R-27-26

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NEW YORK 17, N.Y.

AEROSPACE INFORMATION REPORT

AIR 860

AIRCRAFT ELECTRICAL HEATING SYSTEMS

Issued 1-10-65
Revised

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(Material Specification--Subject: Cable, Resistance Heating, Aluminum Jacket)

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APPENDIX II - AIRCRAFT "A"

1. 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.

2. 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.

3. SCOPE

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

3.2 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.

3.3 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.

4. GENERAL INFORMATION

4.1 General Design Considerations

4.1.1 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.

4.1.2 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.

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

4.1.4 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.

4.1.5 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.

4.1.6 Control of Heating Elements - Control of electrical heating elements is simple.

4.1.7 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.

4.1.8 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.

PREPARED BY SAE COMMITTEE AC-9,
AIRCRAFT ENVIRONMENTAL SYSTEMS

APPENDIX I

AIRCRAFT "A"

Section 1

GENERAL AIRCRAFT INFORMATION

TYPE	ENGINES Type	ENGINES No.	ALTITUDE	CABIN DIFF. PR.	FUSELAGE Mat.	FUSELAGE Max. Breadth Outside	FUSELAGE Max. Breadth Inside	FUSELAGE 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. Fwd.	Pr. Vol. Cargo Compt. Rear	Pass. & Crew Compt. Pr. Volume	Insulation Mat.	Insulation Density	Insulation Walls	Insulation 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) Insulation Cargo Fl.	FUSELAGE (Continued) Air Supply Ducts Insulation	CABIN PRESS. AIR SOURCES	CABIN COOLING Air Cycle	CABIN COOLING 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

APPENDIX I

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.	-5°F.	75°F.	3.9 KW	10 KW (Duct Heater)
		Cabin	-5°F.	75°F.	5.9 KW	11.3 KW (Radiant Panels)
	Ground 15 lb Fresh Air	Flt. Sta.	-5°F.	75°F.	9.0 KW	10 KW (Duct Heater)
	50 lb Fresh Air	Cabin	-5°F.	75°F.	23.0 KW	30 KW (Radiant Panels plus duct heater)
	30,000 ft Cruise with 8000 Ft. Cabin	Flt. Sta.	-60°F.	75°F.	5.6 KW	10.0 KW (Duct Heater)
		Cabin	-60°F.	75°F.	7.6 KW	9.7 KW (Radiant Panels)

APPENDIX I

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. 1 and Fig. 2	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. 1)	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. thick-ness
				See Figures 3 & 5	

FLOOR PANELS DETAILS - HONEYCOMB HEATED CONSTRUCTION					INSTALLATION METHOD	
BONDING	ELECTRICAL RESIST. CABLE Install. & Mat.	ELECTRICAL RESIST. CABLE Capacity	ELEC. TERMINAL	MOUNTING SPACERS	SCREWS	
MIL-A-5090 Adhesive System	Installation See Fig. 3 Install in crushed groove Material See App. II	20 watts per sq. ft. Power 115/208 VAC 3 phase 400 cycle	See Fig. 7 Install per Fig. 4	See Fig. 6 See Fig. 5	No. 10 Flat Head	

APPENDIX I

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS (Continued)

FLOOR PANELS

DETAILS - HONEYCOMB HEATED

FUNCTIONAL TEST

DIELECTRIC TEST - HEATING ELEMENT TERMINALS

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

DIELECTRIC TEST - TEMPERATURE SENSOR TERMINALS

TEST EQUIPMENT	TEST CONNEC-TIONS	VOLTAGE	TIME	CRITERIA OF FAILURE	PANEL MARKING
(Same as for heat-ing ele-ment test above)	1. One sensor term. 2. Ground (to panel)	200 AC 60 cycle	1 sec.	No indica-tion of Insul. Breakdown	Mark Panel as having been "Dielectric tested OK"

RESISTANCE TEST - HEATING ELEMENT

TEST EQUIPMENT	TEST CONNECTIONS	TEST REQUIREMENT	TEST TOLERANCE
1. Wheat-stone 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

APPENDIX I

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS (continued)

WALL AND WINDOW HEATING PANELS

LOCATION	TYPES USED	DETAILS, PANELS, WALL AND WINDOW		
		CONSTRUCTION		
		MATERIAL AND SIZE		BONDING
		Core	Plates	
See Figs. 2A and 2B	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. 1 Similar to Floor Panel Fig. 3 Material See App. II	20 watts per sq ft. Power 115/208 VAC 3 phase 400 cycle

CONSTRUCTION (Continued)

Elec. Terminals	Installation	Functional Test
See Fig. 7	See Figs. 1, 2, 2A, 2B	Check Elec. & Dielectric Tests
Elec. Bonding per Fig. 2B	Special Extrusions and clips	

APPENDIX I

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

← Same as for floor panels →

APPENDIX I

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. 8 Below cargo structural floor. No. per comp't 42 panels fwd. 43 panels aft	See Fig. 9 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. 9 Material See Appendix II	61 watts per sq. ft. Power 115/208 VAC 3 phase 400 cycle	See Fig. 7 See Fig. 9A	See Figs. 8 & 9

FUNCTIONAL TEST

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

APPENDIX I

SPECIFIC DESIGN AND OPERATION INFORMATION

FLIGHT STATION - ELECTRIC DUCT HEATER

LOCATION	TYPE AND CONSTRUCTION	ELECTRICAL
See Fig. 10 Located in flight station air supply duct	See Fig. 12	See Fig. 11 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. 13 for Test Setup	At Sea Level	At 8000' Press. Alt.
1. Continuity test 2. Airflow distribution across face of heater must be uniform 3. Electrical sequence per Table I. 4. Overheat test - no airflow - Thermal protector to operate within 90 seconds.	Air Flow 30#/min. Air "In" Temp. 70^{o}F Max. Temp. Rise 79^{o}F Max Pr. Drop .50 in. H_2O Max. Surface Temp. 300^{o}F Normal Surface Temp. 200 to 250^{o}F.	22#/min. 70^{o}F. 108^{o}F. .40 in. H_2O 350^{o}F. 200 to 250^{o}F.

APPENDIX I

SPECIAL DESIGN AND OPERATION INFORMATION

CABIN - ELECTRICAL DUCT HEATER		
LOCATION	TYPE AND CONSTRUCTION	ELECTRICAL
See Fig. 10 located in cabin air supply duct	See Figure 14	See Figure 15 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. 16 for test setup 1. Continuity test 2. Airflow distribution across face of heater 3. Electrical sequence test per Table II 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.

TABLE I

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 II

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

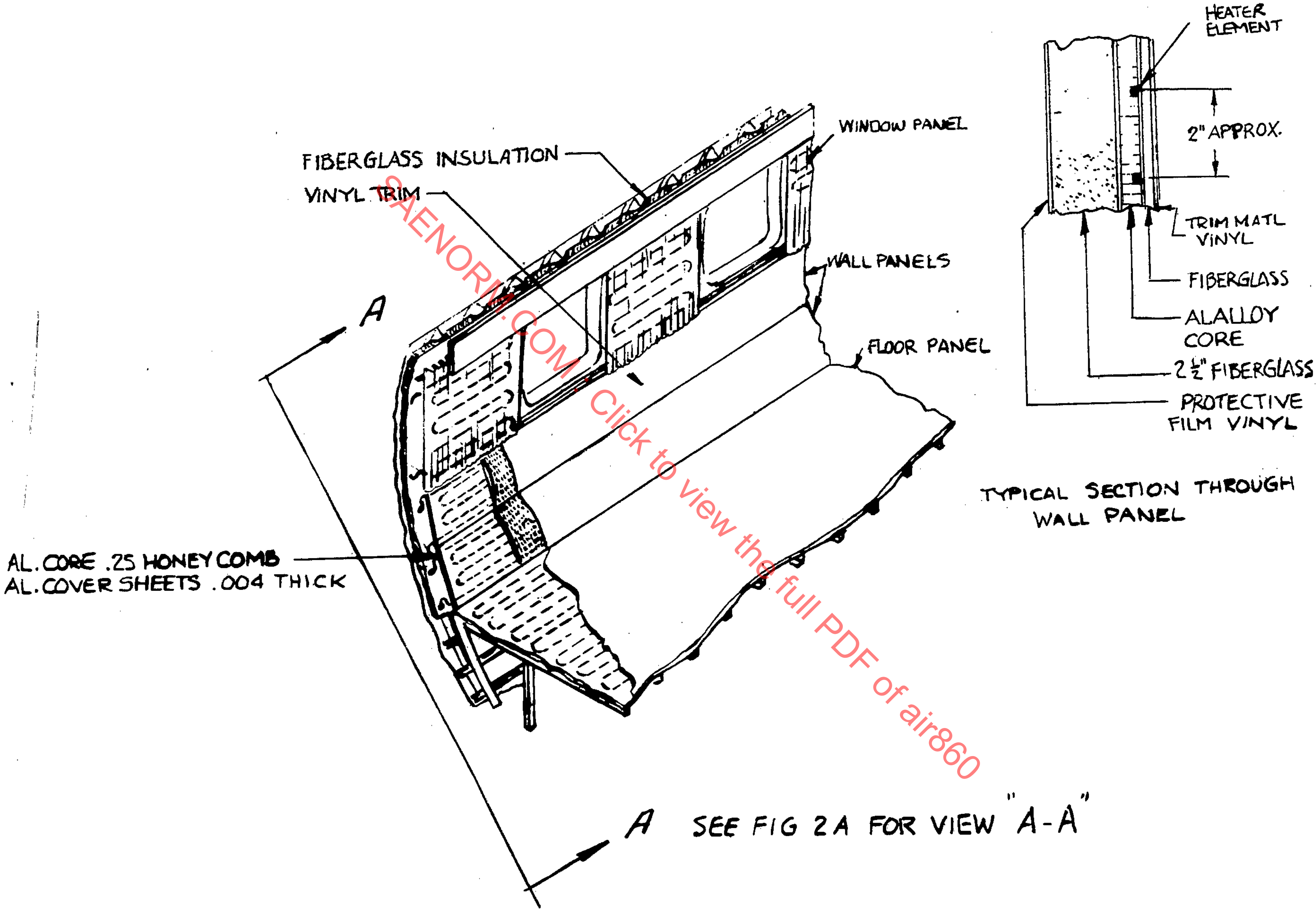

Figure 1. Cabin Wall and Floor Radiant Panels

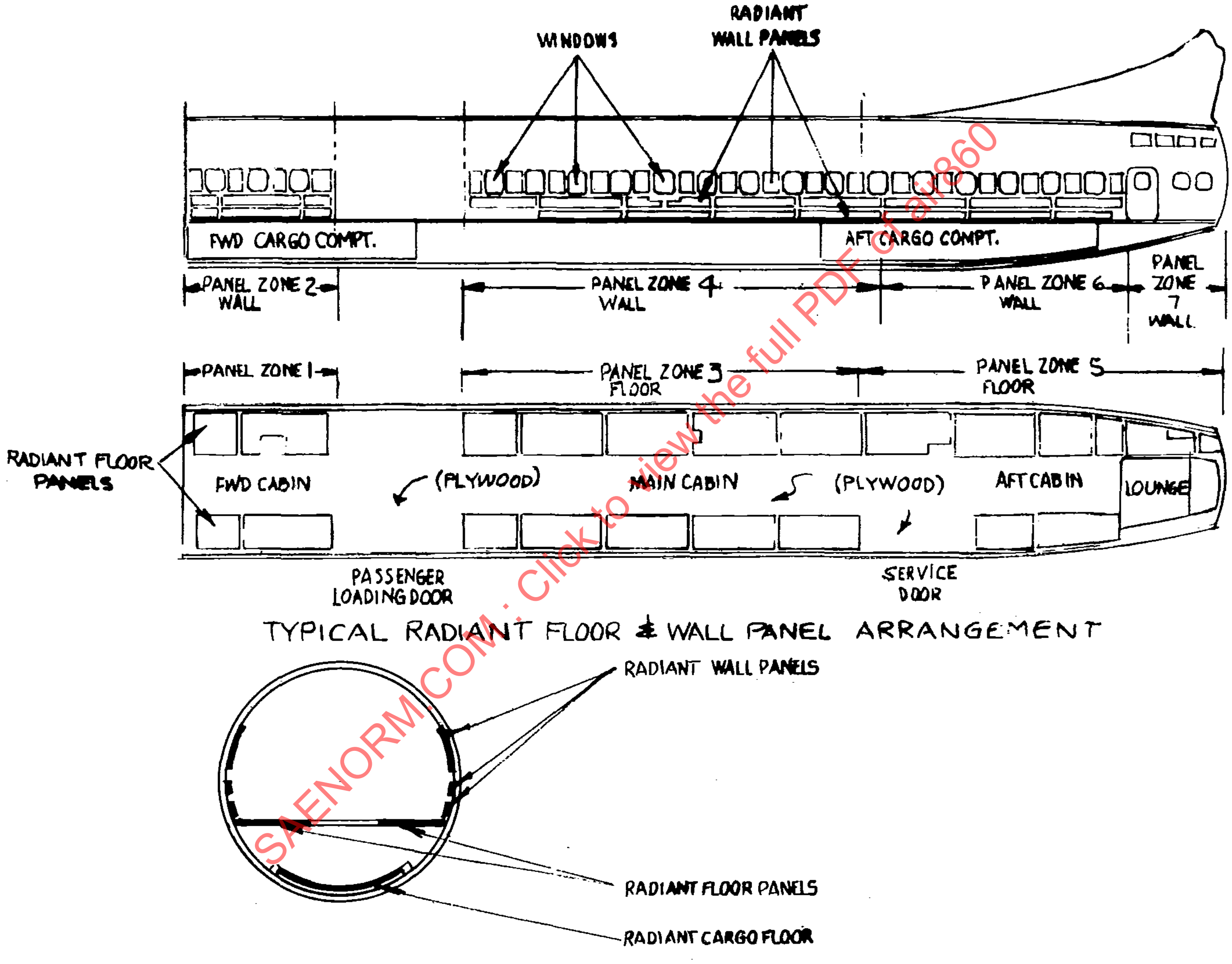

Figure 2. Radiant Heating Panels

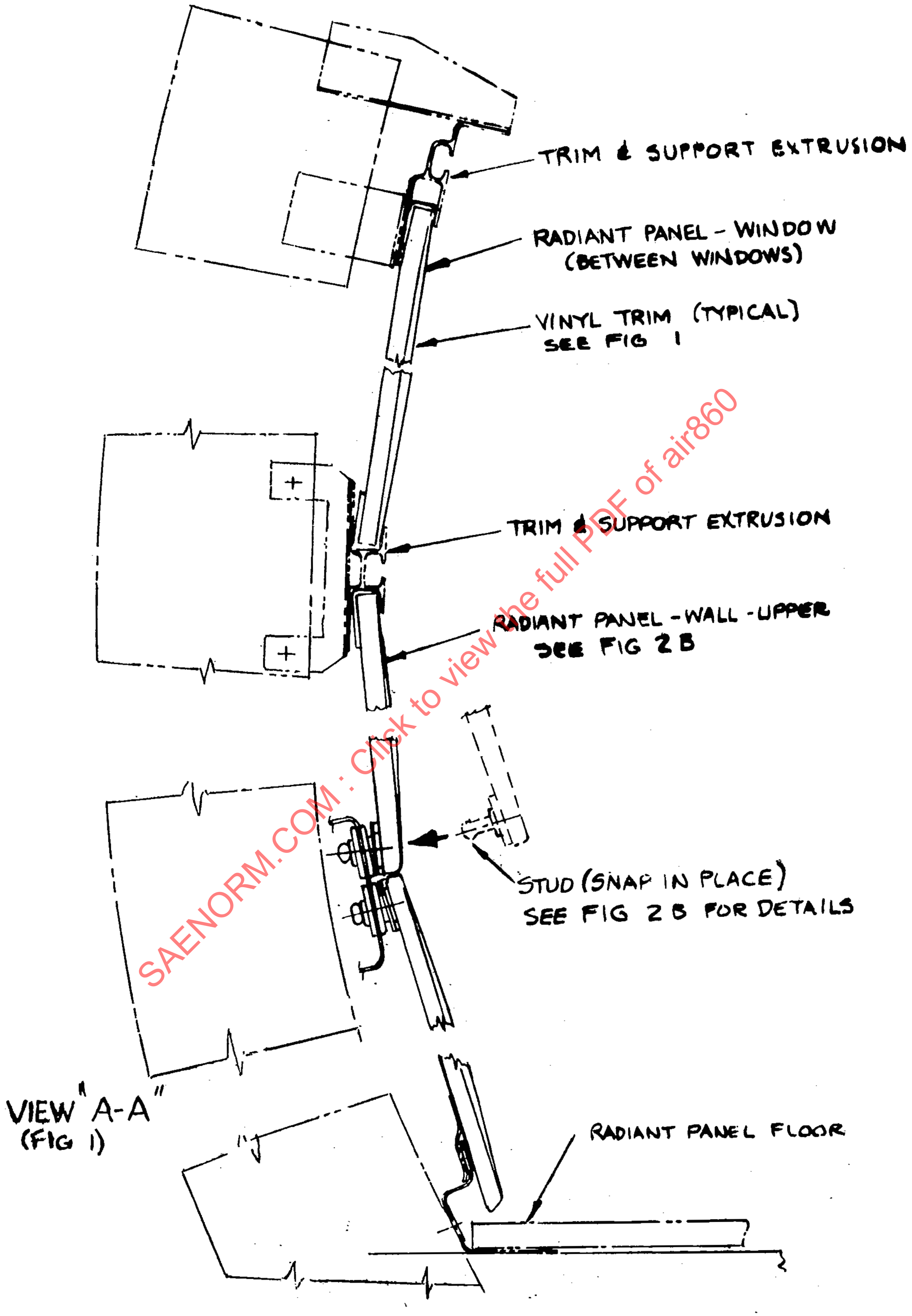

Figure 2A. Cabin Wall and Floor Radiant Panels - Sect. View

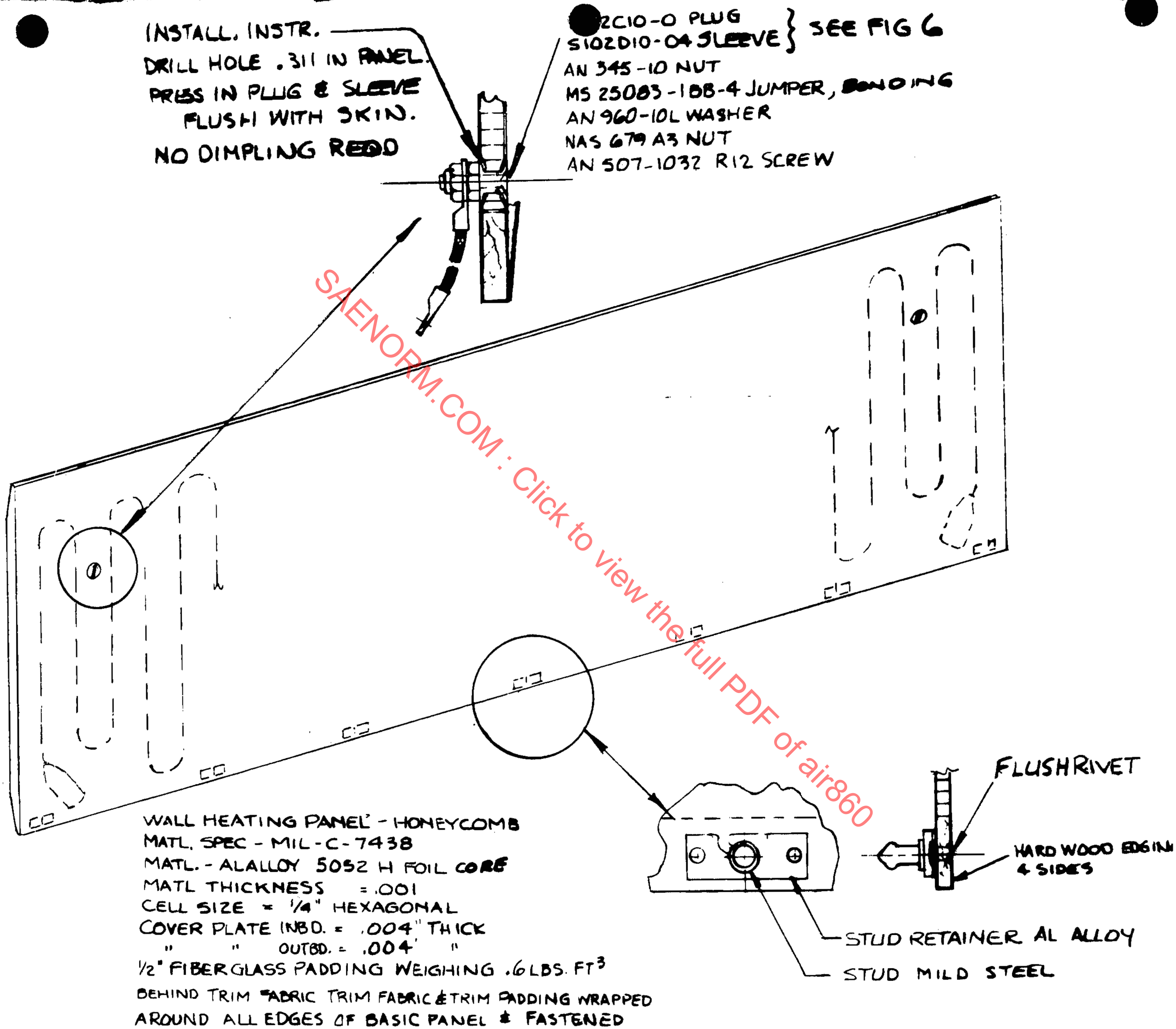

Figure 2B. Wall Panel - Upper

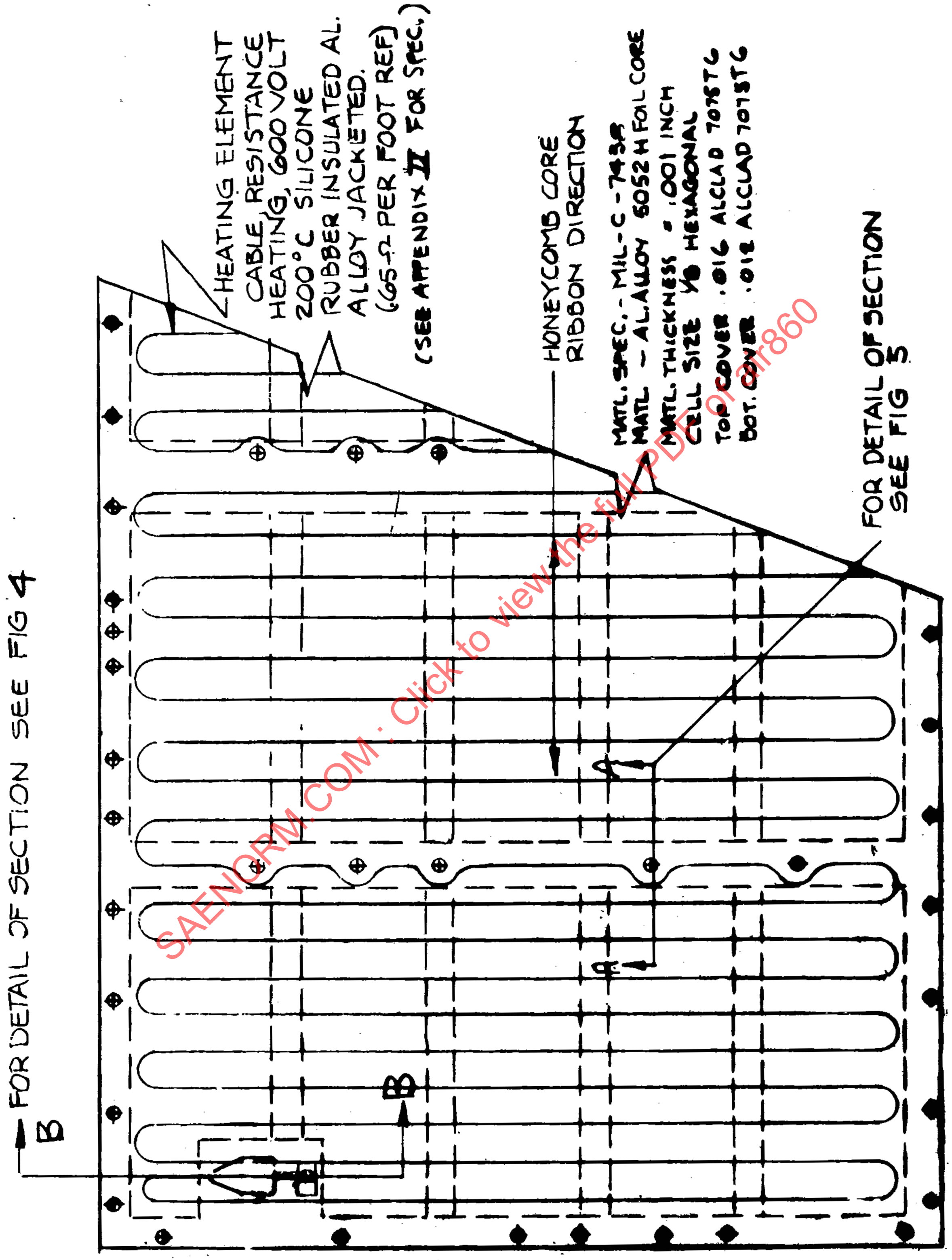

Figure 3. Cabin Floor Radiant Panel Assembly

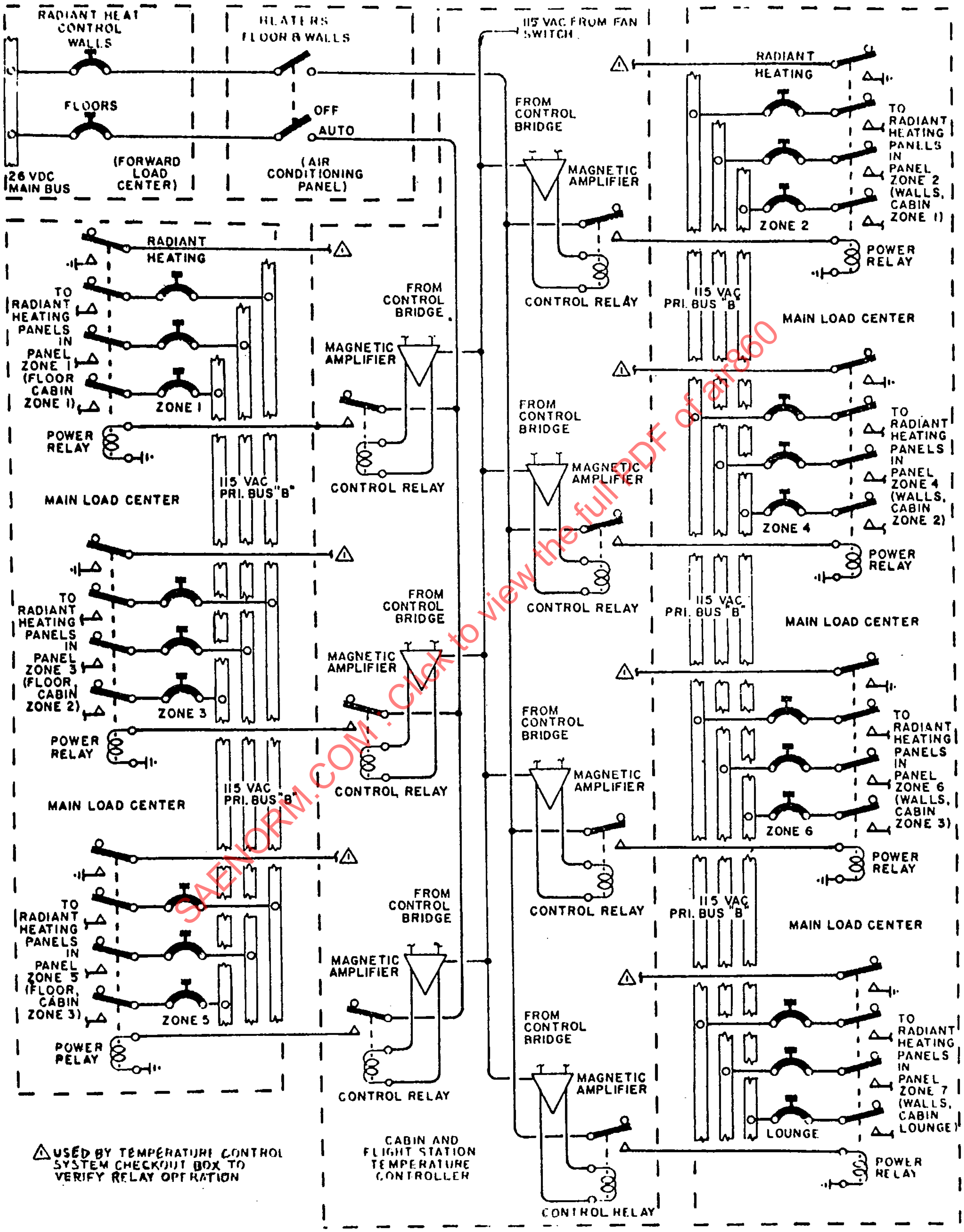

Figure 3A. Radiant Heat Panels Control

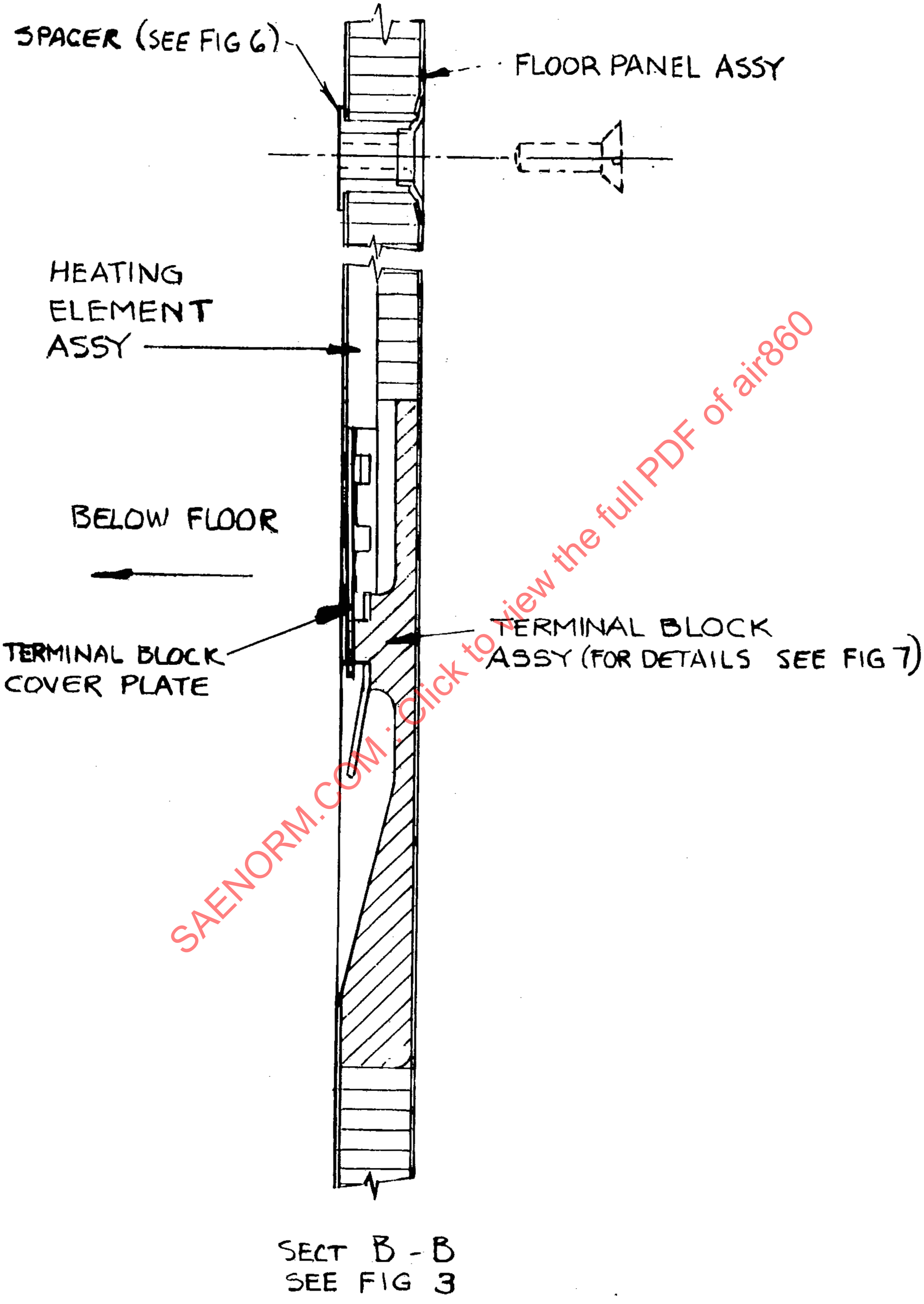

Figure 4. Section - Terminal Block - Floor Panel Installation

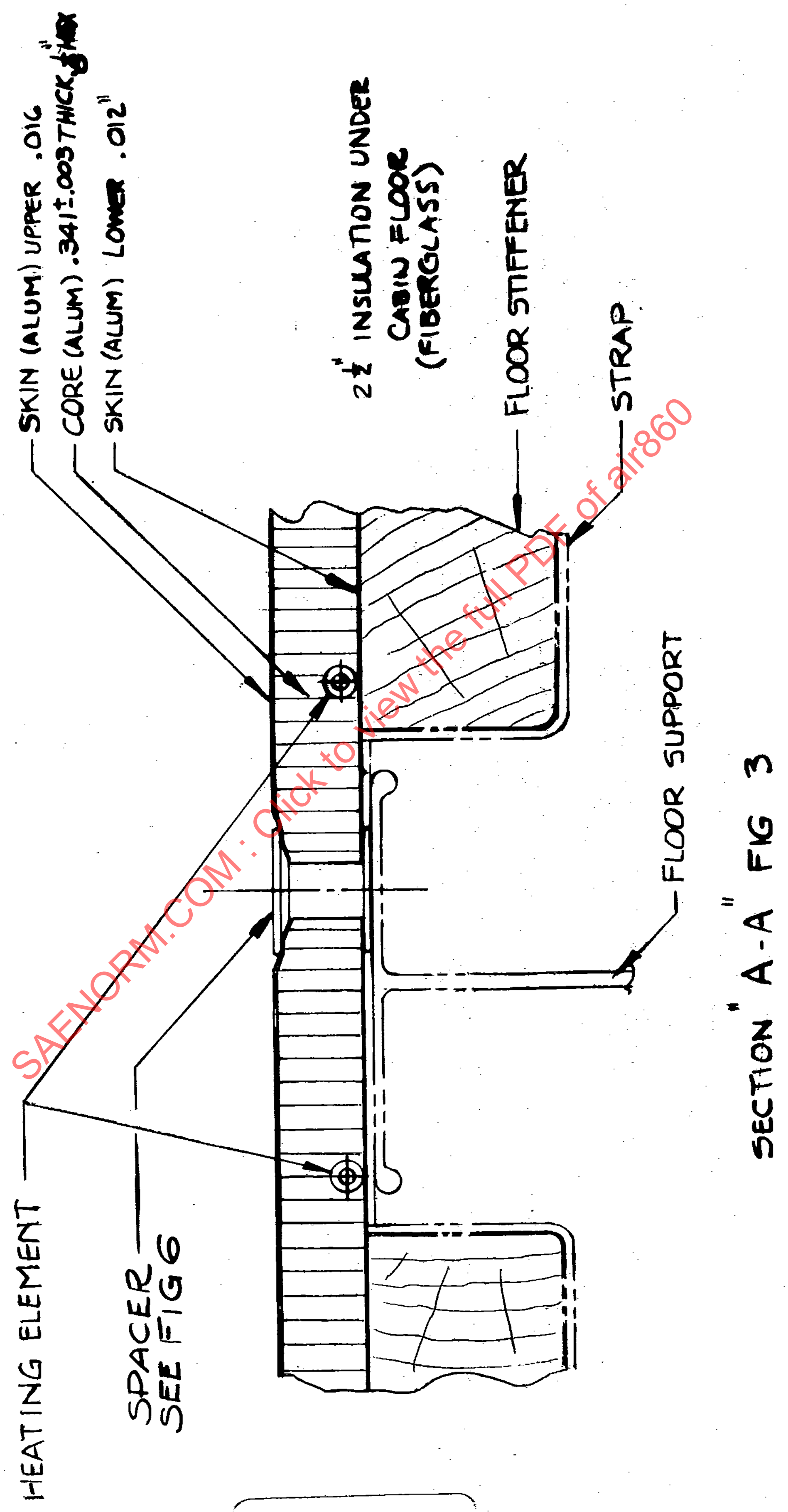

Figure 5. Section of Cabin Floor Radiant Panel Installation

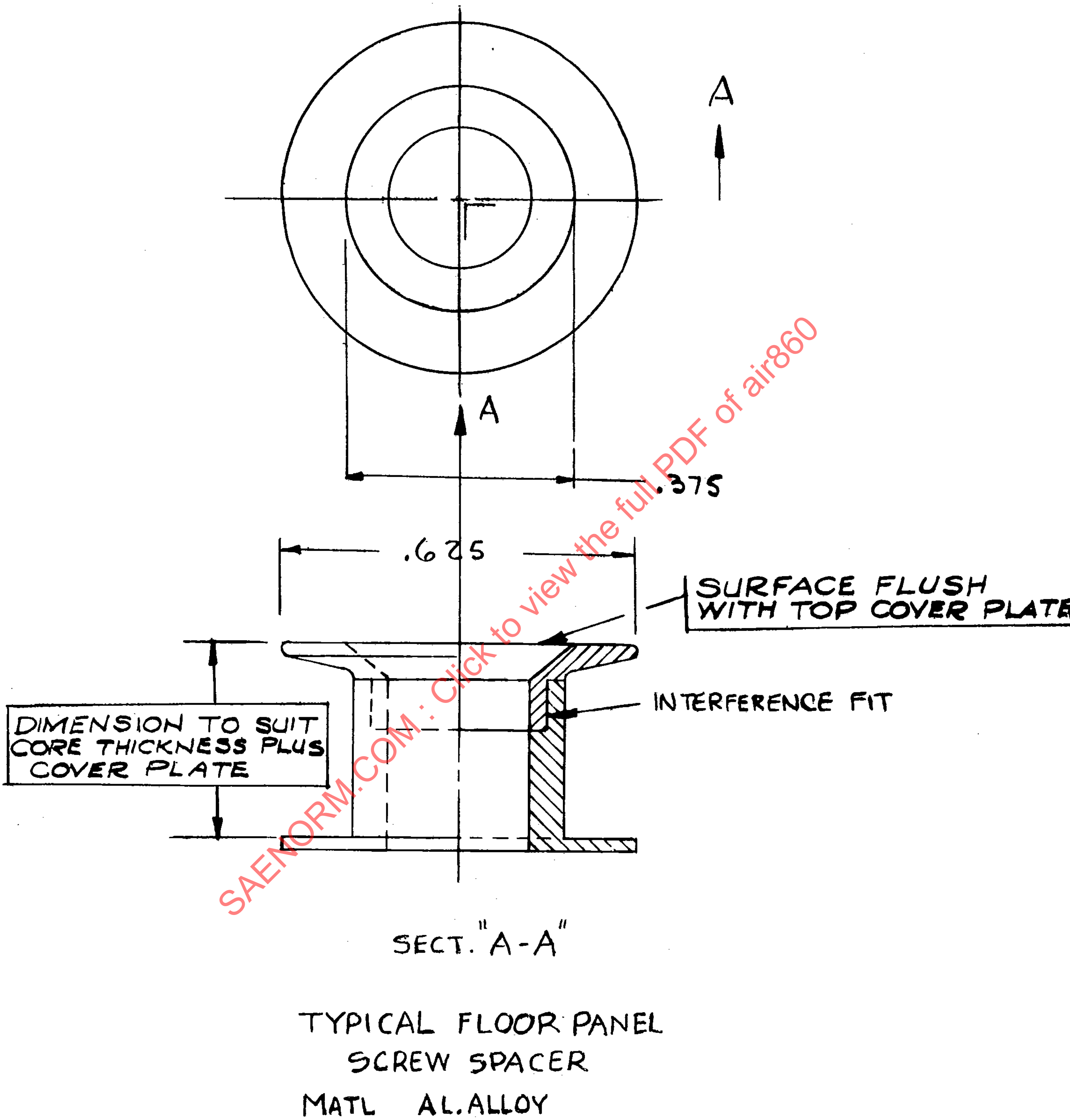

Figure 6. Spacer - Screw - Radiant Panel

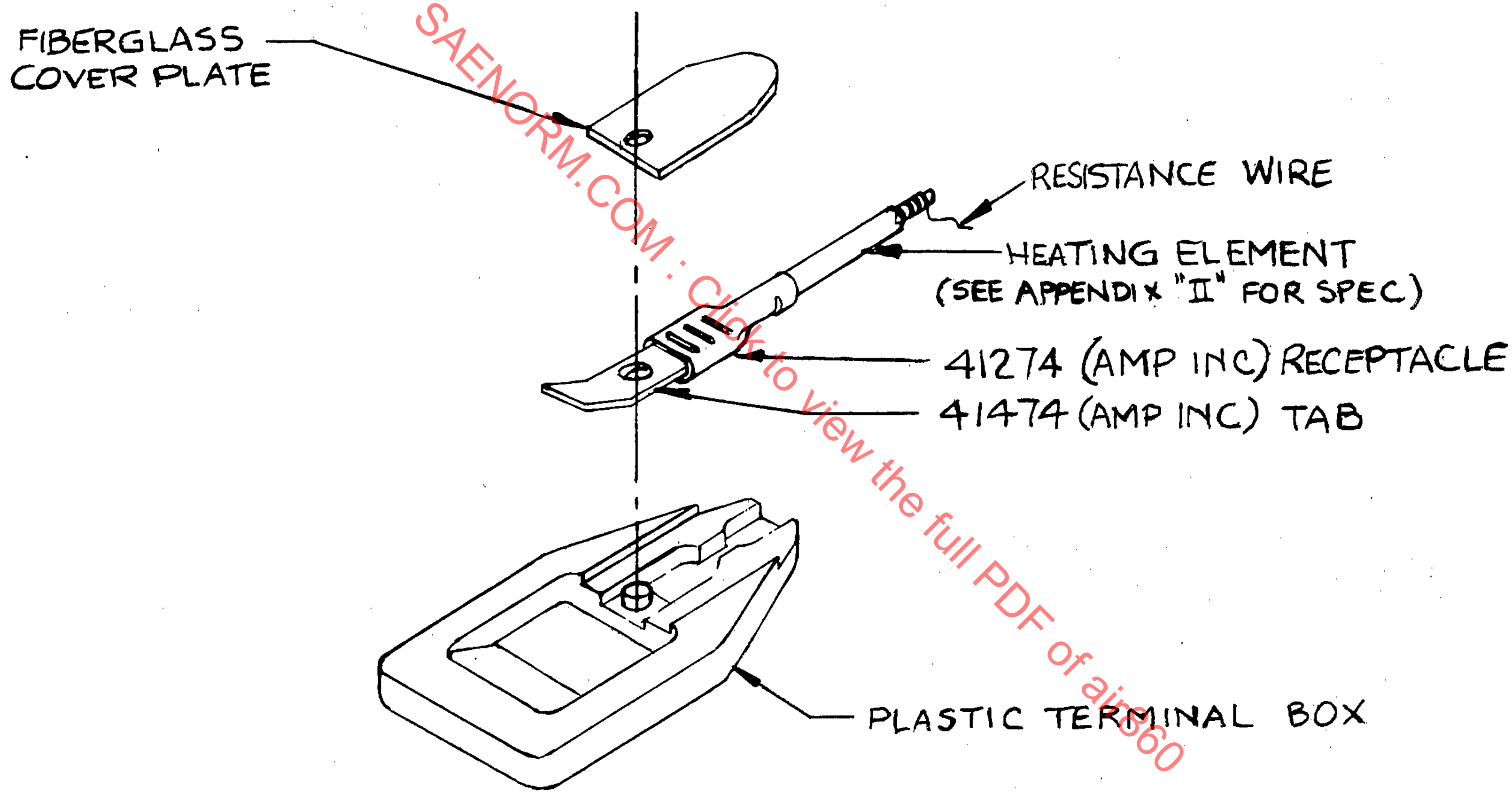

Figure 7. Terminal Block Details

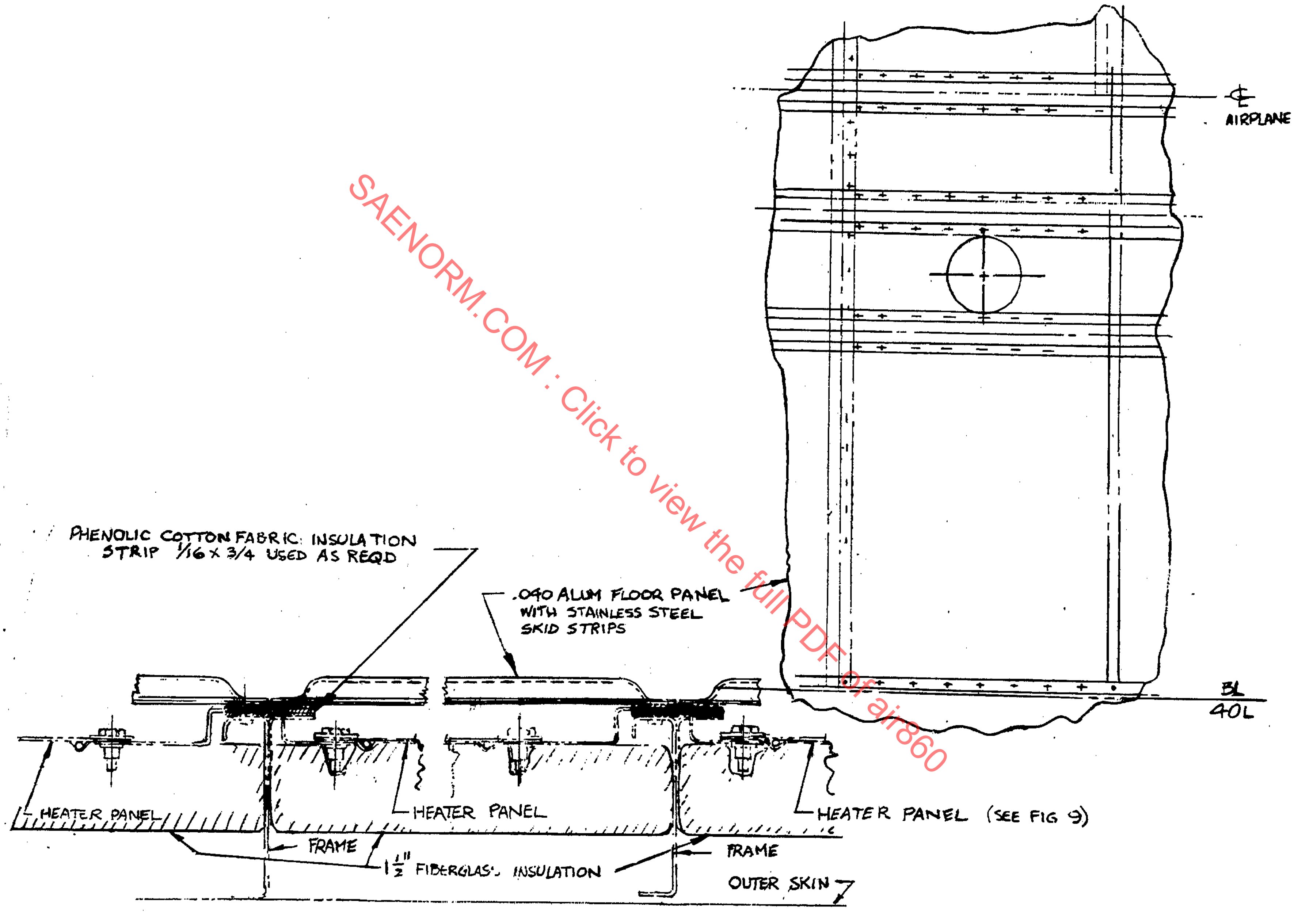

Figure 8. Cargo Compartment Floor and Radiant Panel Installation

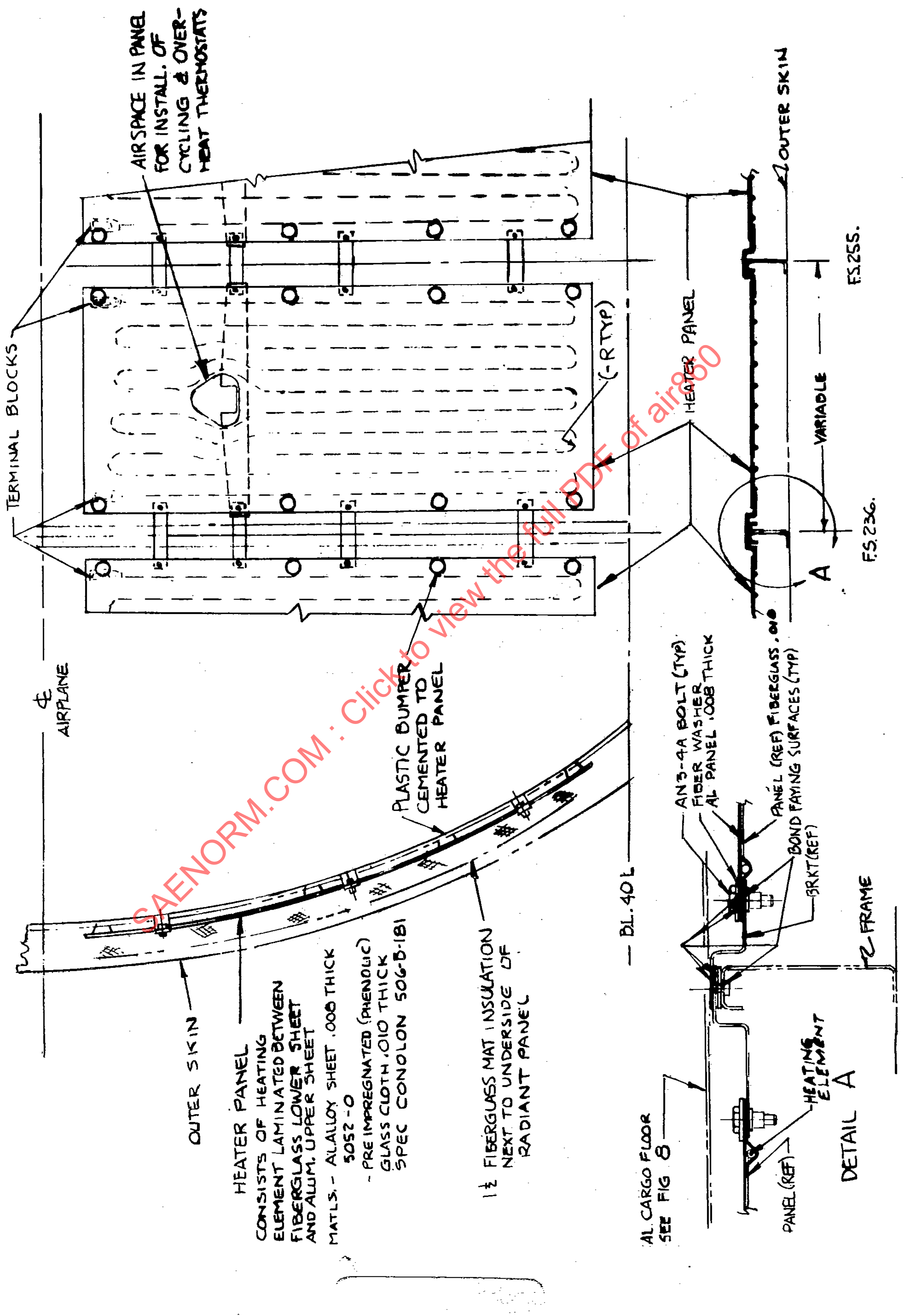

Figure 9. Cargo Compartment Radiant Panel (Typ)

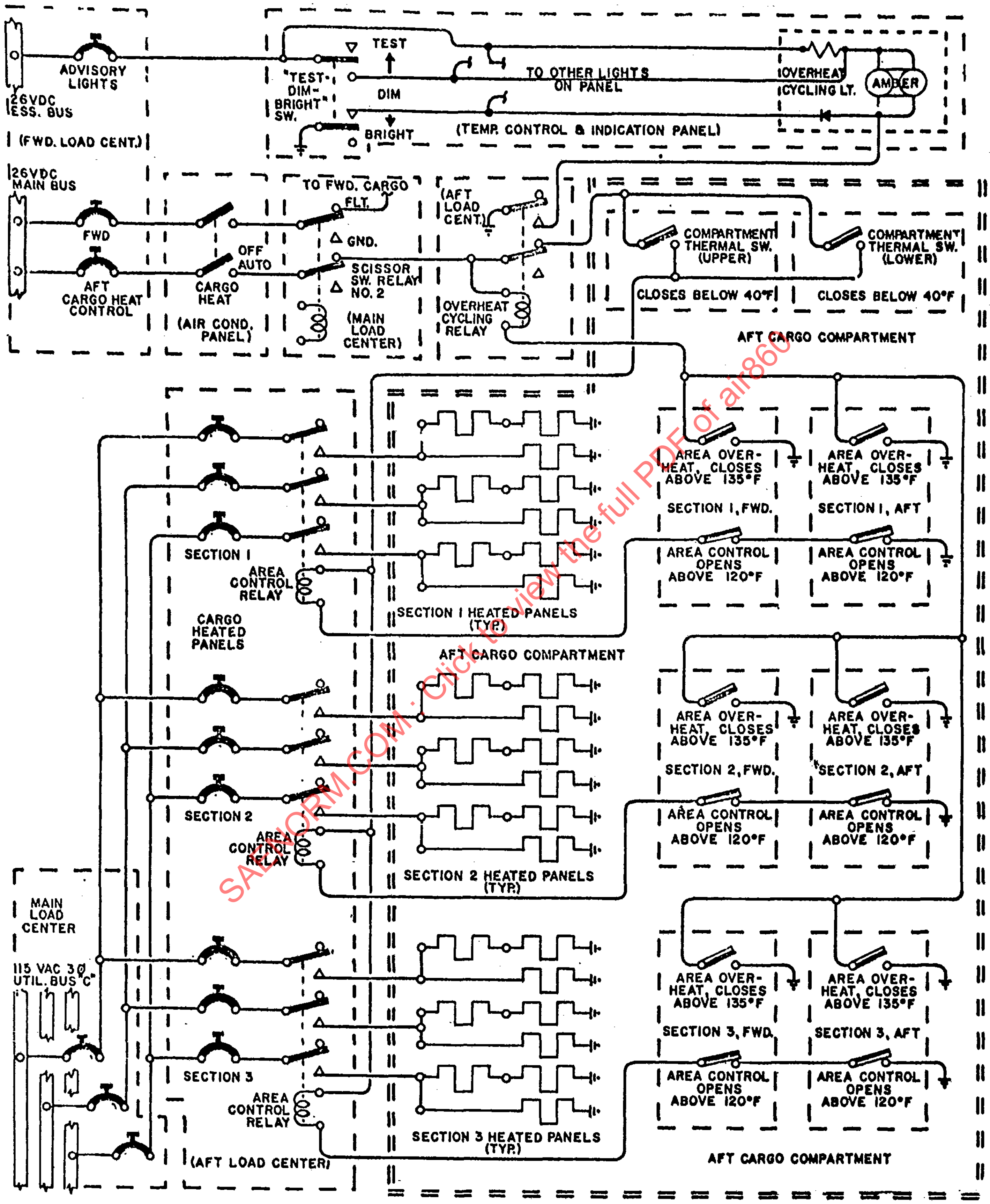

Figure 9A. Cargo Compartment Heating Circuit

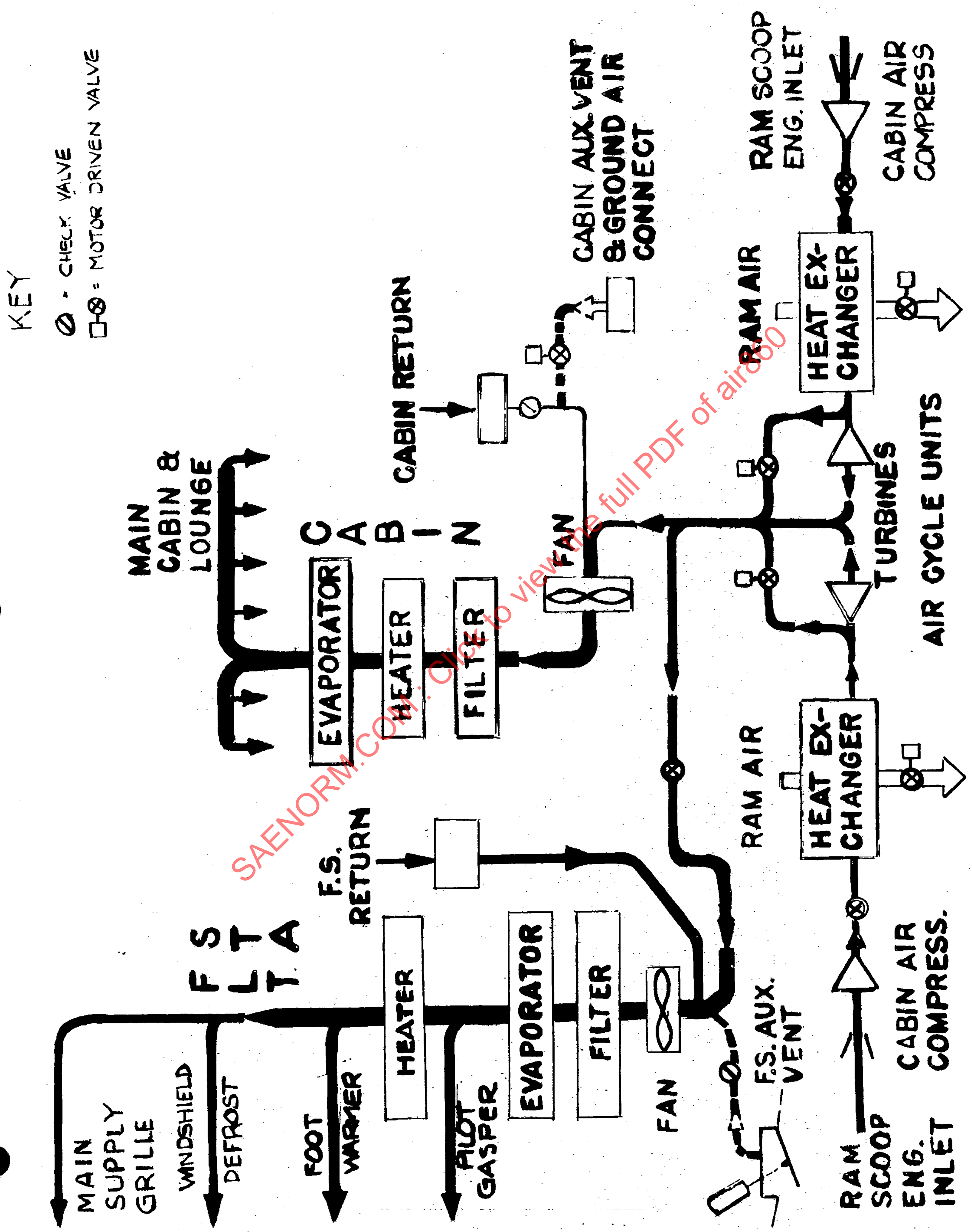

Figure 10. Schematic of Air Conditioning System

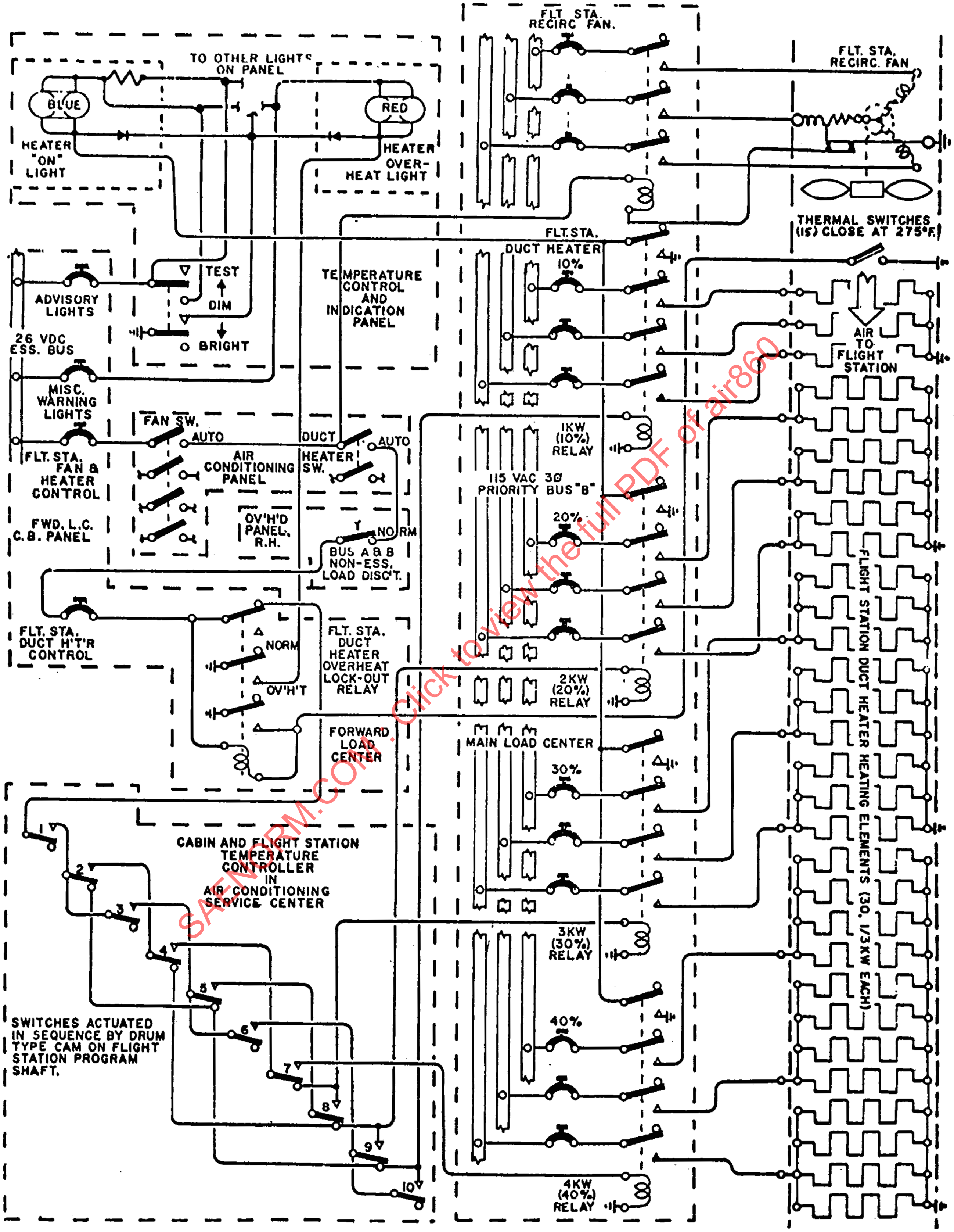

Figure 11. Flight Station Duct Heater and Recirculation Fan Circuits

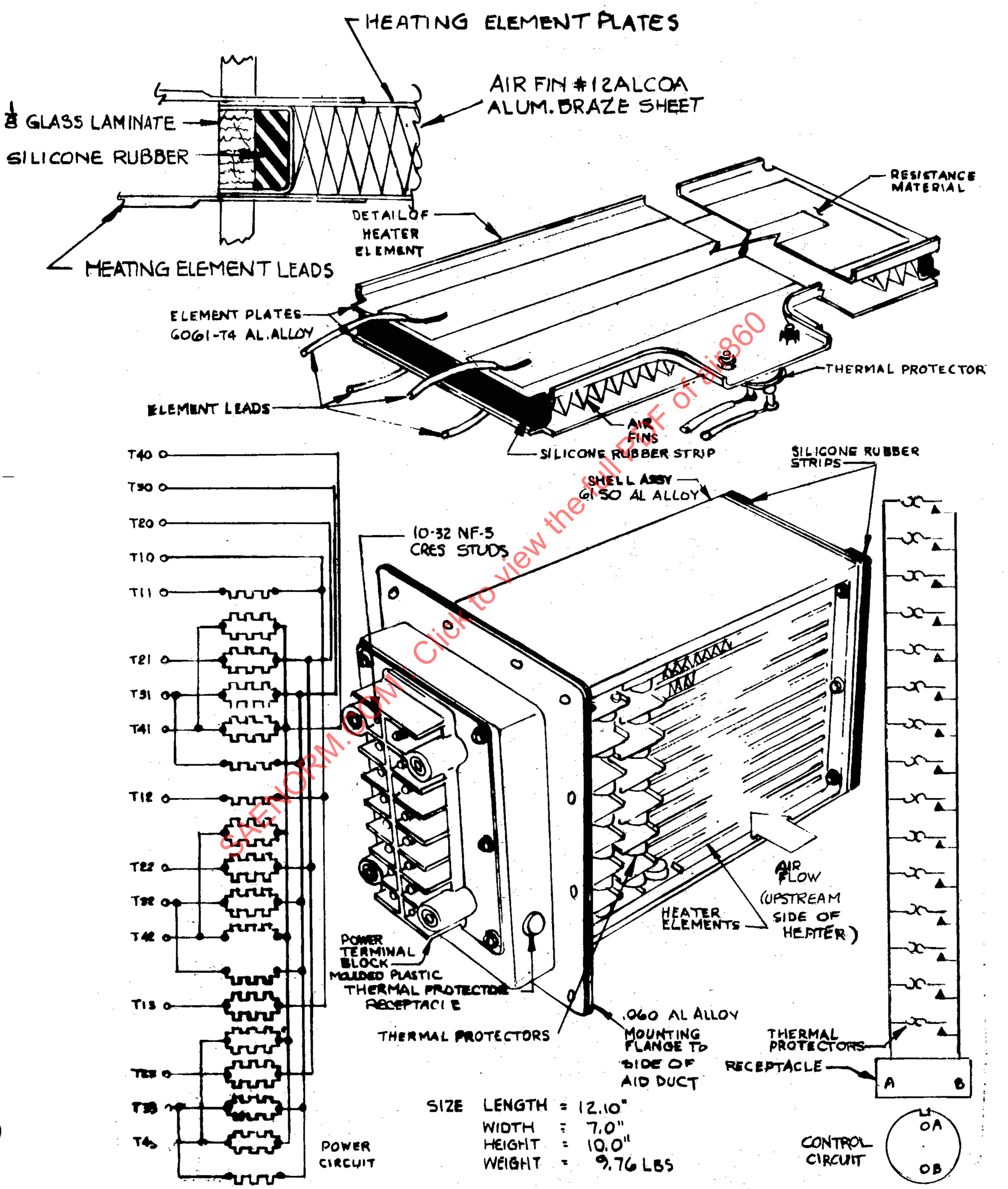

Figure 12. Flight Station Duct Heater Details

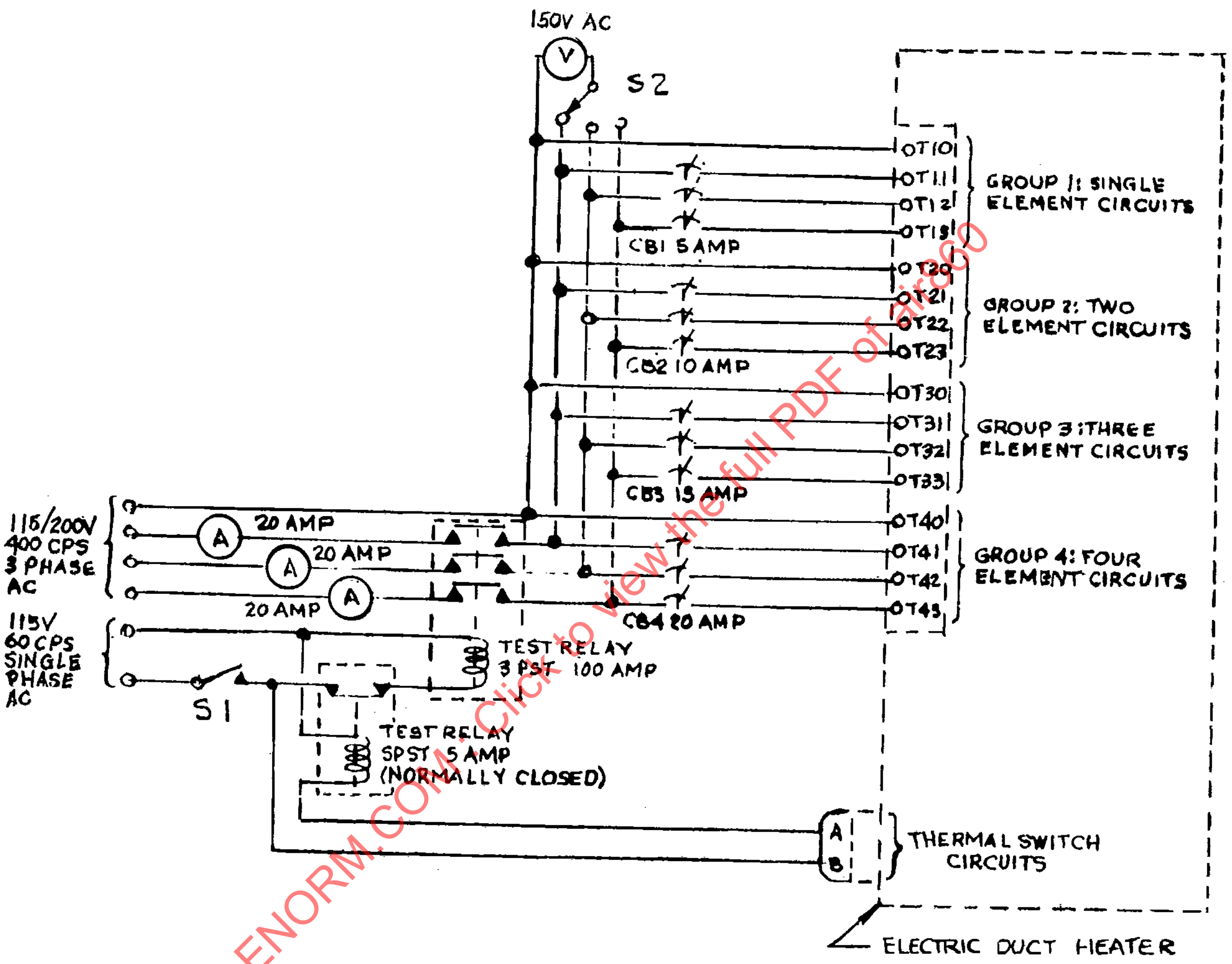

Figure 13. Flight Station Duct Heater Functional Test Setup

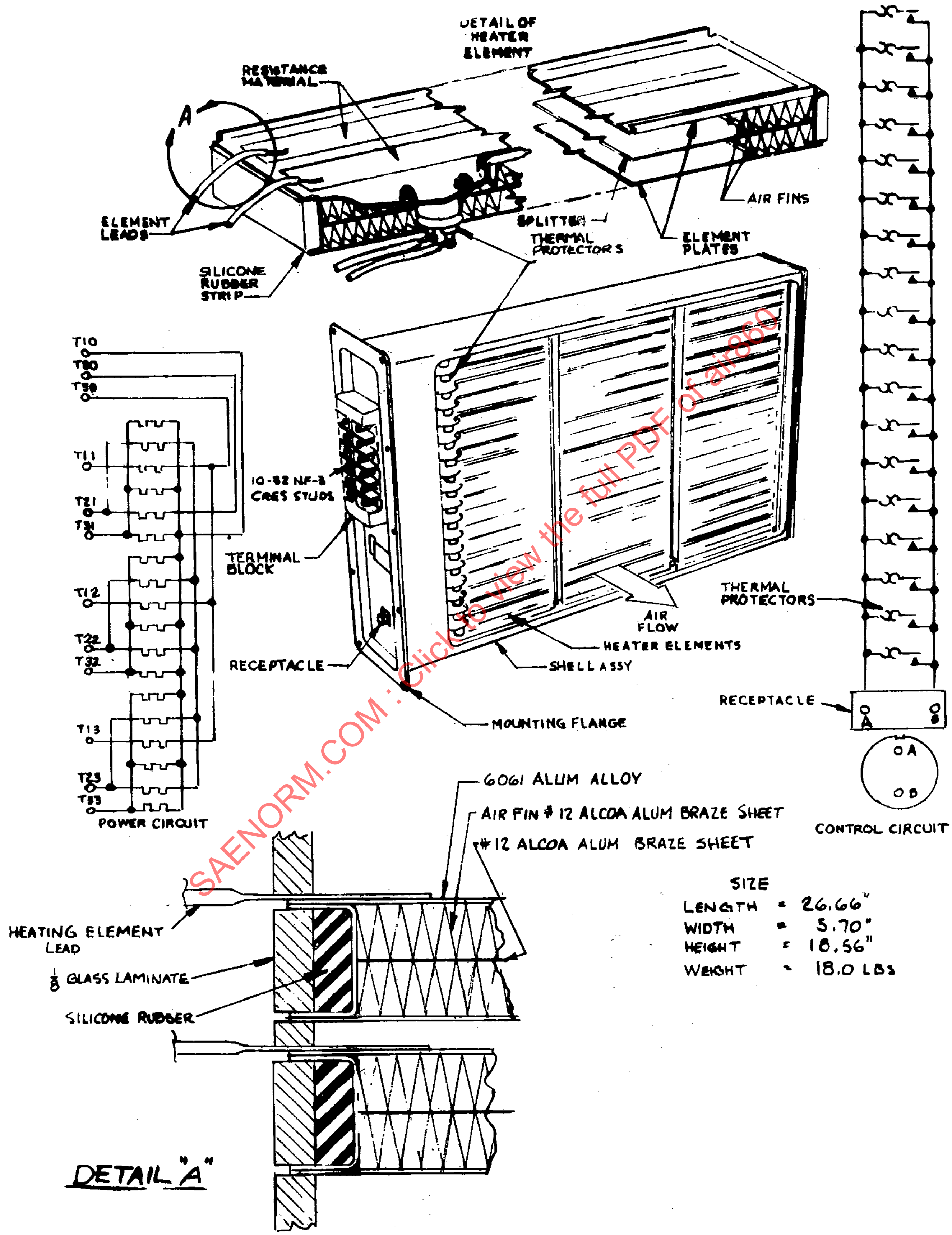

Figure 14. Cabin Duct Heater Details

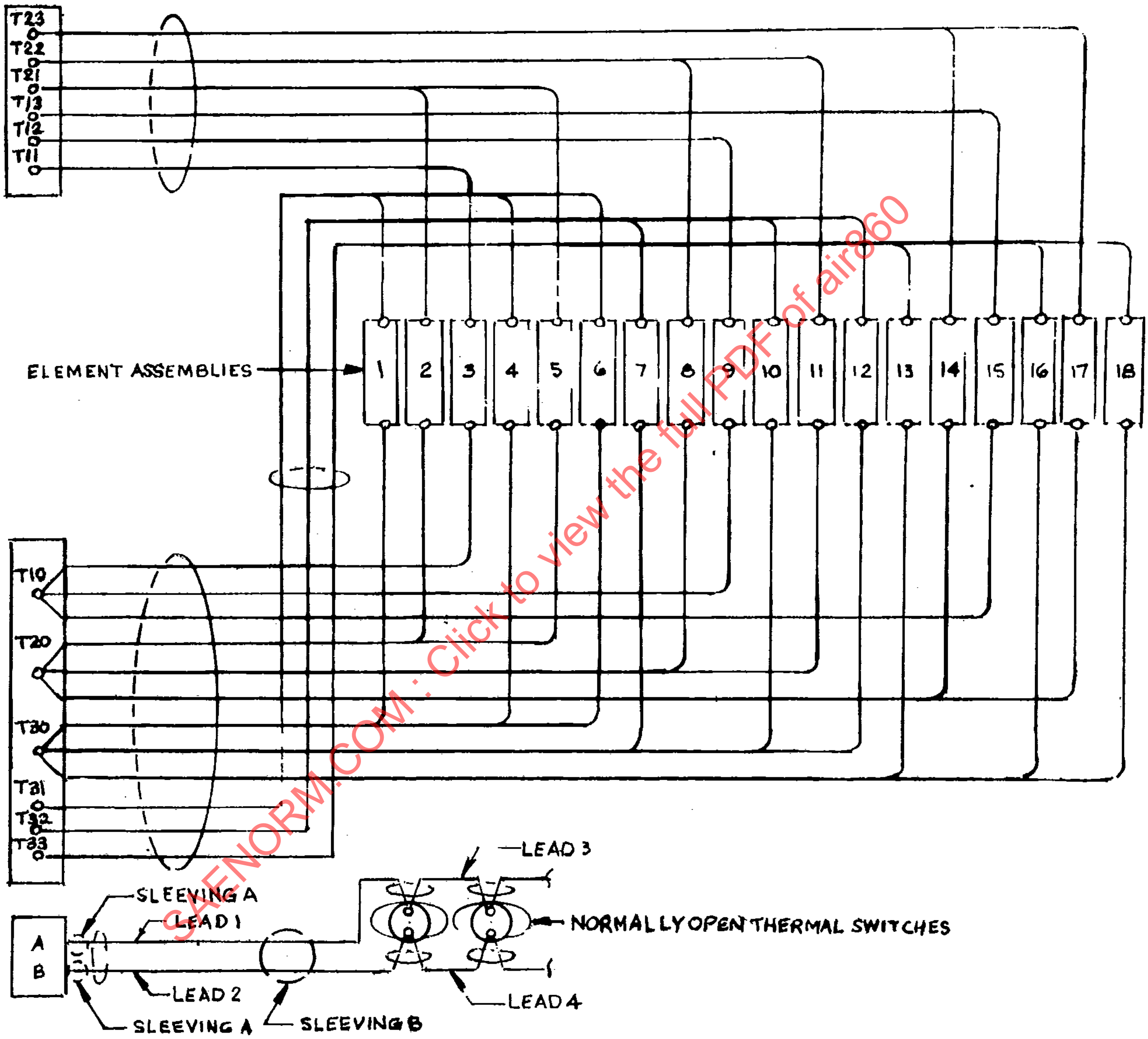

Figure 15. Cabin Duct Heater Electrical Circuit

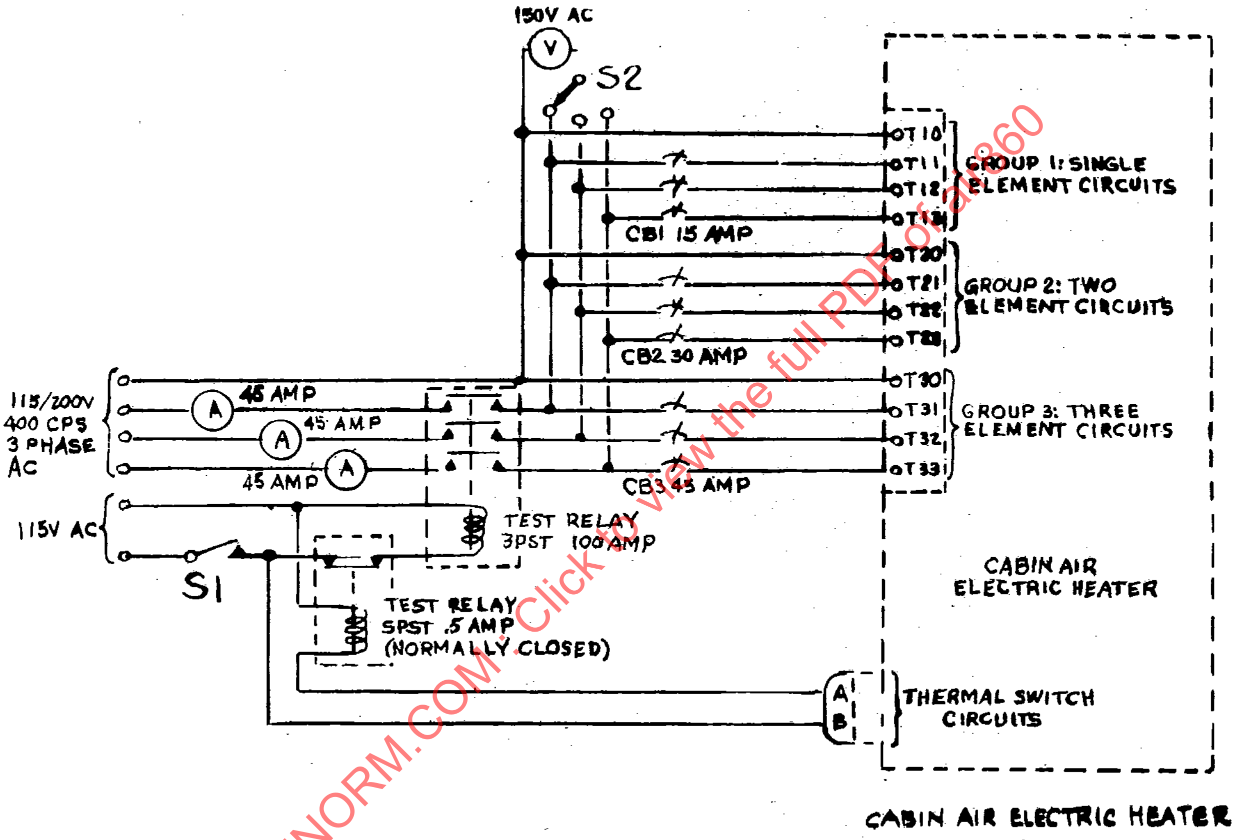

Figure 16. Cabin Duct Heater Functional Test Setup

MATERIAL SPECIFICATION

Subject: CABLE, RESISTANCE HEATING, ALUMINUM JACKET

1. SCOPE - This specification covers jacketed cables for use as heating elements in aircraft cabin and baggage compartments.

2. CLASSIFICATION - Cable shall be of the following types, as specified:

Table I - CABLE, RESISTANCE HEATING, ALUMINUM JACKET

Type	Resistance, Ohms, per foot	Color Code	
		Body	Tracer
I	13.75	Blue	White
II	12.60	White	White
III	6.95	Red	White
IV	4.00	Yellow	White
V	3.12	Green	White
VI	2.69	Blue	Blue
VII	4.60	Green	Blue
VIII	2.32	Yellow	Blue
IX	1.61	White	Blue
X	1.22	Blue	Red
XI	0.84	Yellow	Red
XII	0.65	White	Red
XIII	0.31	Green	Red
XIV	0.41	Red	Red

3. APPLICABLE DOCUMENTS

3.1 The following specifications and standards, of the issue in effect on the date of purchase order, form a part of this specification to the extent specified herein:

MIL-W-16878 Wire, Electrical Insulated, High Temperature
MIL-STD-104 Limits for Electrical Insulation Color

4. REQUIREMENTS

4.1 Materials - The materials and principal component parts for the cable shall be as specified herein. However, when a definite material is not specified, a material shall be used which will enable the cables to meet the requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of the finished product.

4.2 Conductor - The conductor shall be metallic and of such form as to meet the resistance requirements of Section 2. A center core with spirally wound conductor may be used.

4.2.1 Resistance - The conductor resistance specified in ohms per foot of finished cable measured at 70°F; allowable tolerance from the nominal resistance is ± 5%.

4.2.2 Termination - The conductor shall be capable of termination in a practical manner by mechanical methods.

4.3 Insulation - The conductor (or conductor and core) shall be continuously covered with a concentric layer of heat resistant and flexible insulating compound that shall be close-fitting, but with no adherence. The insulation shall provide protection against condensation moisture and shall be capable of accepting the identification required (paragraph 4.11).

4.4 Jacket - A close fitting aluminum braid jacket shall constitute the outer covering of the cable. There shall be no splices or loose ends permitted in the woven braid.

4.5 Cable Dimensions and Weight - The overall diameter of the finished cable shall not exceed 0.130 inch; the conductor (or conductor and core) diameter shall not exceed 0.050 inch. The weight of the finished cable shall not exceed 8.0 pounds per thousand feet determined for any piece of 100 feet or more in length. Unless otherwise specified on the purchase order, not more than 25% of the cable in each order and of each type may be delivered in lengths of 150 to 250 feet, and the remainder shall be in lengths over 250 feet.

4.6 Dielectric Strength - The dielectric strength of the cable shall be such that it withstands without failure a test potential of 1500 volts root mean square (rms) at commercial frequency applied for one minute between the cable conductor and a 5% salt solution, at a temperature of 68 to 77°F. The immersed length shall be twelve inches; the protruding ends shall not be stripped of insulation closer than 2 inches from the salt solution.

4.7 High Temperature - The cable shall show no indication of failure after 96 hours of operation with the conductor heated to 392°F by application of voltage to a test sample.

4.8 Aging - The same sample used in the high temperature test (paragraph 4.7) shall be subjected to five cycles of: (a) 18 hours at 347°F conductor temperature (by voltage application) and (b) six or more hours at ambient room temperature. After this aging test, the cable shall show no indication of failure or loss of specified dielectric strength (paragraph 4.6).

4.9 Bending - The completed cable shall withstand one tight turn around a 1/4 inch diameter mandrel without collapse or failure of the jacket. When this sample is returned to reasonable straightness by hand, it shall not break (either conductor or jacket) and it shall pass the test for dielectric strength (paragraph 4.6).

4.10 Jacket Strength - The jacket shall be sufficiently strong and dense to withstand lengthwise crushing of the cable against the sharp edges of a 0.001 inch aluminum honeycomb core with 1/8 inch cells. Any gashes or cuts that penetrate the insulation material may be cause for rejection.

4.10.1 Jacket Coverage - The woven braid shall be applied in a manner to cover not less than 90% of the underlying insulation. Coverage shall be determined in accordance with the procedure required in Spec. MIL-W-16878.

4.11 Type Identification - Identification of types shall follow the color code listed in Section 2. The colors in the finished cable shall fall within the light and dark limits of the applicable color chips of Standard MIL-STD-104.

4.11.1 Helical Striping - Coding shall be accomplished by the use of white insulation (paragraph 4.3) in conjunction with colored helical stripes. The width of each color stripe shall be not less than 0.015 inch, but the body stripe shall be at least twice the width of the tracer stripe.

4.11.2 Alternative - As an alternative to helical striping, and acceptable only if prior specific approval is granted (see paragraph 5.2), coding may be accomplished by the use of solid color insulation (body color) and colored core material (tracer color).

4.12 Workmanship - Cable shall be free of imperfections of manufacture which will materially affect the appearance or serviceability or will prevent satisfaction of requirements specified herein.

5. QUALITY ASSURANCE PROVISIONS

5.1 Reports - Unless otherwise specified, the vendor shall furnish two copies of a certified report of the results of tests to determine conformance to the requirements of this specification. This report shall include the purchase order number, material specification number, type, manufacturer's stock or lot number and date of tests.

5.2 Approval - A vendor shall not begin to supply material to this specification until samples are submitted to the Materials and Processes Group, and thereafter, the materials and methods of manufacture shall not be changed without prior approval from the Materials and Processes Group.

6. PREPARATION FOR DELIVERY

6.1 Shipping Reels - Each shipping reel shall be permanently and legibly marked to give the following information:

Cable, Resistance Heating, Aluminum Jacket
Material Spec. ____________________
Type ____________ Length ______________
Purchase Order No. ______________
Manufacturer ______________________
Date of Manufacture ________________

6.1.1 Multiple Lengths - When more than one length is shipped on a reel (see paragraph 4.5), the individual piece lengths shall be marked on the reel.

6.1.2 Drum Diameter - The minimum drum diameter of each reel shall be 3-1/2 inches.

R-27-26

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.
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AEROSPACE INFORMATION REPORT

AIR 860

AIRCRAFT ELECTRICAL HEATING SYSTEMS

Issued 1-10-65
Revised

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(Material Specification--Subject: Cable, Resistance Heating, Aluminum Jacket)

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APPENDIX I - AIRCRAFT "A"

Section 2

APPENDIX II - AIRCRAFT "A"

1. 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.

2. 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.

3. SCOPE

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

3.2 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.

3.3 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.

4. GENERAL INFORMATION

4.1 General Design Considerations

4.1.1 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.

4.1.2 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.

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

4.1.4 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.

4.1.5 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.

4.1.6 Control of Heating Elements - Control of electrical heating elements is simple.

4.1.7 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.

4.1.8 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.

PREPARED BY SAE COMMITTEE AC-9,
AIRCRAFT ENVIRONMENTAL SYSTEMS

APPENDIX I

AIRCRAFT "A"

Section 1

GENERAL AIRCRAFT INFORMATION

TYPE	ENGINES Type	ENGINES No.	ALTITUDE	CABIN DIFF. PR.	FUSELAGE Mat.	FUSELAGE Max. Breadth Outside	FUSELAGE Max. Breadth Inside	FUSELAGE 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) Insulation Cargo Fl.	FUSELAGE (Continued) Air Supply Ducts Insulation	CABIN PRESS. AIR SOURCES	CABIN COOLING Air Cycle	CABIN COOLING 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

APPENDIX I

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 $\pm$ 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)

APPENDIX I

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. 1 and Fig. 2	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. 1)	Al. Al. 5052H Foil Spec. MIL-C-7438 Cell Size 1/8 in. Hex Thickness = .001 in. Cell Depth = .341 $\pm$ .003	Top Cover Plate Alclad 7075T6 Spec. QQ-A-287 .016 in thickness Bottom Cover Plate Alclad 7075T6 Spec. QQ-A-287 .012 in. thick-ness
				See Figures 3 & 5	

FLOOR PANELS

DETAILS - HONEYCOMB HEATED CONSTRUCTION					INSTALLATION METHOD	
BONDING	ELECTRICAL RESIST. CABLE Install. & Mat.	ELECTRICAL RESIST. CABLE Capacity	ELEC. TERMINAL	MOUNTING SPACERS	SCREWS	
MIL-A-5090 Adhesive System	Installation See Fig. 3 Install in crushed groove Material See App. II	20 watts per sq. ft. Power 115/208 VAC 3 phase 400 cycle	See Fig. 7 Install per Fig. 4	See Fig. 6 See Fig. 5	No. 10 Flat Head	

APPENDIX I

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS (Continued)

FLOOR PANELS

DETAILS - HONEYCOMB HEATED

FUNCTIONAL TEST

DIELECTRIC TEST - HEATING ELEMENT TERMINALS

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

DIELECTRIC TEST - TEMPERATURE SENSOR TERMINALS

TEST EQUIPMENT	TEST CONNEC-TIONS	VOLTAGE	TIME	CRITERIA OF FAILURE	PANEL MARKING
(Same as for heat-ing ele-ment test above)	1. <u>One</u> sensor term. 2. Ground (to panel)	200 AC 60 cycle	1 sec.	No indica-tion of Insul. Breakdown	Mark Panel as having been "Dielectric tested OK"

RESISTANCE TEST - HEATING ELEMENT

TEST EQUIPMENT	TEST CONNECTIONS	TEST REQUIREMENT	TEST TOLERANCE
1. Wheat-stone 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

APPENDIX I

PASSENGER COMPARTMENT - ELECTRIC RADIANT PANELS (continued)

WALL AND WINDOW HEATING PANELS

LOCATION	TYPES USED	DETAILS, PANELS, WALL AND WINDOW		
		CONSTRUCTION		
		MATERIAL AND SIZE		BONDING
		Core	Plates	
See Figs. 2A and 2B	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. 1 Similar to Floor Panel Fig. 3 Material See App. II	20 watts per sq ft. Power 115/208 VAC 3 phase 400 cycle

CONSTRUCTION (Continued)

Elec. Terminals	Installation	Functional Test
See Fig. 7	See Figs. 1, 2, 2A, 2B	Check Elec. & Dielectric Tests
Elec. Bonding per Fig. 2B	Special Extrusions and clips	

APPENDIX I

FUNCTIONAL TEST		
Dielectric Test Heating Elements	Dielectric Test Temp. Sensors	Resistance Test. Heating Elements
← Same as for floor panels →		

APPENDIX I

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. 8 Below cargo structural floor. No. per comp't 42 panels fwd. 43 panels aft	See Fig. 9 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. 9 Material See Appendix II	61 watts per sq. ft. Power 115/208 VAC 3 phase 400 cycle	See Fig. 7 See Fig. 9A	See Figs. 8 & 9

FUNCTIONAL TEST

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

APPENDIX I

SPECIFIC DESIGN AND OPERATION INFORMATION

FLIGHT STATION - ELECTRIC DUCT HEATER

LOCATION	TYPE AND CONSTRUCTION	ELECTRICAL
See Fig. 10 Located in flight station air supply duct	See Fig. 12	See Fig. 11 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. 13 for Test Setup	At Sea Level	At 8000' Press. Alt.
1. Continuity test	Air Flow 30#/min.	22#/min.
	Air "In" Temp. 70^{o}F	70^{o}F.
2. Airflow distribution across face of heater must be uniform	Max. Temp. Rise 79^{o}F	108^{o}F.
	Max Pr. Drop .50 in. H_2O	.40 in. H_2O
	Max. Surface Temp. 300^{o}F	350^{o}F.
3. Electrical sequence per Table I.	Normal Surface Temp. 200 to 250^{o}F.	200 to 250^{o}F.
4. Overheat test - no airflow - Thermal protector to operate within 90 seconds.		

APPENDIX I

SPECIAL DESIGN AND OPERATION INFORMATION

CABIN - ELECTRICAL DUCT HEATER

LOCATION	TYPE AND CONSTRUCTION	ELECTRICAL
See Fig. 10 located in cabin air supply duct	See Figure 14	See Figure 15 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. 16 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_2O	.30 in. H_2O
	Max. Surface Temp. 300°F.	350°F.
3. Electrical sequence test per Table II	Normal Surface Temp. 150 to 200°F.	150 to 200°F.
4. Overheat test - no airflow - thermal protector to operate within 90 seconds		

TABLE I

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 II

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

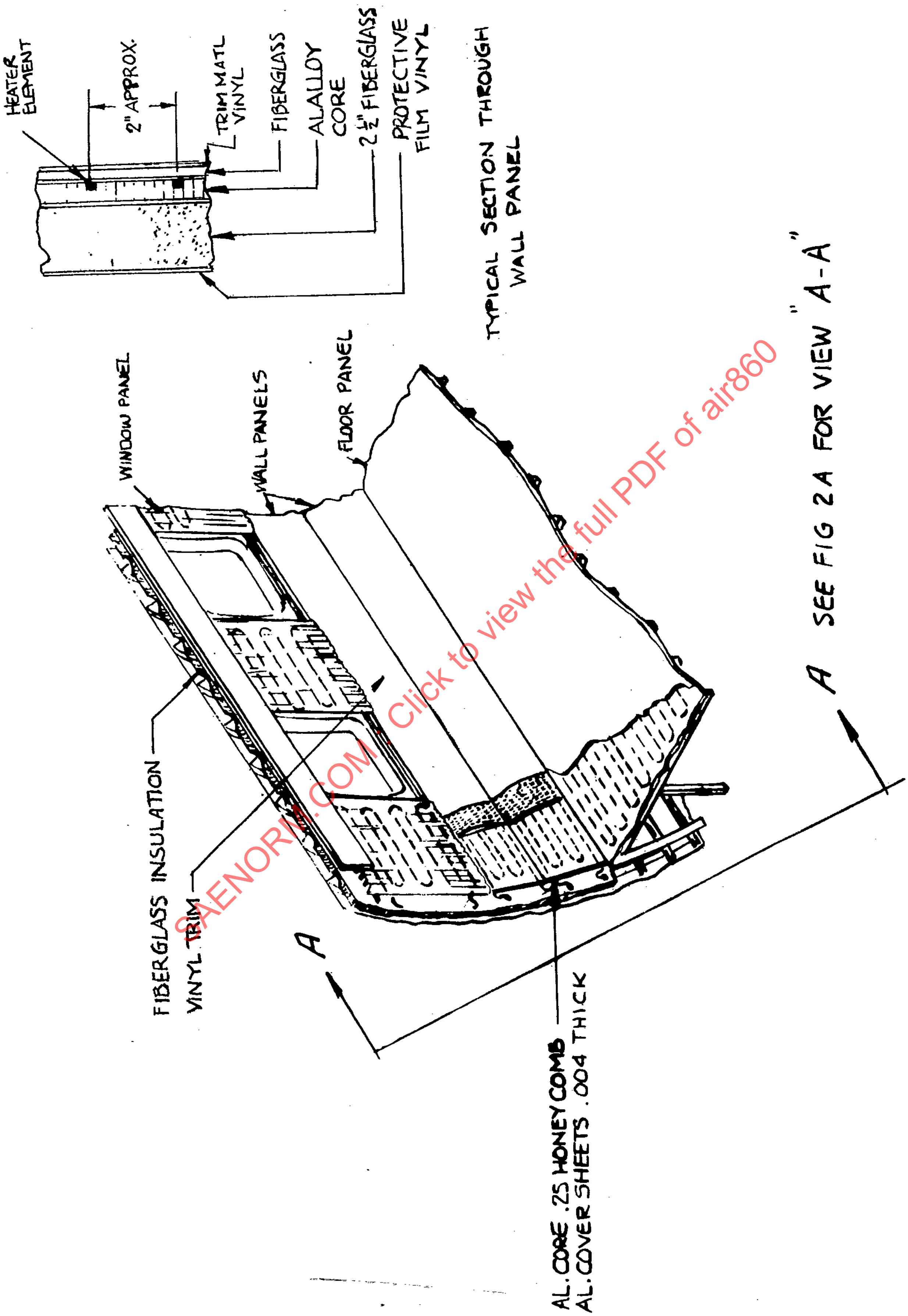

Figure 1. Cabin Wall and Floor Radiant Panels

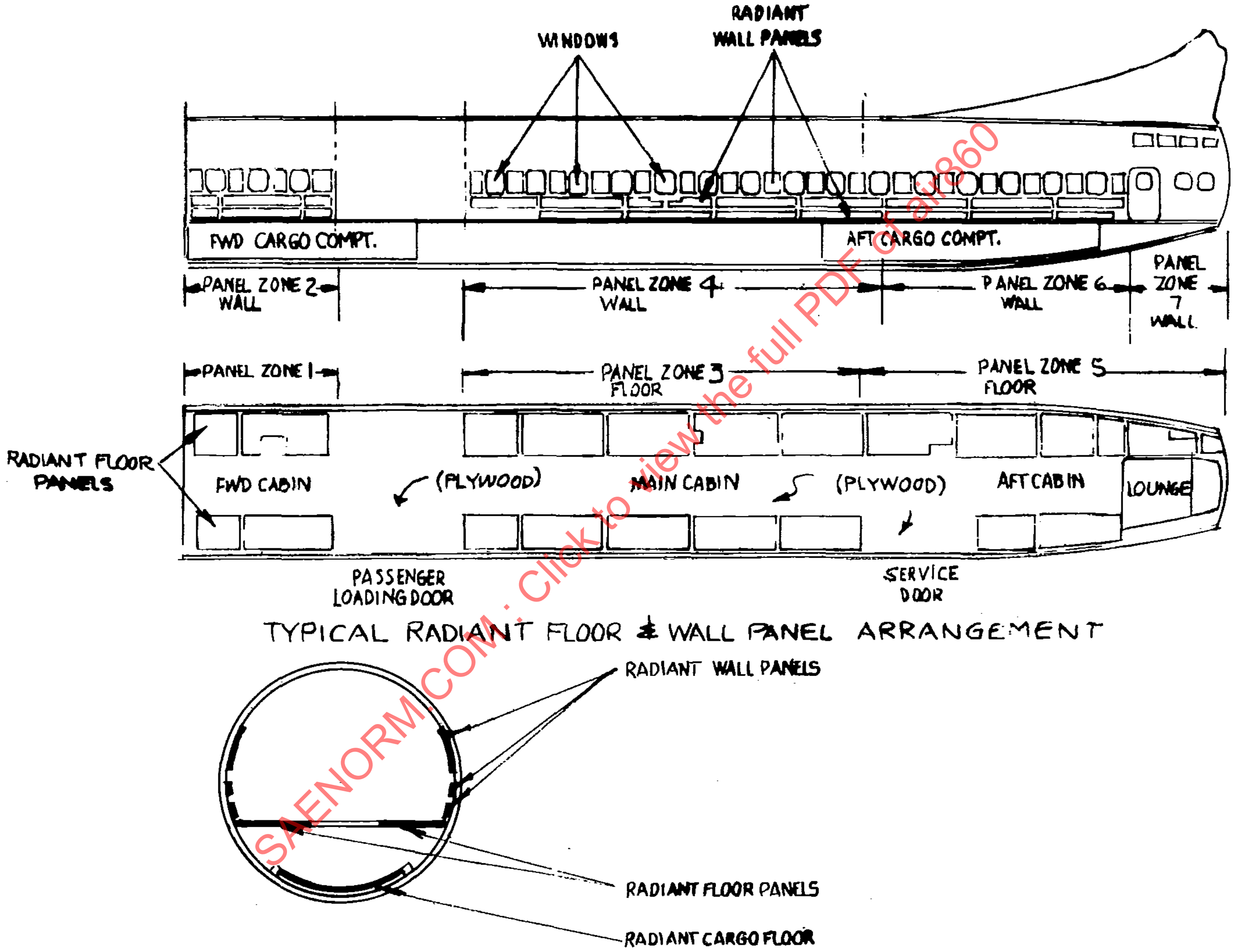

Figure 2. Radiant Heating Panels

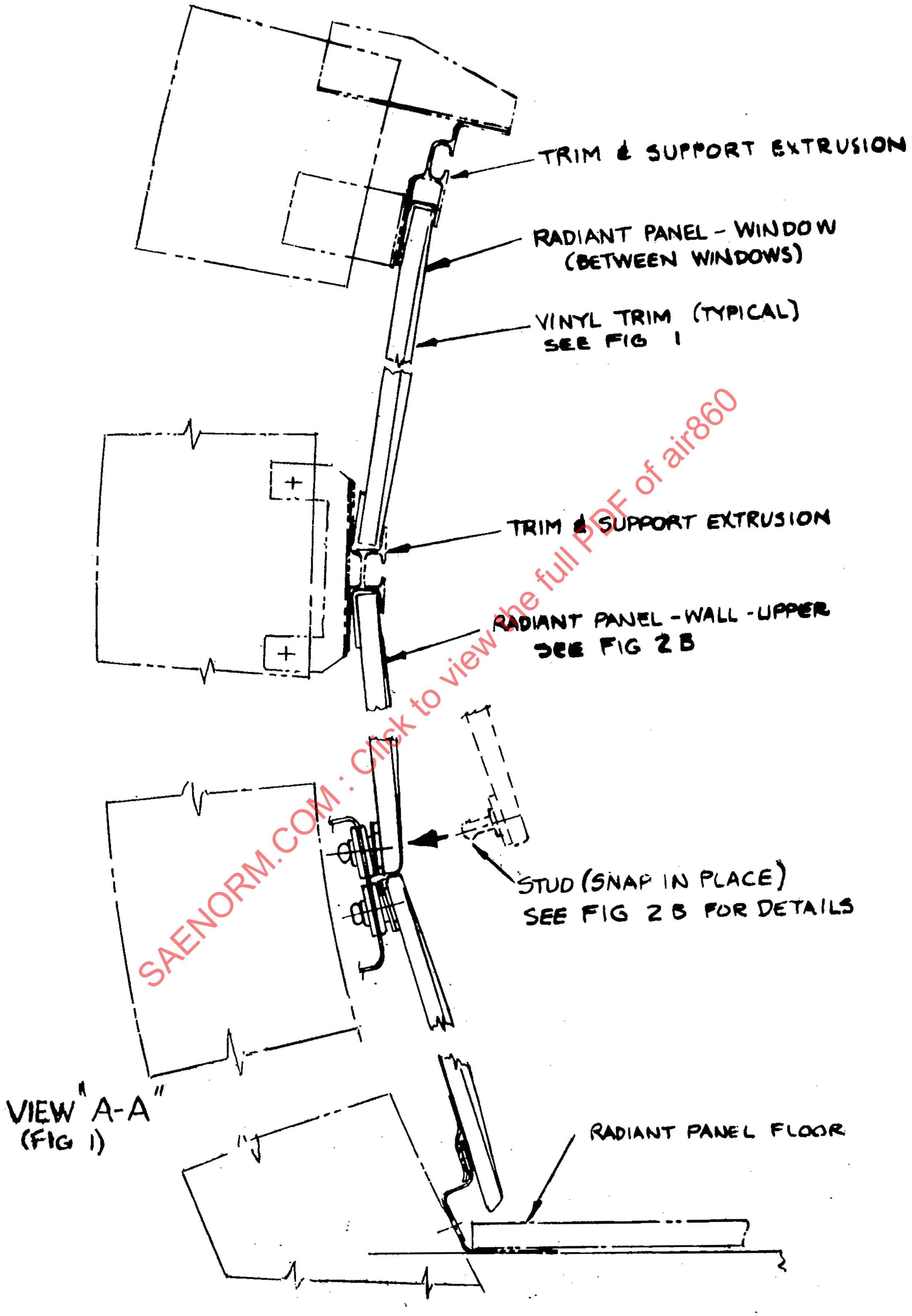

Figure 2A. Cabin Wall and Floor Radiant Panels - Sect. View

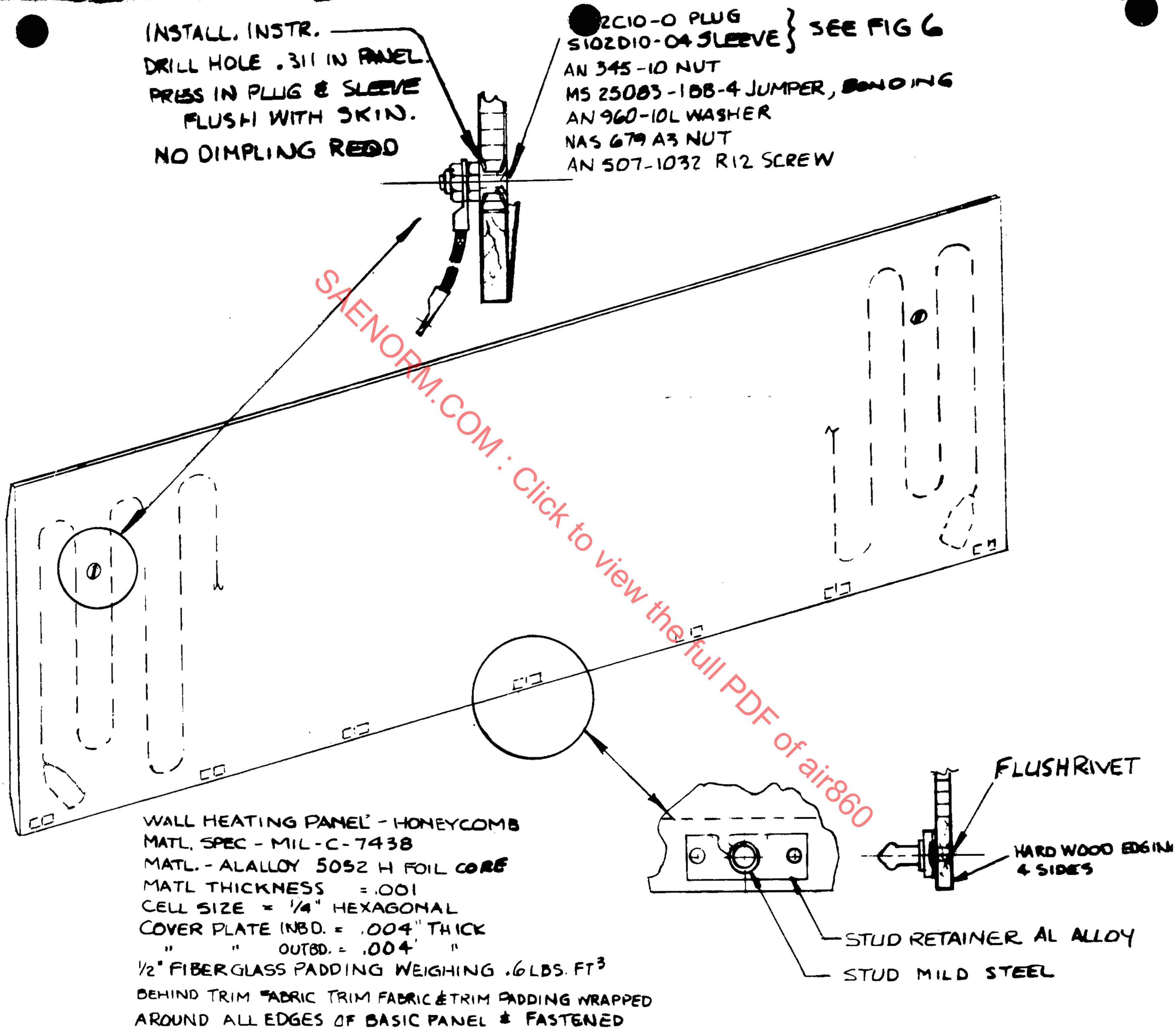

Figure 2B. Wall Panel - Upper

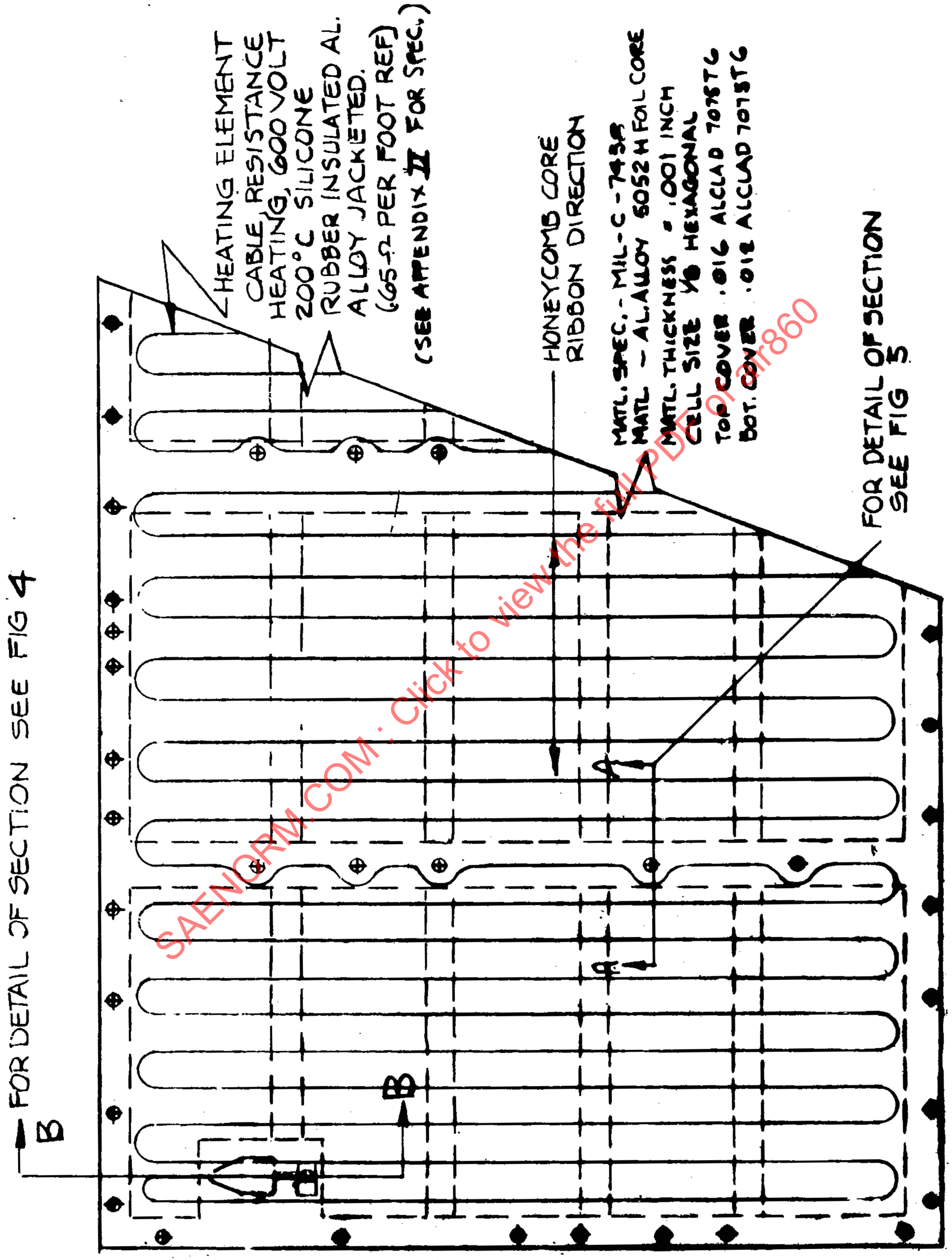

Figure 3. Cabin Floor Radiant Panel Assembly

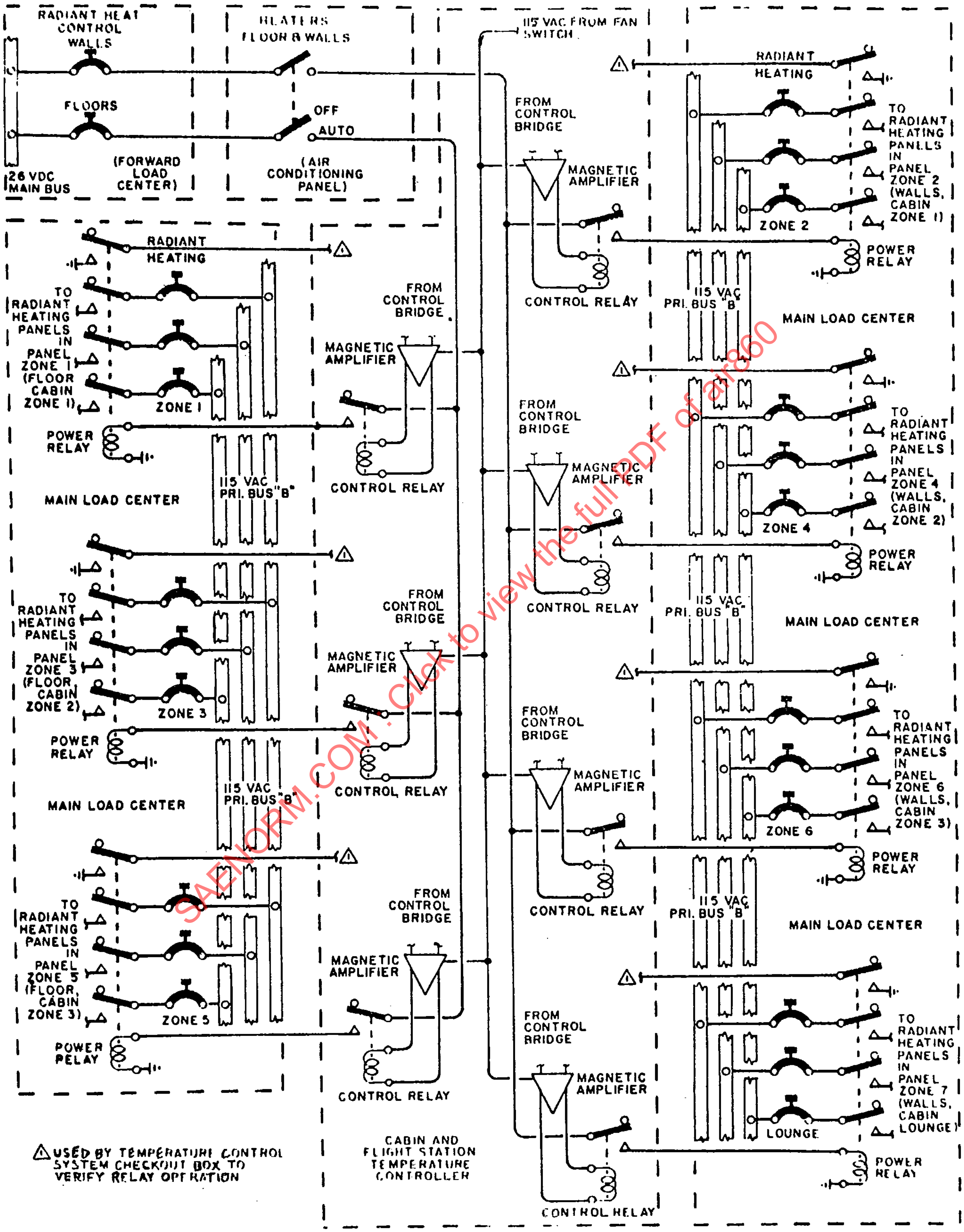

Figure 3A. Radiant Heat Panels Control

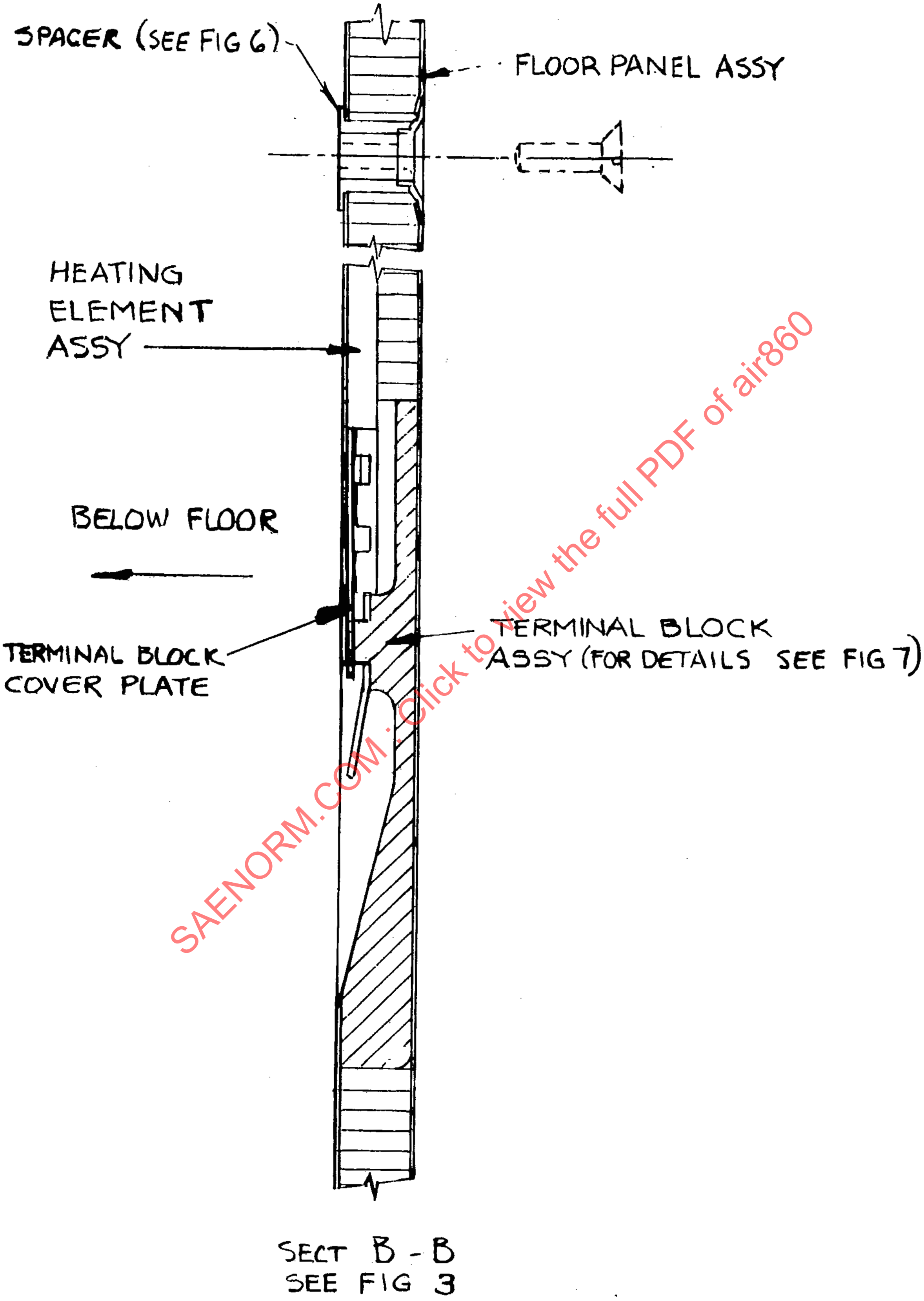

Figure 4. Section - Terminal Block - Floor Panel Installation