AEROSPACE INFORMATION REPORT

SAE AIR860 REV. A

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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.

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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.

APPENDIX A

AIRCRAFT "A"

Section 1

GENERAL AIRCRAFT INFORMATION

TYPE	ENGINES		ALTITUDE	CABIN DIFF. PR.	FUSELAGE			
	Type	No.			Mat.	Max. Breadth		Press. Vol.
						Outside	Inside	
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 Cargo Fl.	Air Supply Ducts Insulation		Air Cycle	Vapor Cycle
1-1/2 in.	1-1/2 in. Fiber-glass - Mylar	Engine Driven Compressor (EDC) 2 Used	2 Used	2 Used

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

CARGO COMPARTMENT HEATING METHODS	TEMPERATURE REQMTS. A/C SYSTEM HEATING					
	In Flight			Ground Operation		
	Amb.	Occ. Area	Cargo	Amb.	Cab & Flt.	Cargo
Elec. Resist. Panels, Floor	-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 ± 2°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	Flt. Sta. Cabin	-5°F.	75°F.	9.0 KW	10 KW (Duct Heater)
	50 lb Fresh Air		-5°F.	75°F.	23.0 KW	30 KW (Radiant Panels 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)

Section 2

SPECIFIC DESIGN AND OPERATION INFORMATION

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS

FLOOR PANELS

LOCATION	TYPES USED			DETAILS - HONEYCOMB HEATED CONSTRUCTION Material and Size: Core	Plates
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)	Al. Al. 5052H Foil Spec. MIL-C-7438 Cell Size 1/8 in. Hex Thickness = .001 in. Cell Depth = .341 ± .003	Top Cover Plate Alclad 7075T6 Spec. QQ-A-287 .016 in thickness Bottom Cover Plate Alclad 7075T6 Spec. QQ-A-287 .012 in. thickness
				See Figures A4 & A6	

FLOOR PANELS
DETAILS - HONEYCOMB HEATED

BONDING	CONSTRUCTION: ELECTRICAL RESIST. CABLE Install. & Mat.	Capacity	ELEC. TERMINAL	MOUNTING SPACERS	INSTALLATION METHOD: SCREWS	
MIL-A-5090 Adhesive System	Installation See Fig. A4 Install in crushed groove Material See App. B	20 watts per sq. ft. Power 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)

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. One 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	$\pm$ 10% from Resist. per detail drawing

FIGURE A1 (Continued)

WALL AND WINDOW HEATING PANELS

LOCATION	TYPES USED	DETAILS, PANELS, WALL AND WINDOW		
		CONSTRUCTION		
		MATERIAL AND SIZE		BONDING
		Core	Plates	
See Figs. 3A and 3B	Honeycomb Heated 1/4 in. thick 32 Sidewall Panels 37 Windows	Al. Al. 5052H Foil Spec. MIL-C-7438 Cell size 1/4 in. Hex. Thickness .001 Cell Depth 1/4 in.	Inboard Cover Plate Al. Al. .004 in. thick Outboard Cover Plate Al. Al. .004 in. thick	MIL-A-5090 Adhesive System

CONSTRUCTION (continued)

Edging	Trim	Trim Padding	Elec. Resistance Cable	
			Install. & Mat.	Capacity
Hardwood inserts on 4 edges	Cabin Side "Naugahyde" or "Duratrim" vinyl coated fabrics. Cemented or stapled to panels	Cabin Side 1/2 in. Fiberglass 0.6 lbs. per cu. ft. Install between trim and panel	Installation See Fig. A2 Similar to Floor Panel Fig. A4 Material See App. B	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)

SPECIFIC DESIGN AND OPERATION INFORMATION

CARGO COMPARTMENT - ELECTRIC RADIANT PANELS

CARGO HEATING PANELS

LOCATION	TYPE USED	CONSTRUCTION		
		Material and Size		
		Al. Alloy	Fiberglass Cloth	Bonding
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 fiber-glass, with heating element wires between the two layers.	.008 in.thick 5052-0 Spec. QQ-A-318	.010 thick Phenolic impregnated Spec. "Conolon 506-B-181" "Narmco" or "AF104#120" by 3M Co.	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
	Install. & Mat.	Capacity		
Plastic Foam, Cellulose Acetate Rod	Installation See Fig. A10 Material See Appendix B	61 watts per sq. ft. Power 115/208 VAC 3 phase 400 cycle	See Fig. A8 See Fig. A10A	See Figs. A9 & A10

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	
	At Sea Level	At 8000' Press. Alt.
See Fig. A14 for Test Setup 1. Continuity test 2. Airflow distribution across face of heater must be uniform 3. Electrical sequence per Table A1. 4. Overheat test - no airflow - Thermal protector to operate within 90 seconds.	Air Flow 30#/min. Air "In" Temp. 70°F Max. Temp. Rise 79°F Max Pr. Drop .50 in. H_2O Max. Surface Temp. 300°F Normal Surface Temp. 200 to 250°F.	22#/min. 70°F. 108°F. .40 in. H_2O 350°F. 200 to 250°F.

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 2. Airflow distribution across face of heater 3. Electrical sequence test per Table A2 4. Overheat test - no airflow - thermal protector to operate within 90 seconds	Air Flow 151#/min. Air "In" Temp. 70°F. Max. Temp. Rise 28°F. Max. Pr. Drop .35" H_2O Max. Surface Temp. 300°F. Normal Surface Temp. 150 to 200°F.	116#/min. 70°F. 36°F. .30 in. H_2O 350°F. 150 to 200°F.

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

	TEST INFORMATION			
Energizing Sequence Steps	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

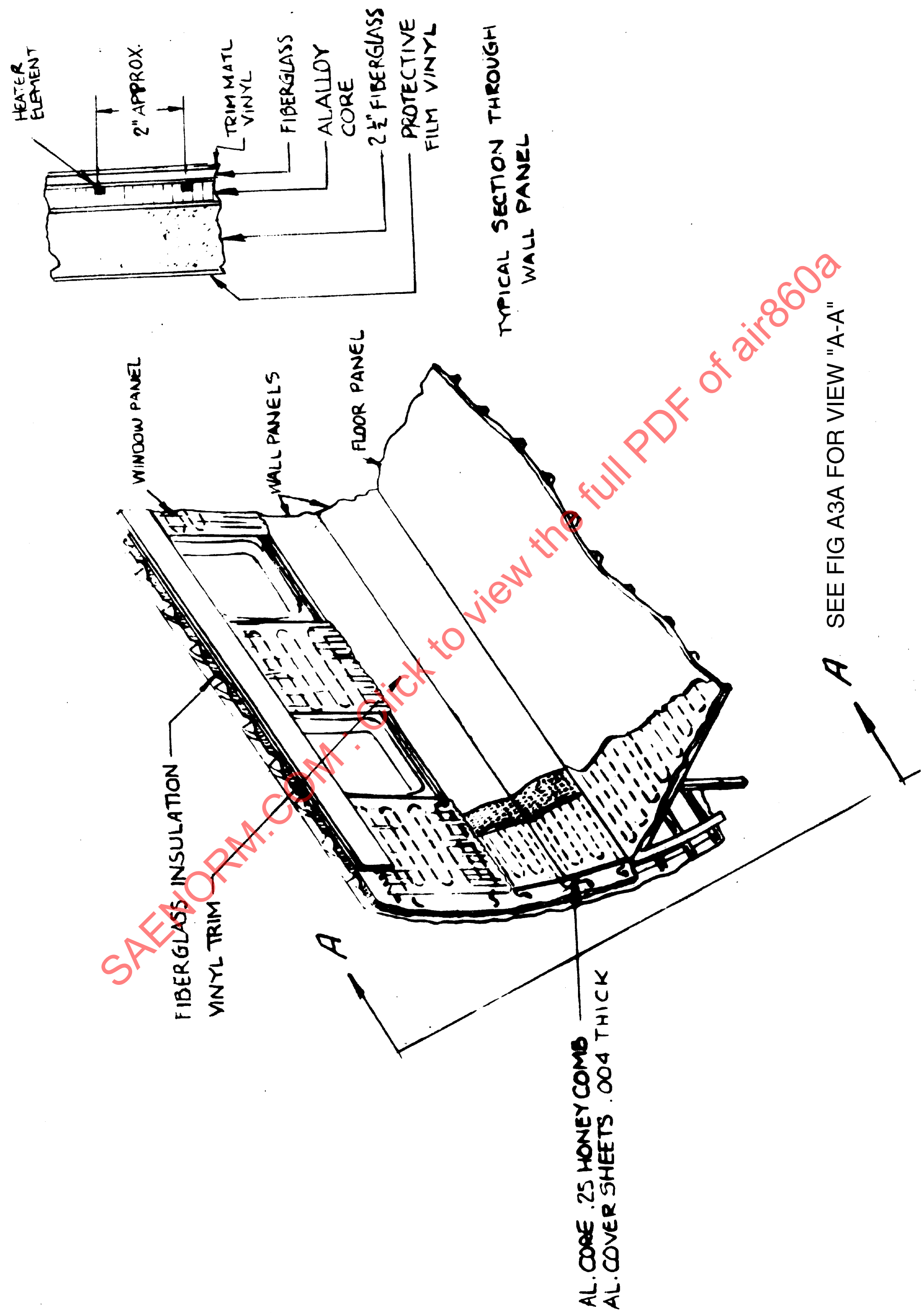

FIGURE A2 - Cabin Wall and Floor Radiant Panels

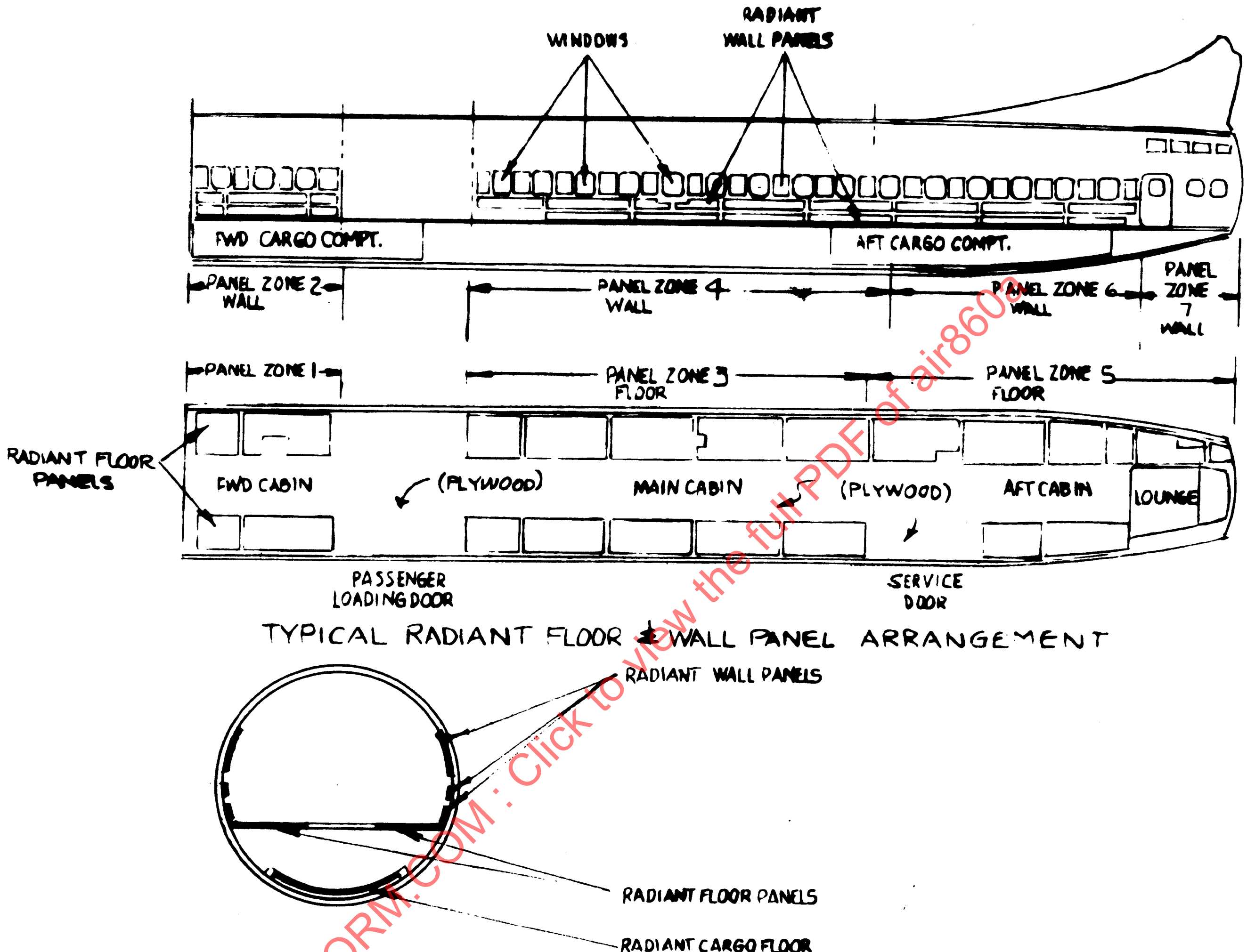

FIGURE A3 - Radiant Heating Panels

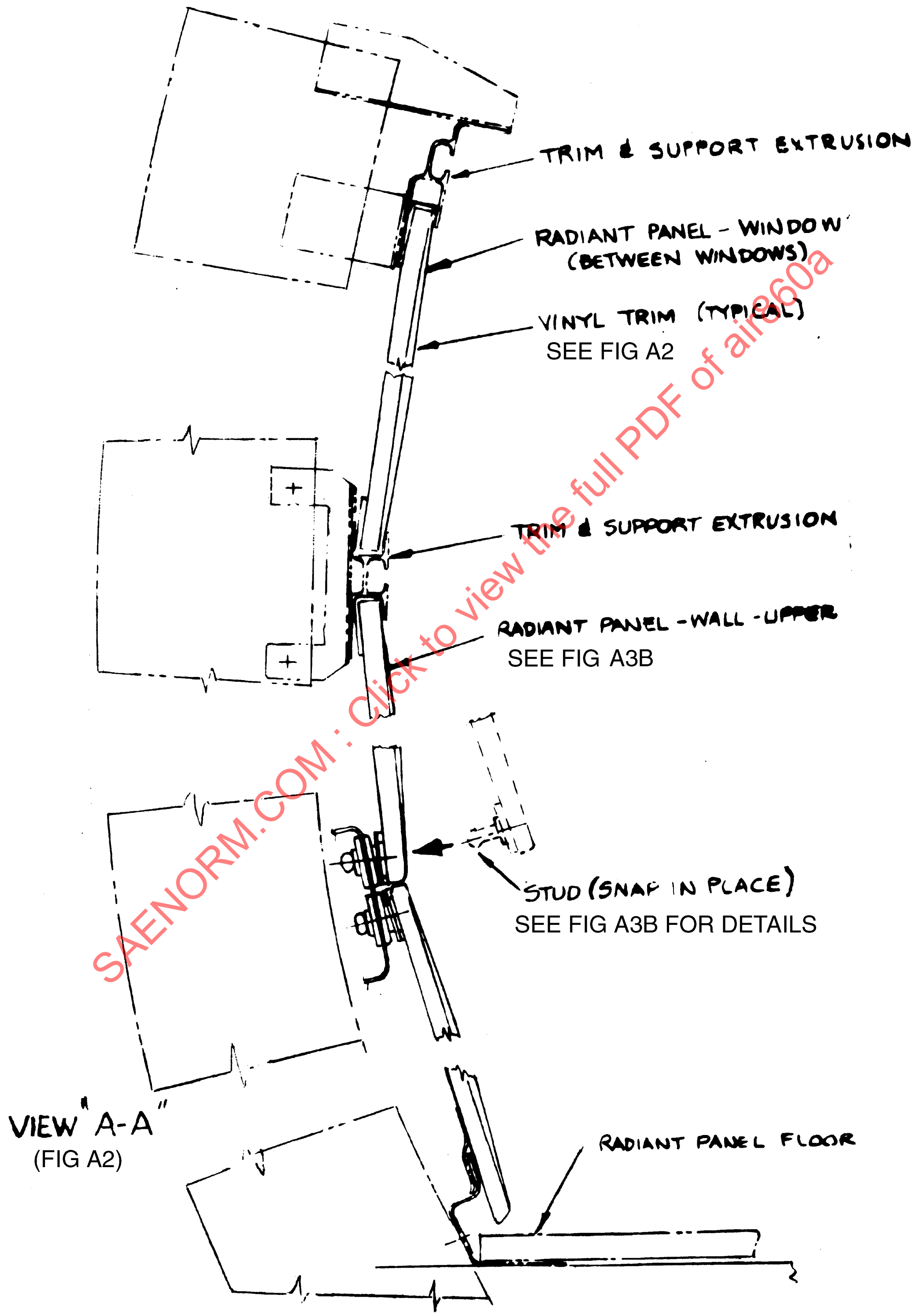

FIGURE A3A - Cabin Wall and Floor Radiant Panels - Sect. View

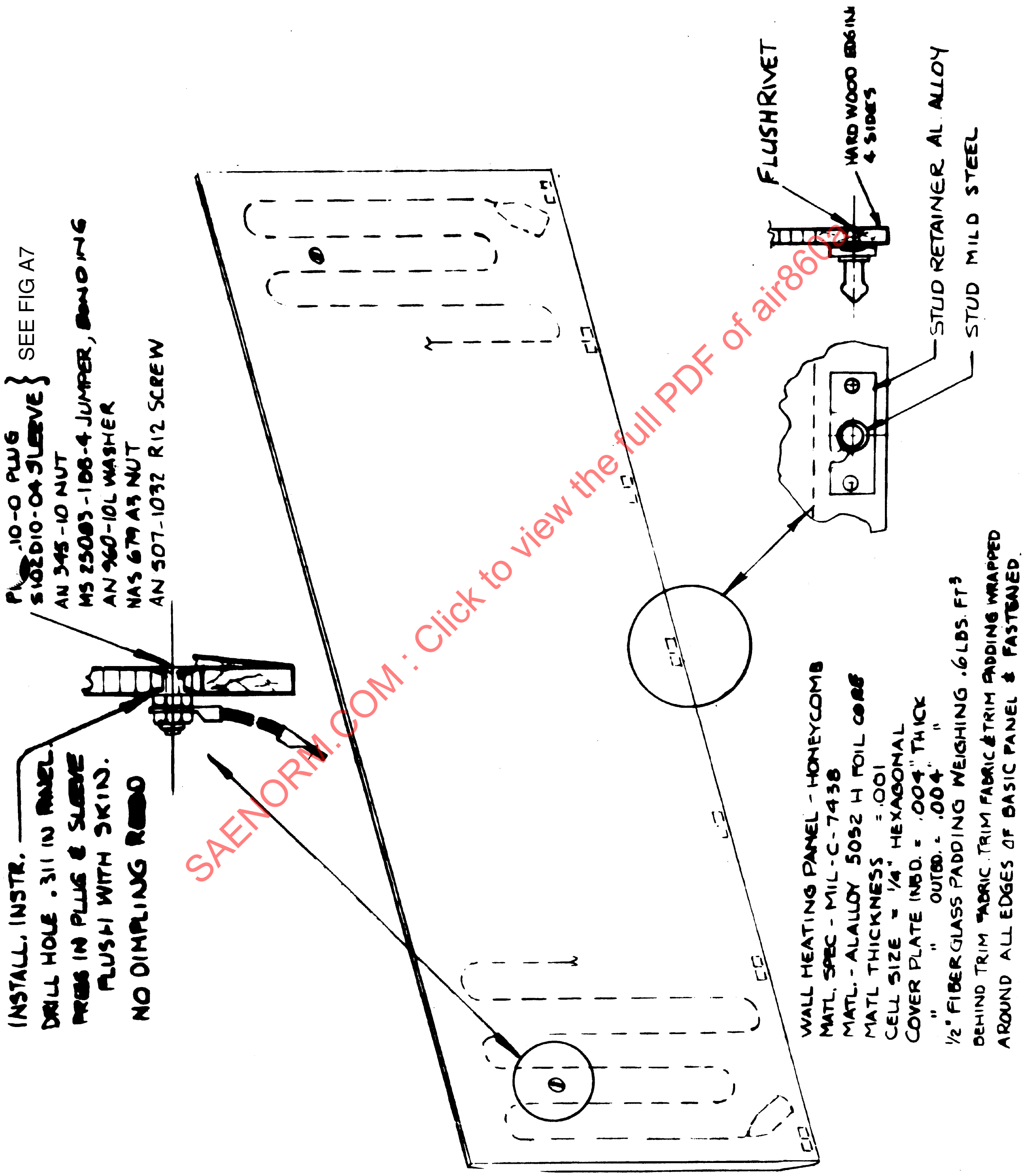

FIGURE A3B - Wall Panel - Upper

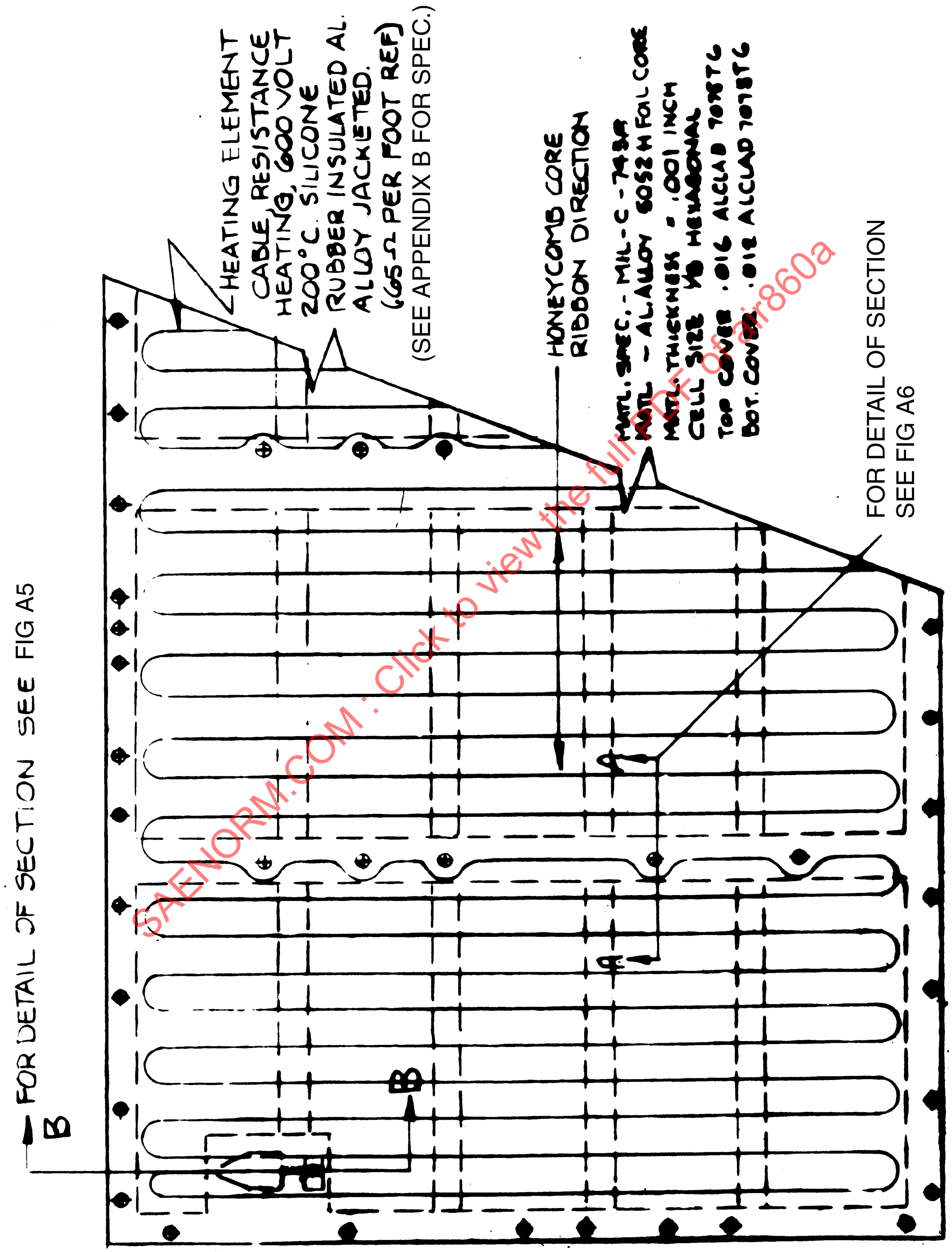

FIGURE A4 - Cabin Floor Radiant Panel Assembly

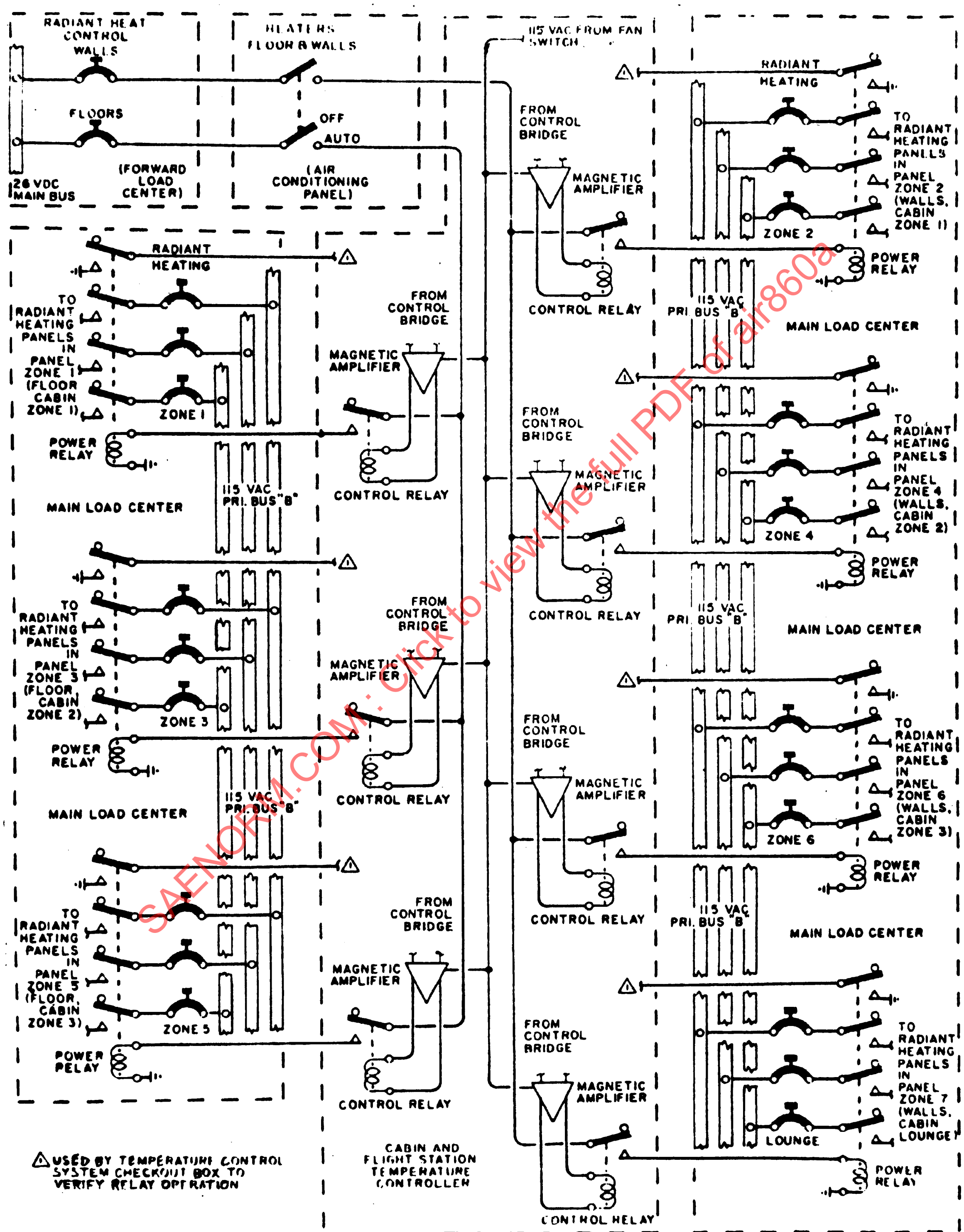

FIGURE A4A - Radiant Heat Panels Control

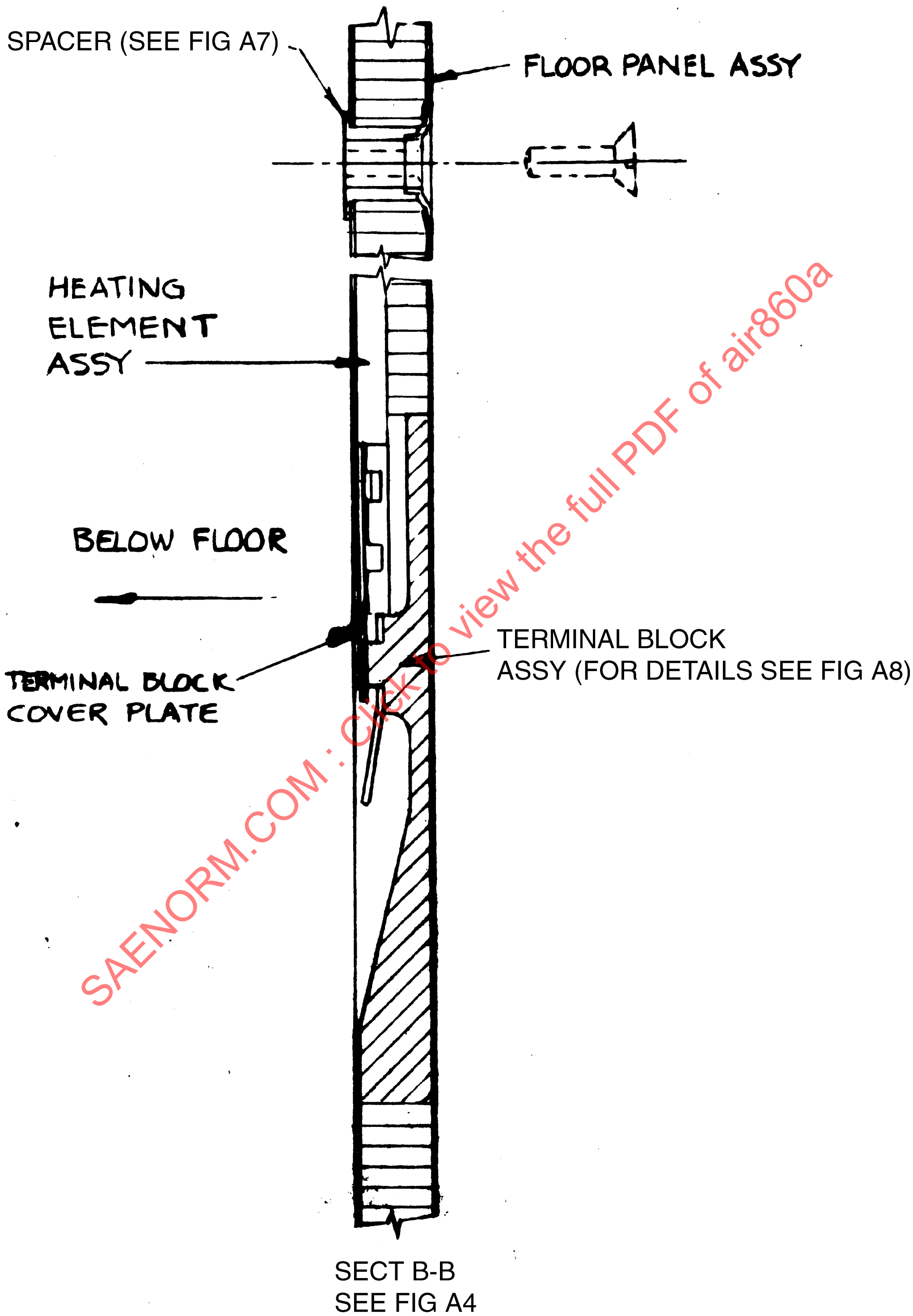

FIGURE A5 - Section - Terminal Block - Floor Panel Installation

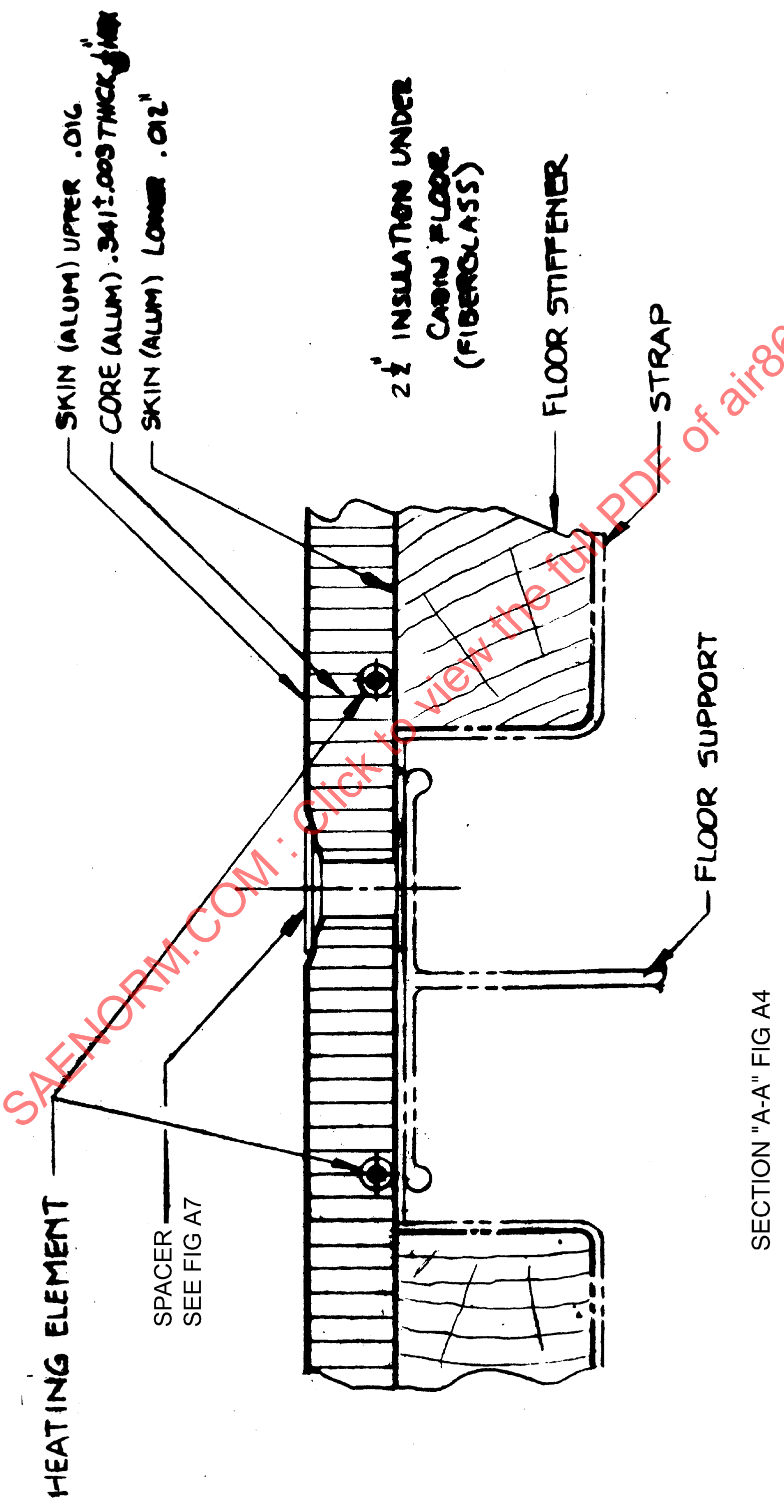

FIGURE A6 - Section of Cabin Floor Radiant Panel Installation

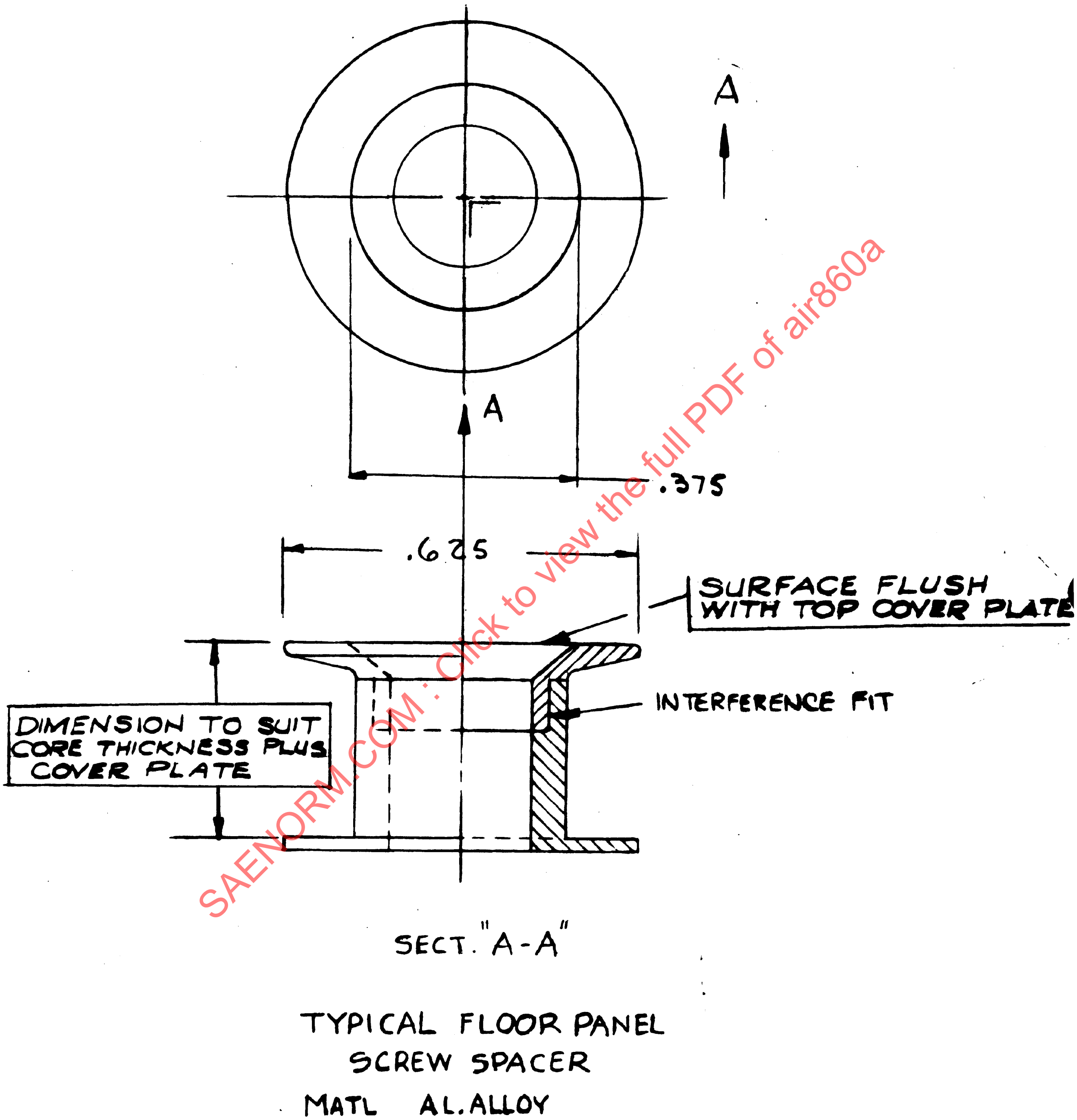

FIGURE A7 - Spacer - Screw - Radiant Panel

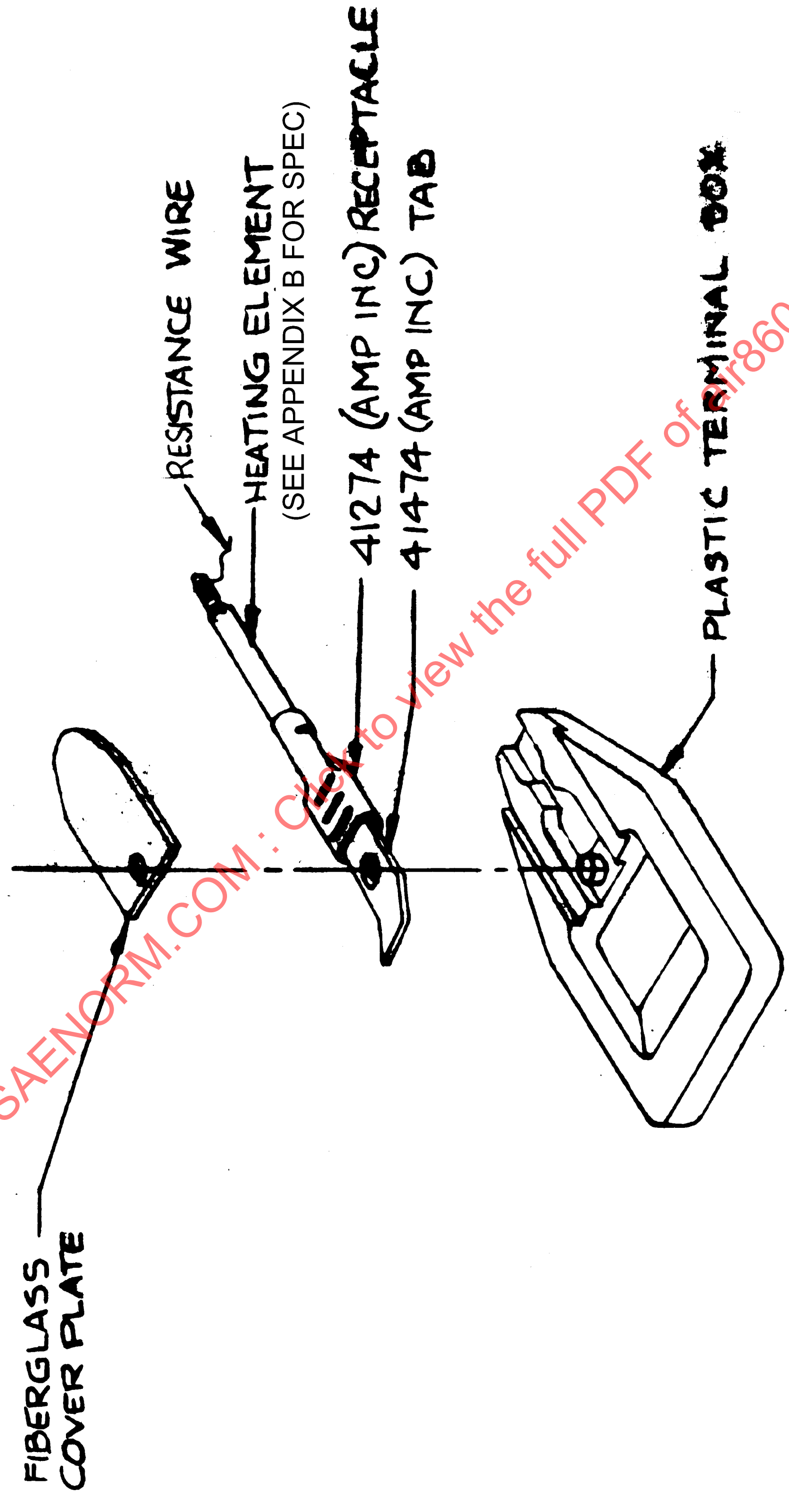

FIGURE A8 - Terminal Block Details

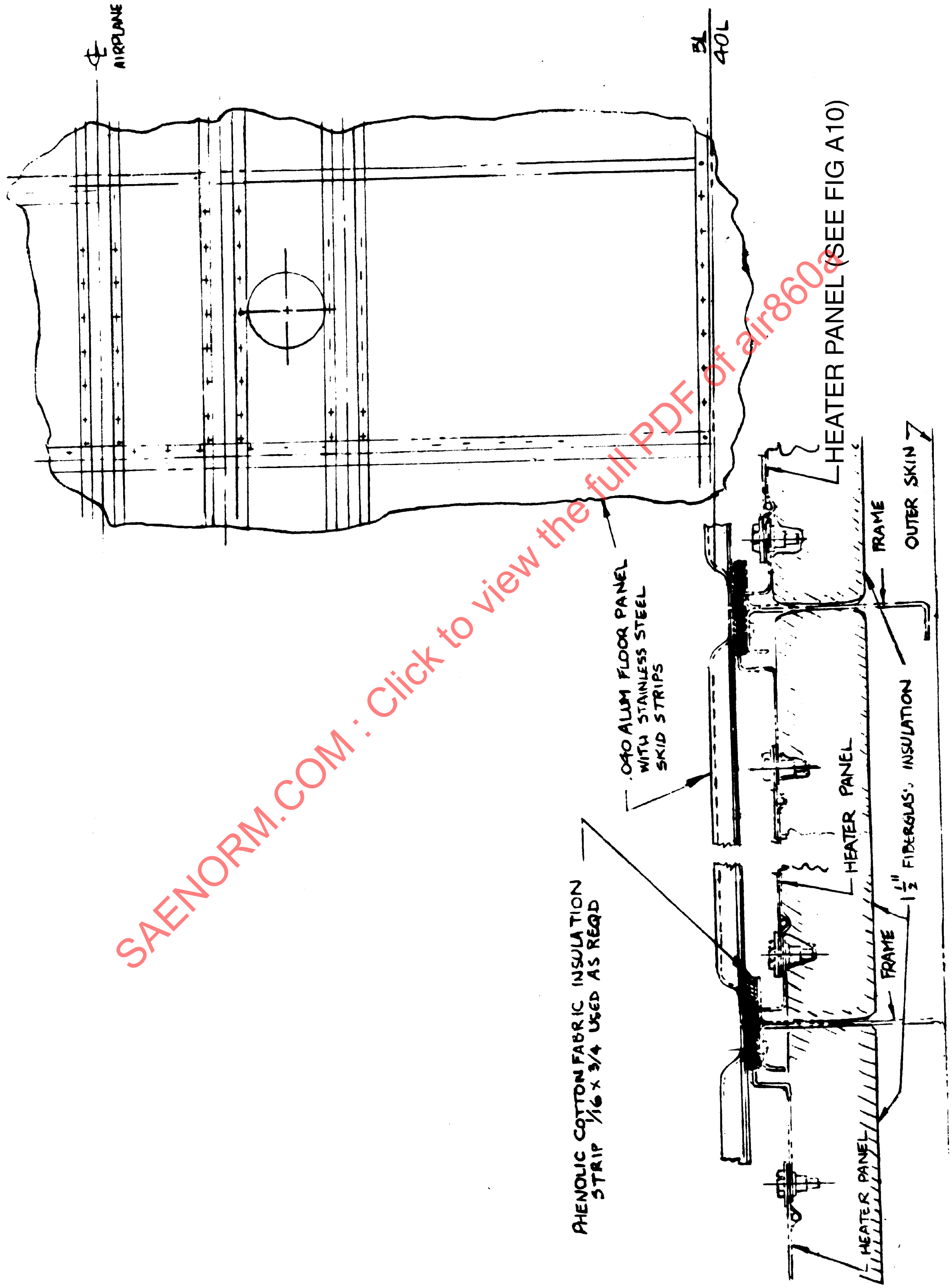

FIGURE A9 - Cargo Compartment Floor and Radiant Panel Installation

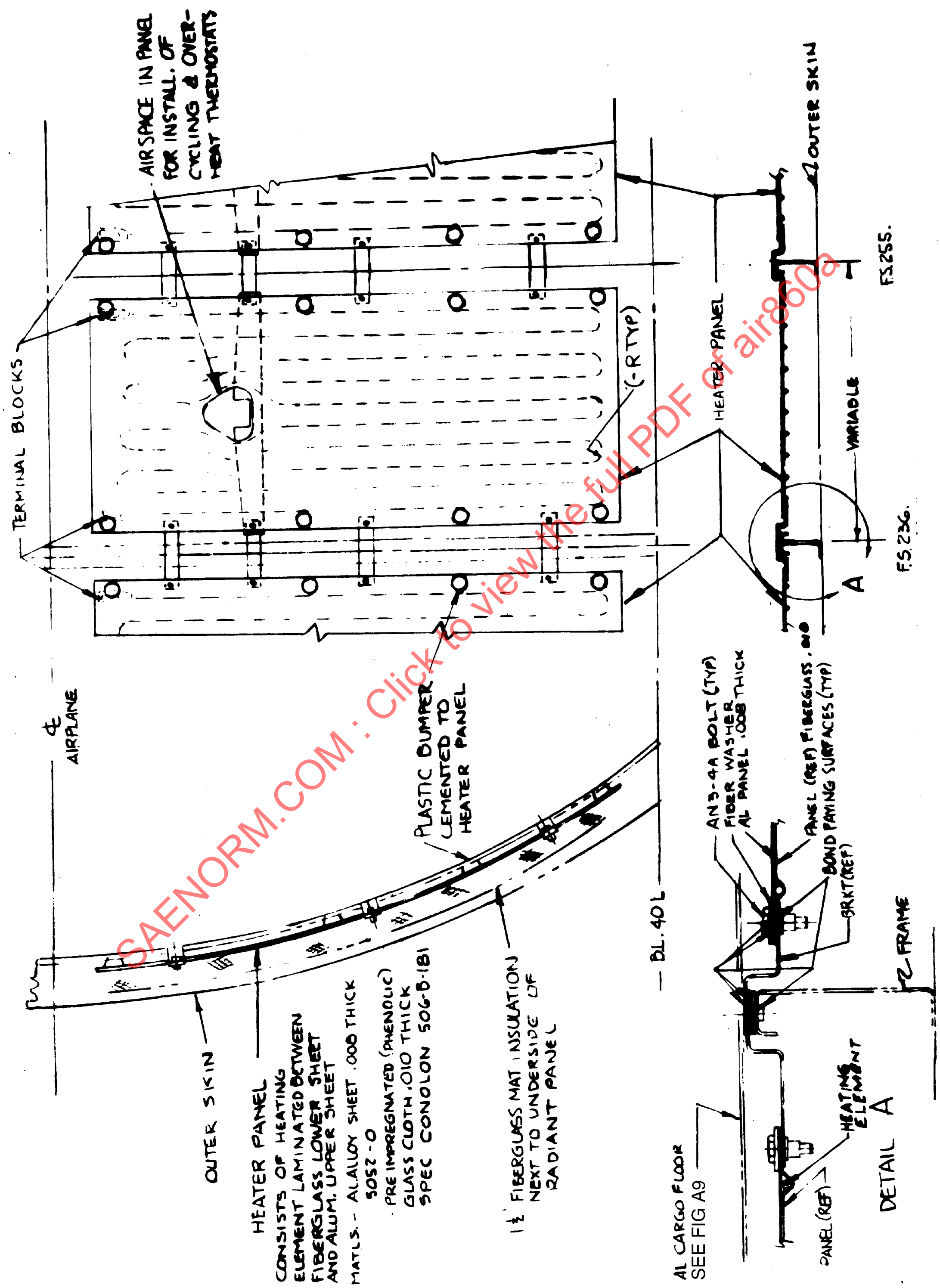

FIGURE A10 - Cargo Compartment Radiant Panel (Typ)

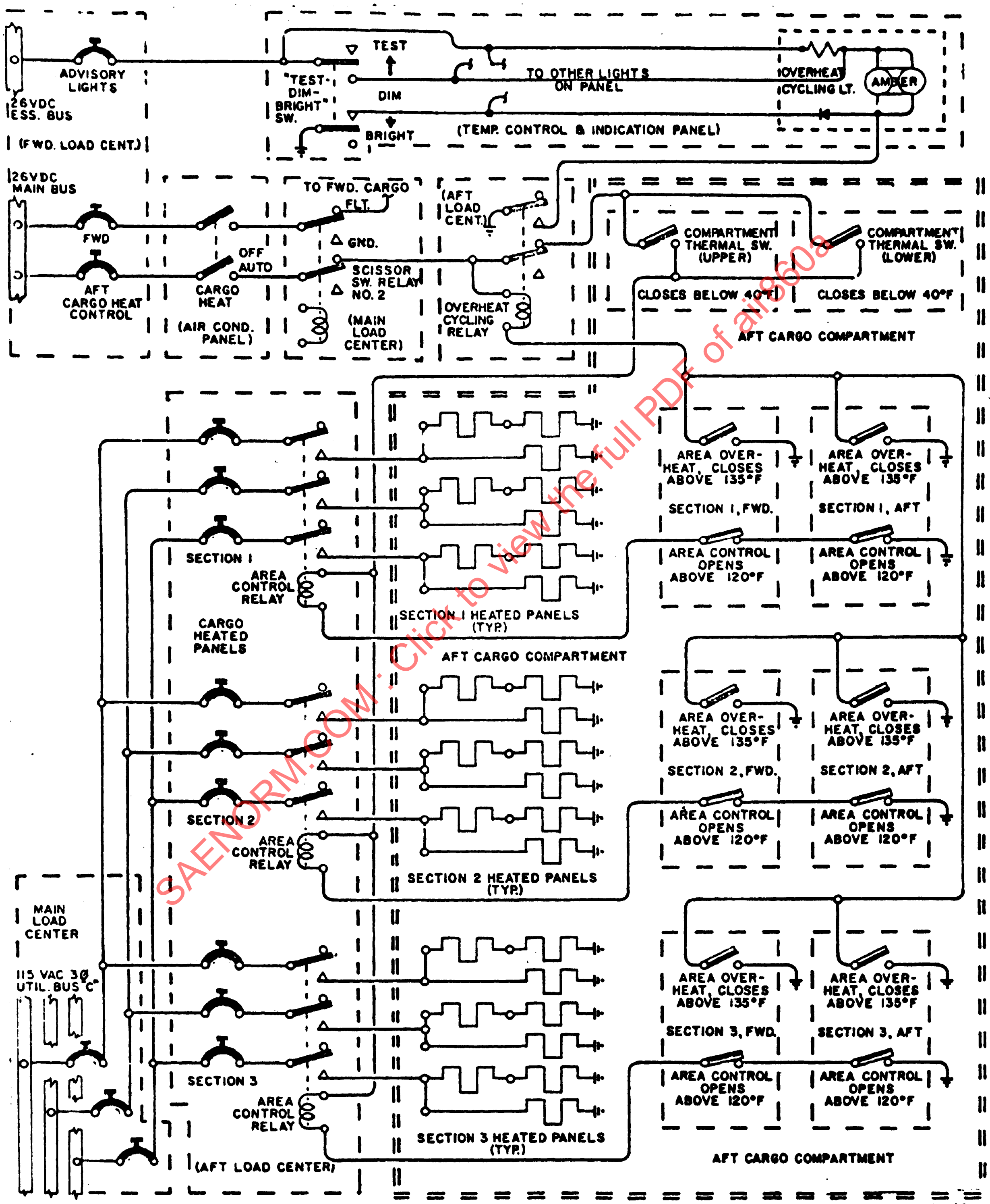

FIGURE A10A - Cargo Compartment Heating Circuit

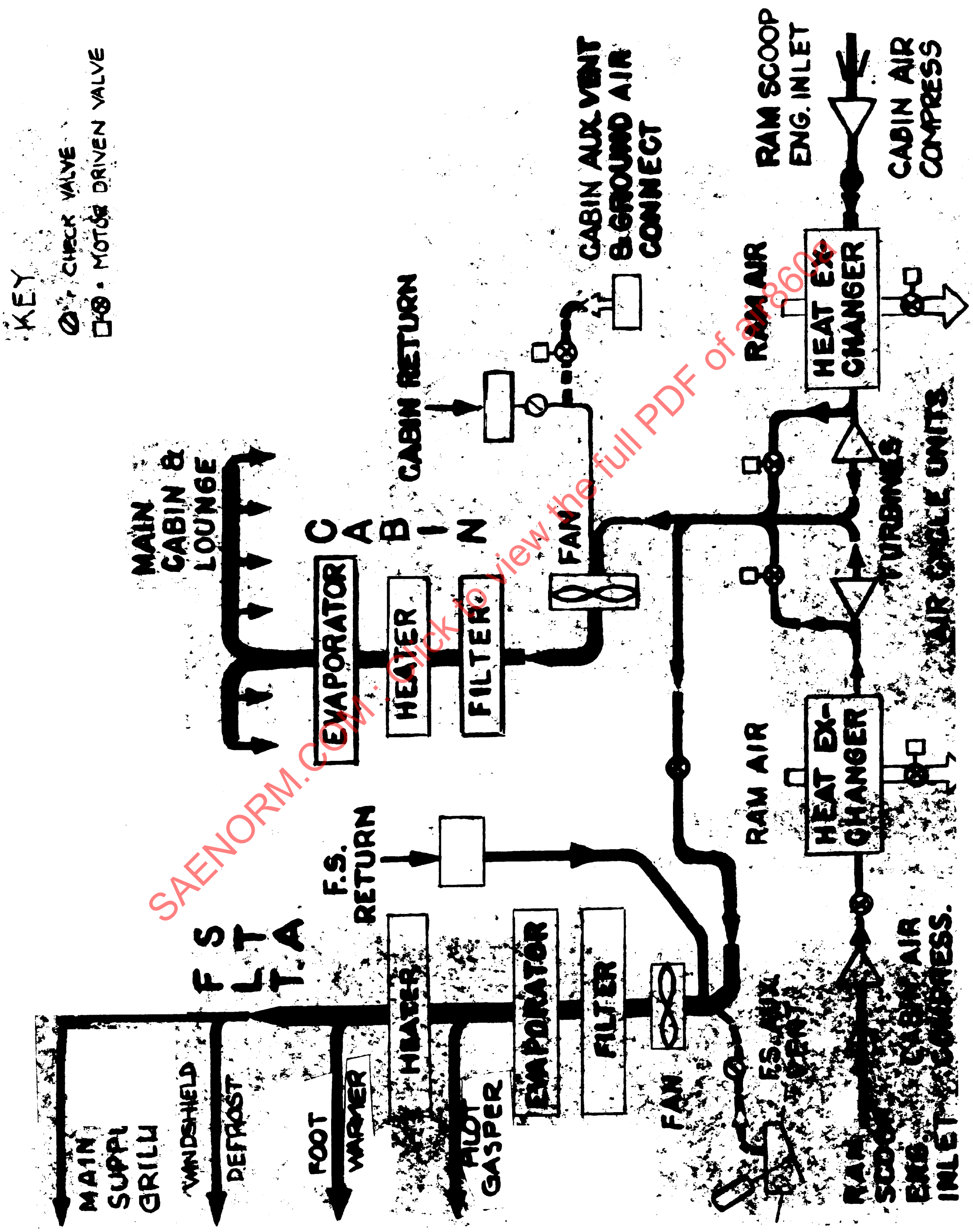

FIGURE A11 - Schematic of Air Conditioning System

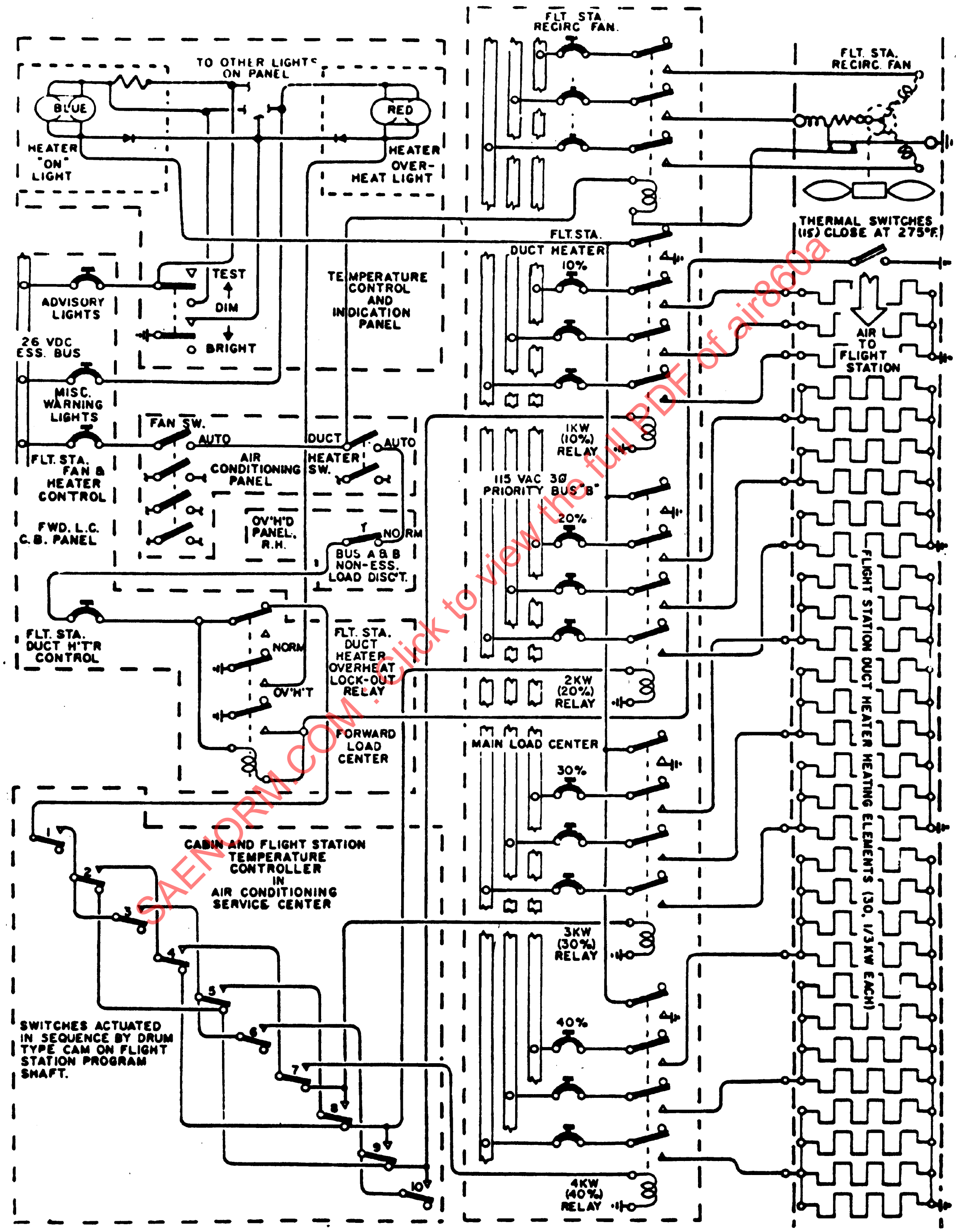

FIGURE A12 - Flight Station Duct Heater and Recirculation Fan Circuits

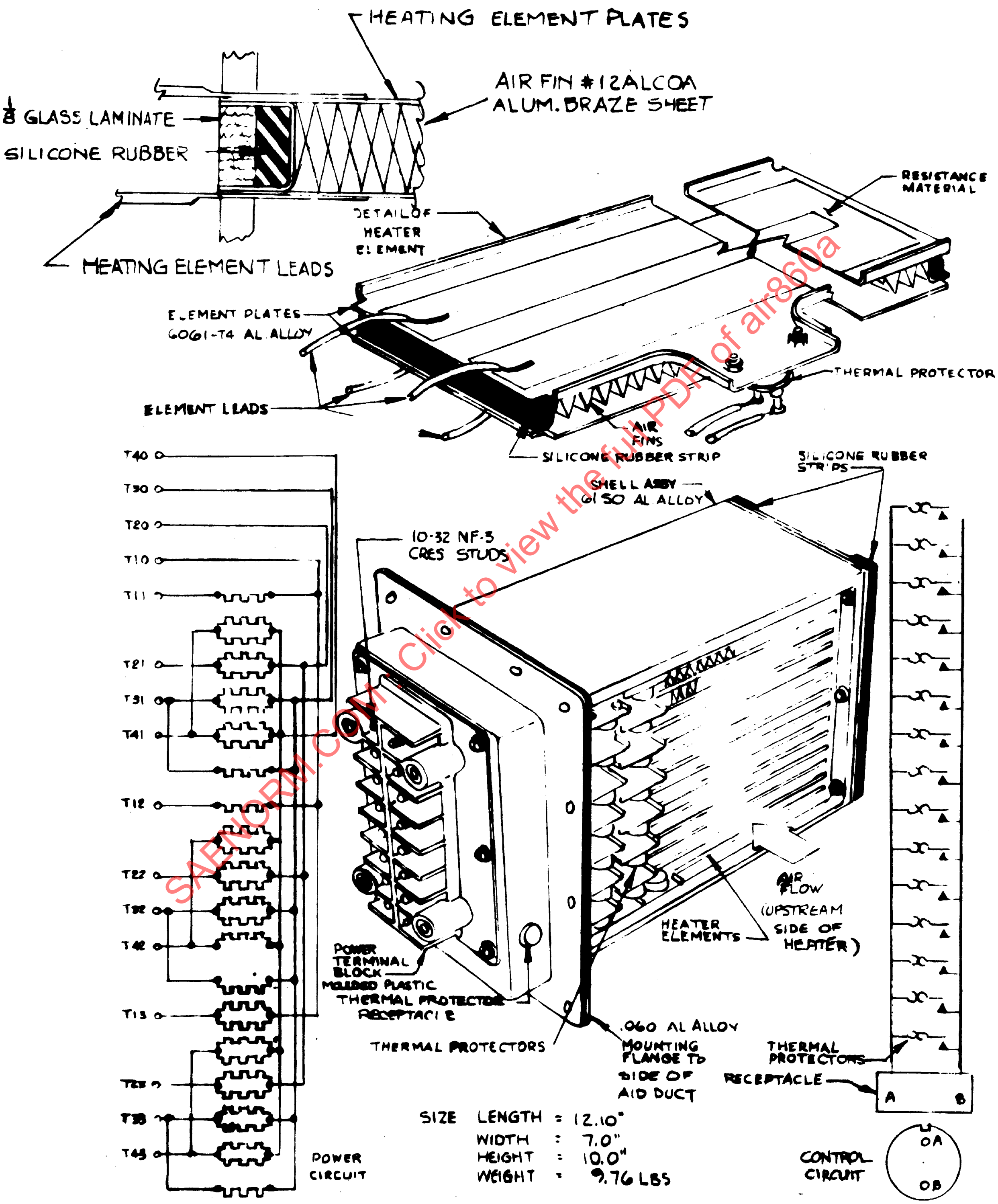

FIGURE A13 - Flight Station Duct Heater Details