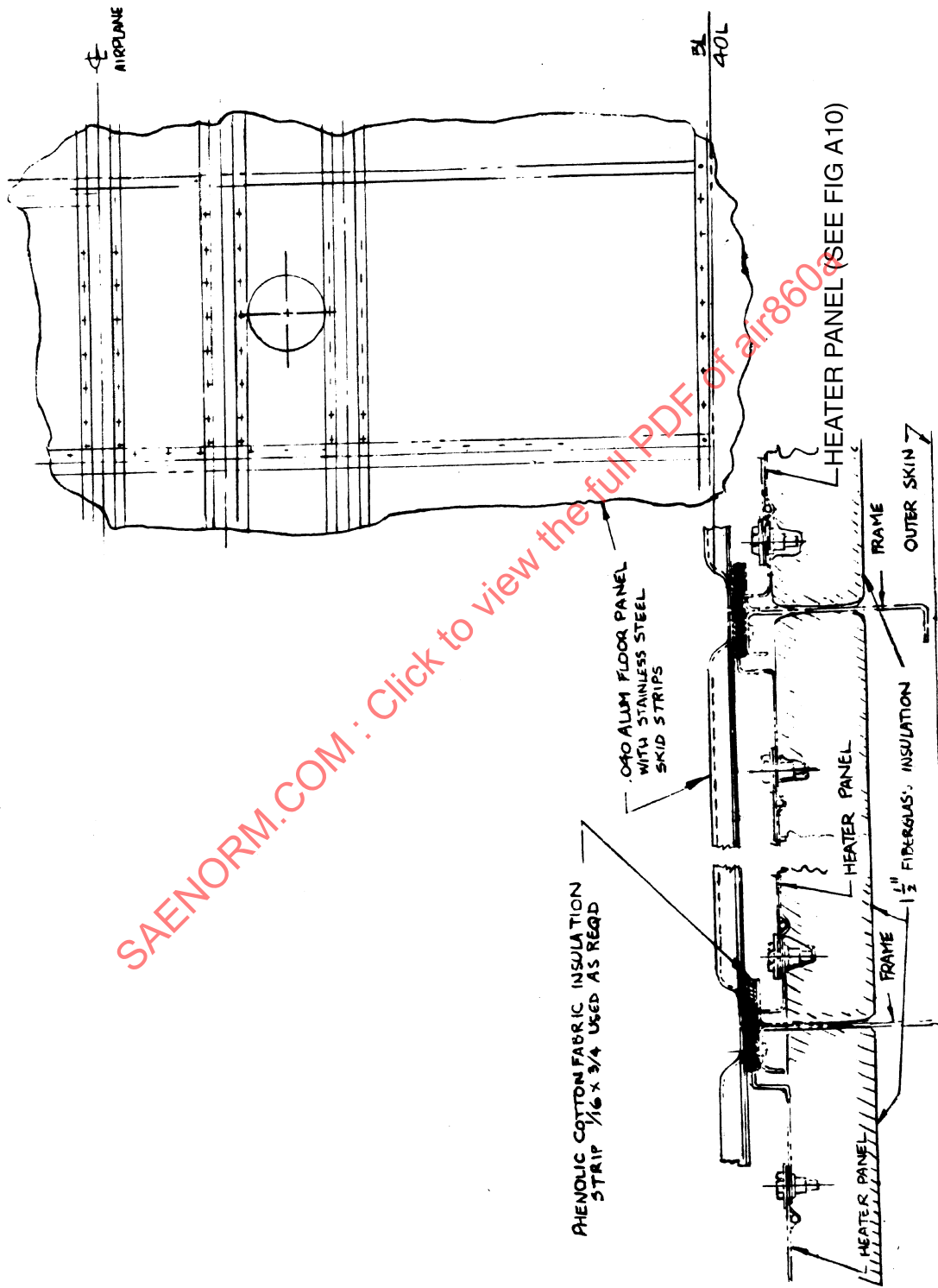


FIGURE A9 - Cargo Compartment Floor and Radiant Panel Installation

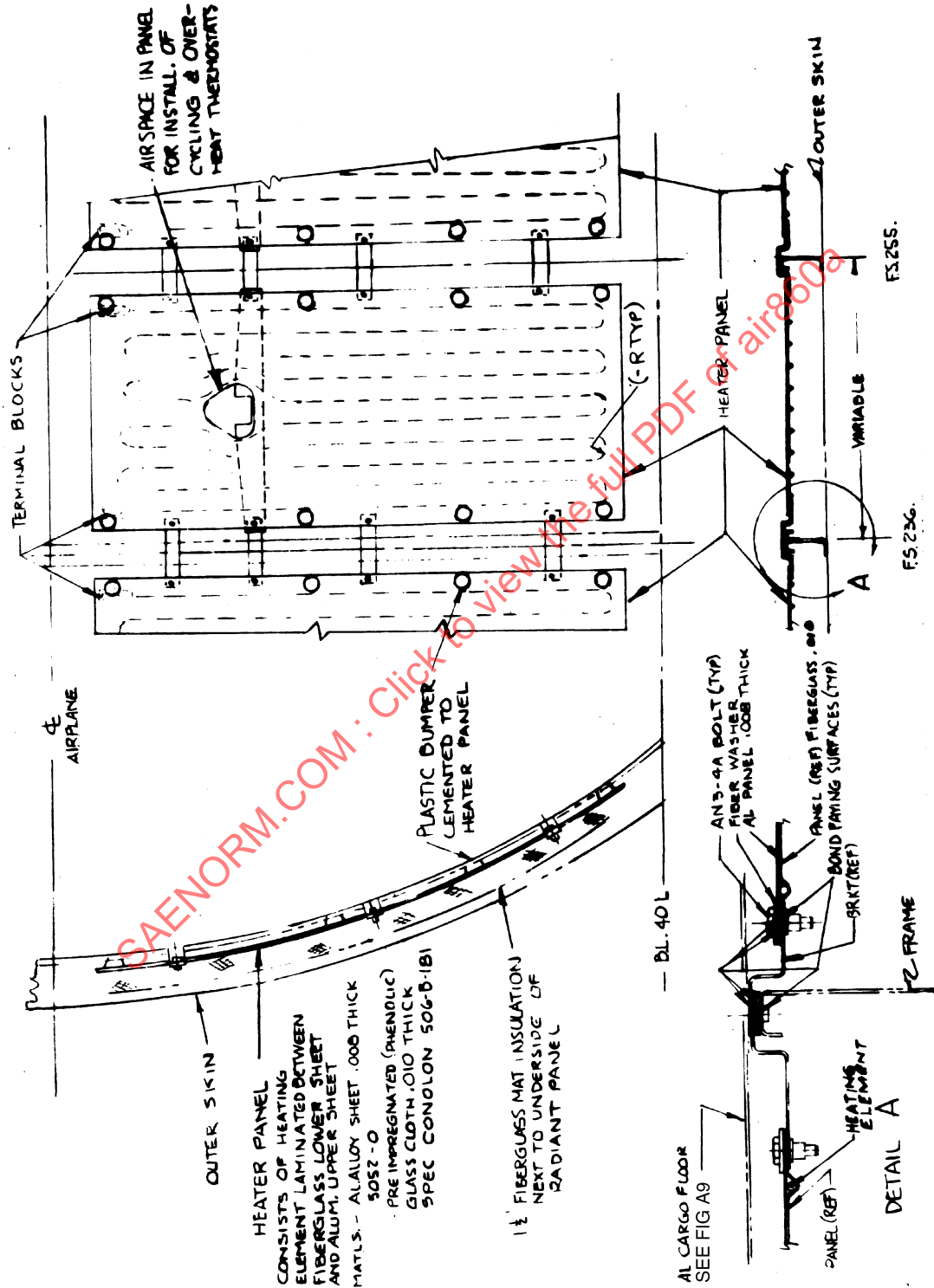


FIGURE A10 - Cargo Compartment Radiant Panel (Typ)

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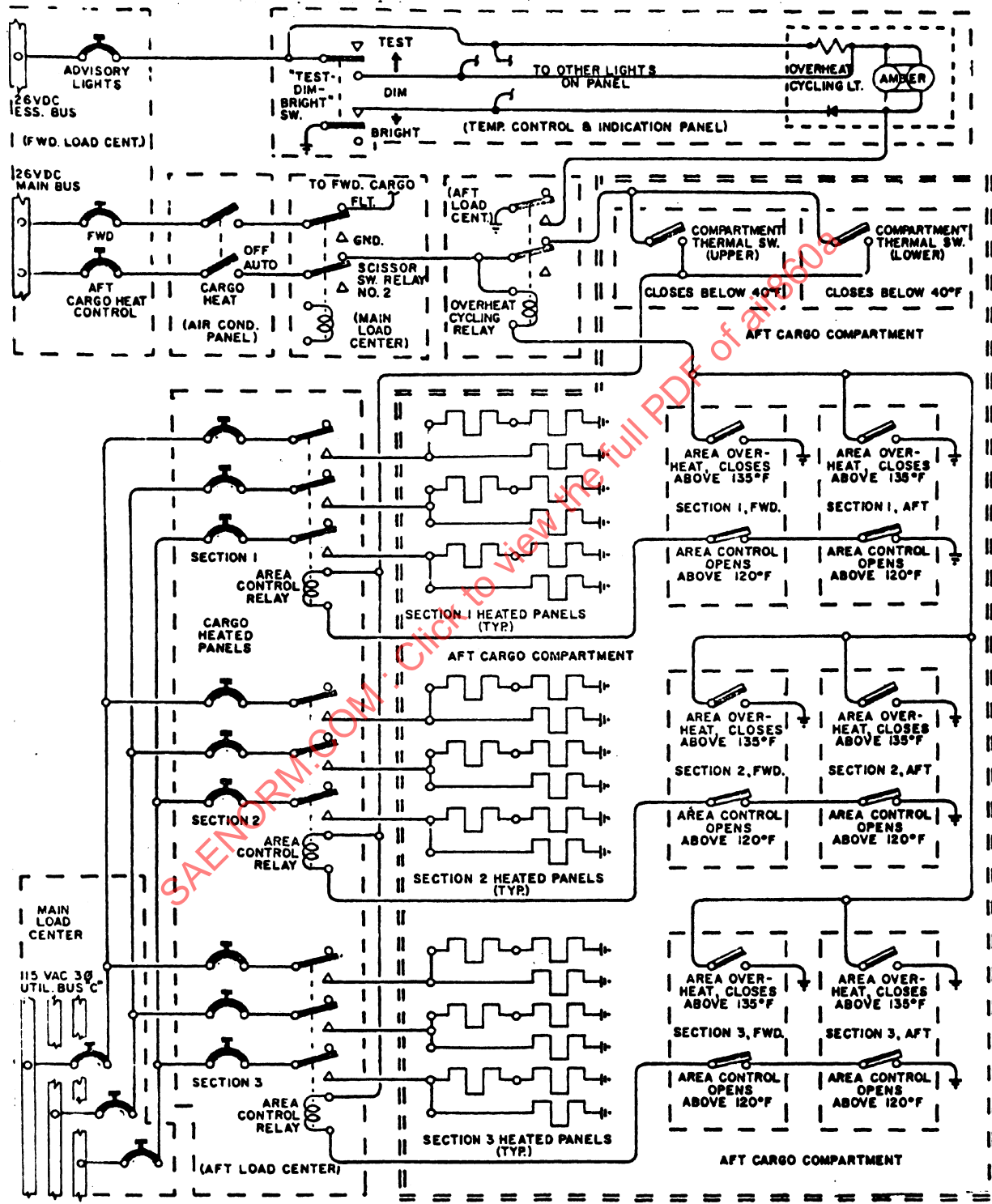


FIGURE A10A - Cargo Compartment Heating Circuit

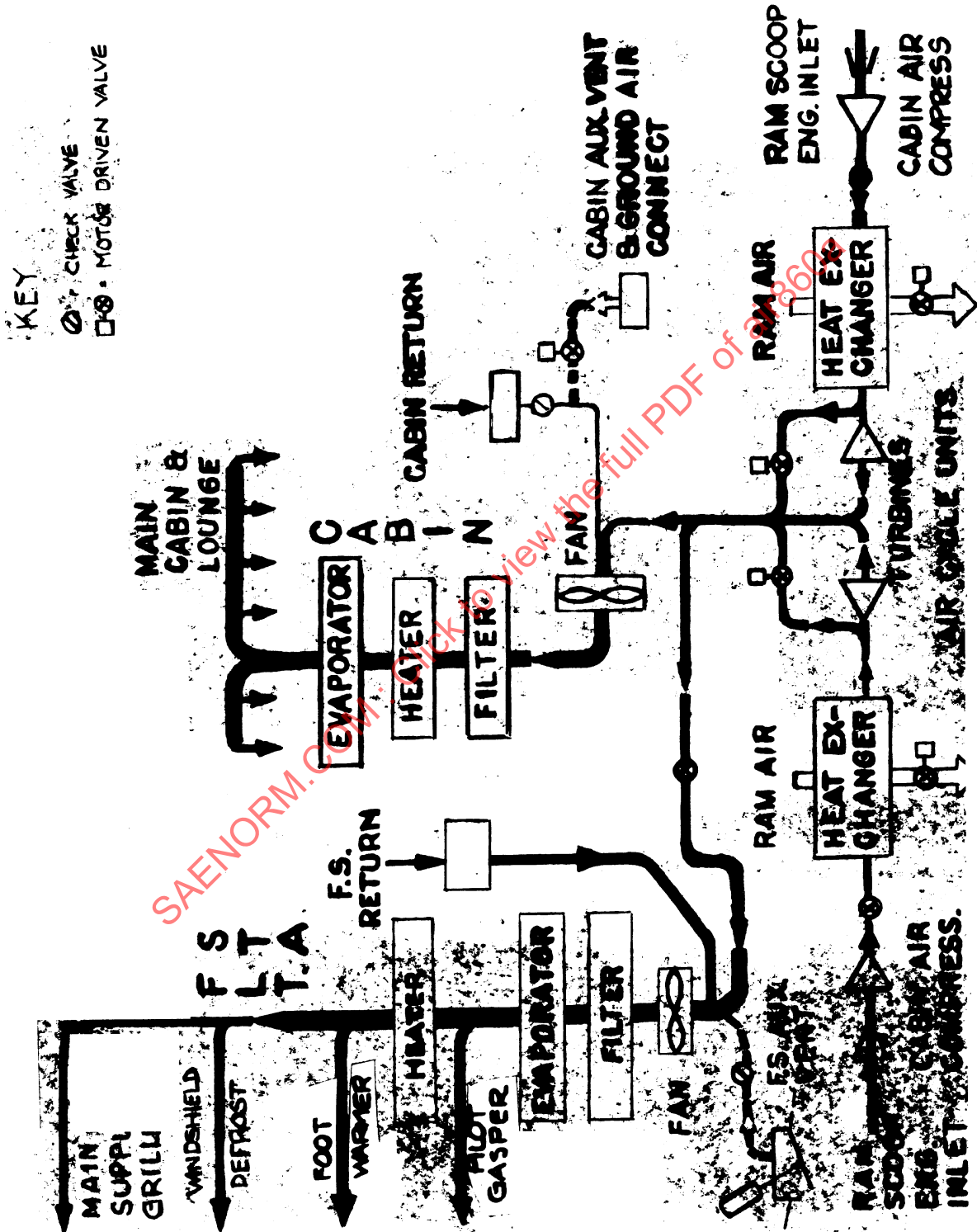


FIGURE A11 - Schematic of Air Conditioning System

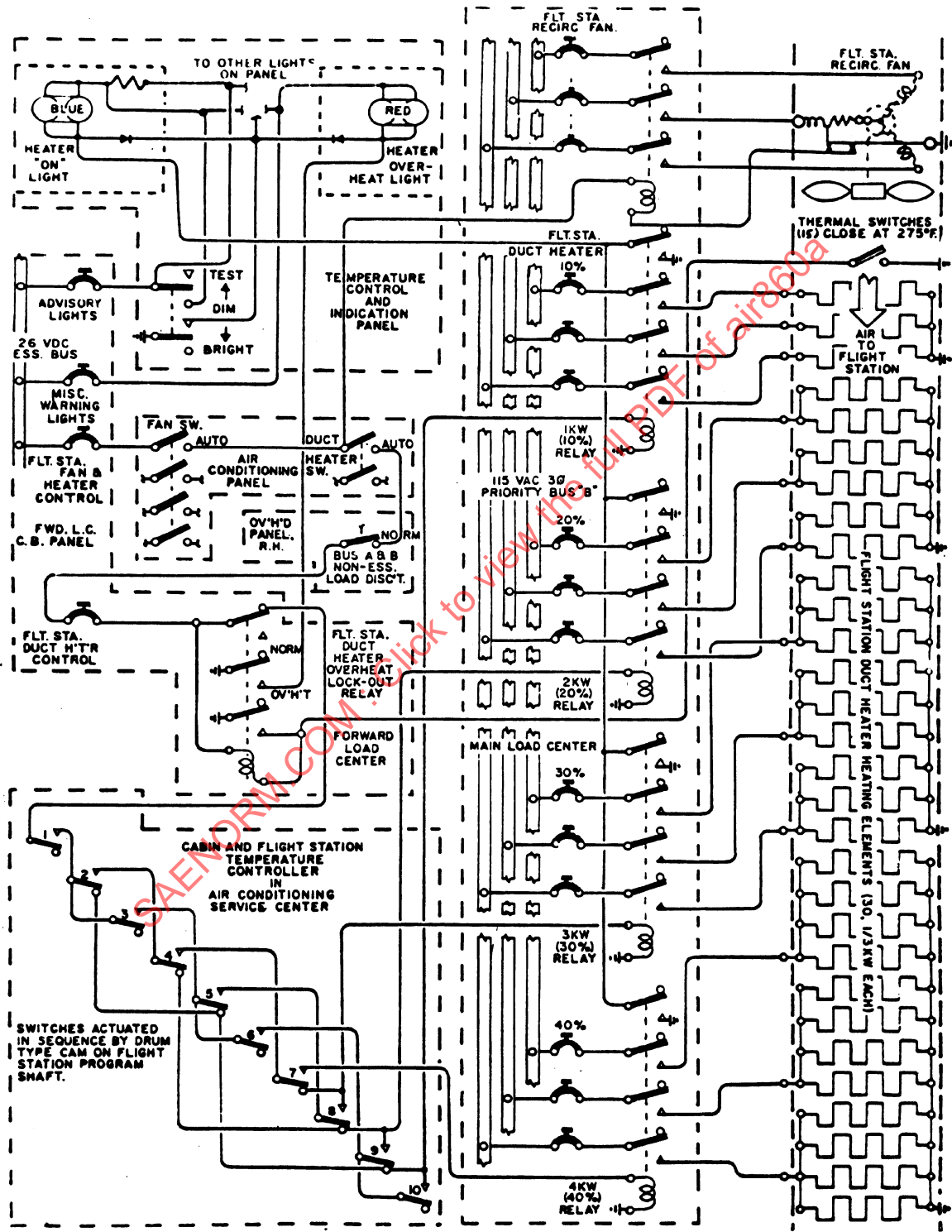


FIGURE A12 - Flight Station Duct Heater and Recirculation Fan Circuits

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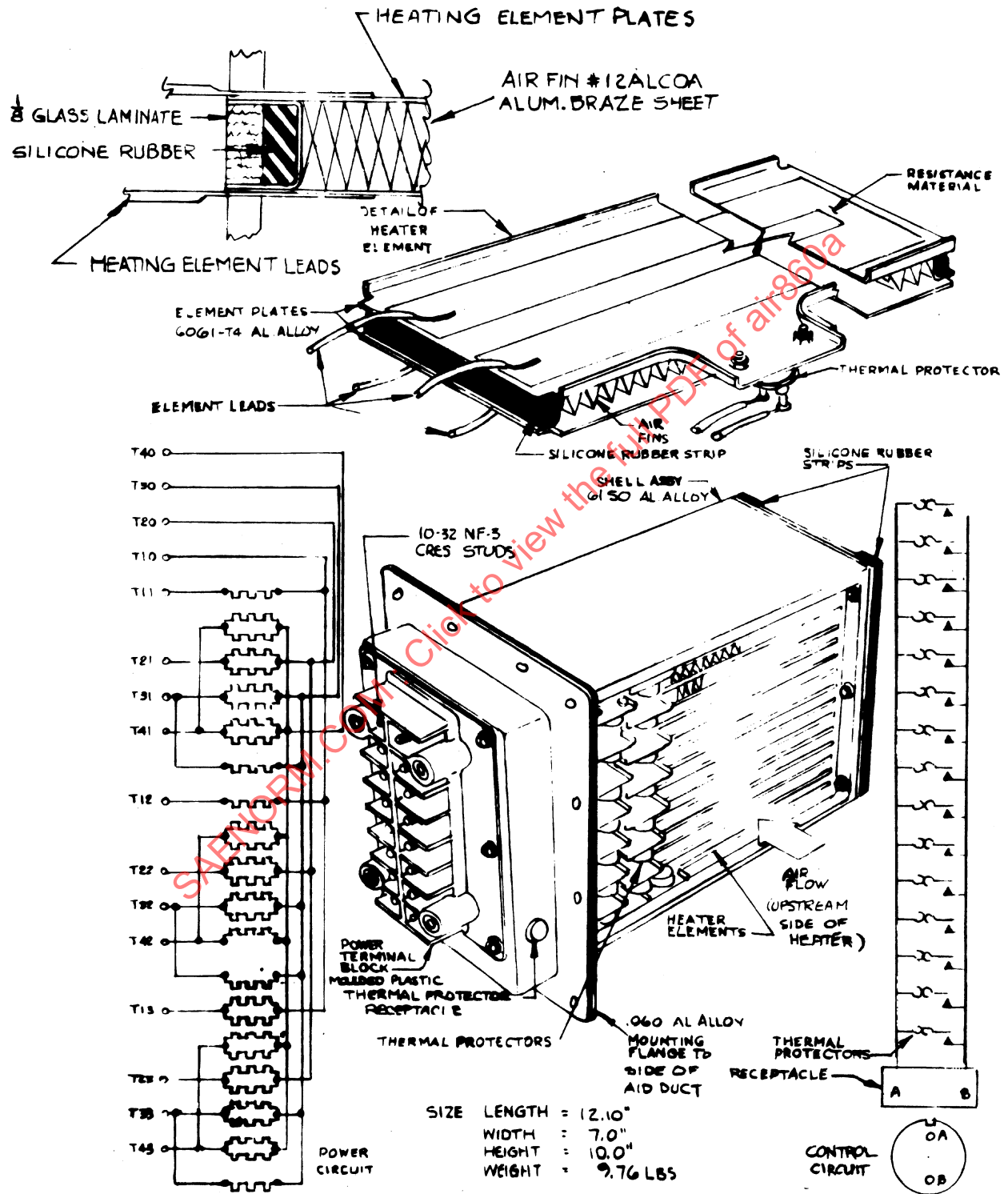


FIGURE A13 - Flight Station Duct Heater Details