GEMINI
8-M Telescopes
Project

TN-TE-G0016

Gemini Support Facility Roof Thermal Analysis

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1. Introduction

Thermal modeling has been performed for two different support facility roof designs. The object of the modeling was to determine whether a ventilated roof would be necessary to prevent buoyant flow from moving off the top of the roof through the telescope light path. The models were also used to determine what roof surface coating would be most appropriate. Steve Hardash of Gemini TSBEG provided drawings of roof structural elements determined by building code requirements and Mauna Kea environmental loading conditions. Data from these drawings were used to produce thermal models which were then solved to obtain the transient temperature response of the structural elements. Two model element temperatures are of importance; the temperature of the outer surface of the roof and the temperature of air cells constrained in the steel decking below the outer surface of the roof. If either of these temperatures are greater than the ambient air temperature during the night, and if there is a flow path between the air constrained in the steel deck and the ambient air, then plumes of buoyancy driven flow will exist over the support facility.

2. Environmental Conditions

2.1 Wind Velocity

The thermal modeling was performed for the 5th percentile value of the ambient wind velocity distribution; 0 m/s. Thus free convection is defined to exist between the outer surface of the roof and the ambient air. This is the most severe condition from the standpoints of both the temperature response of the roof and any "seeing" caused by the roof surface. This is because a high wind speed results in a larger convection coefficient, which will drive the roof temperature closer to the ambient air temperature profile. The same wind will also tend to blow away any plumes before they tend to pass through the light path.

2.2 Ambient Air Temperature

A smoothed thirty day average for the month of August 1992 was used to represent the air temperature at the site. The data was obtained from the UKIRT facility on the summit ridge of Mauna Kea. All of the temperature plots presented herein are referenced to this profile.

2.3 Environmental Radiation: Sky Temperature and Solar Loads

The model utilizes a sky sink element at a continuous temperature of 243°K. Black body view factors of unity are used for the radiative couples between the model elements representing the horizontal roof outer surfaces and the sky. The solar loads on the horizontal surfaces of the roof were determined for the middle of August by utilizing data from the nautical almanac. The following table presents the surface properties of the three candidate coatings used.

Table 2.1 - Surface Properties of Candidate Coatings

Material	Solar Absorptivity	Emissivity
White Ti-0_2 Paint	0.25	0.87
Lo-Mit™ Paint	0.15	0.25
Asphalt	0.90	0.90

3. The Thermal Models

Table 3.1 list the important thermal properties of the model materials.

Table 3.1 - Thermophysical Properties of Model Materials

Material	Density (kg/m^3)	Conductivity (W/m°C)	Sp.Heat (W-hr/kg-°C)
Steel	7854	60.5	0.12
Asphalt (Seal)	2115	0.062	0.25
Plywood	500	0.12	0.35
Roofing Insulation	265	0.050	0.35
Glass Wool (Batt)	30	0.03	0.23

3.1 The Roof Structures

Figure 1 shows a cross section through the ventilated roof formed by joining two sections of 20 gauge steel deck plate, hereafter referred to as the "two-deck" design. The idea behind this construction technique was to create cellular air volumes which could be forced ventilated to control the roof temperature. The outside surface of the roof is a 1/4" asphalt seal membrane coat placed over 1/2" of exterior rated plywood. The underside of the steel deck is covered with 3" of glass wool batt insulation.

Figures 2 through 5 present information on the steel deck plate, joist construction, and joist and support column spacing. This information is used to create the thermal model representing the roof. An important consideration for the roof over the plant room and workshop is that it may one day become the floor of an expanded support facility. Once the seal membrane and plywood has been stripped off, concrete can be poured into the deck plate.

Figure 6 shows an alternative roof composed of only one layer of deck plate, hereafter referred to as the "single-deck" roof. The batt insulation below the deck plate depicted in has been deleted and instead an equivalent thickness of rigid roof insulation is attached atop the deck plate. The insulation is then covered with the 1/4" asphalt seal membrane.

Portions of the roof near the enclosure will be subjected to impact loads from falling ice. Thus either roof option will require a protective barrier for the roof area near the enclosure.

3.2 The Thermal Circuits for the Roof Structures

The equivalent thermal circuits for the two different roof systems are presented **on Figures 7 and 8**. The circuits present the thermal links between model elements for one square meter of outer roof area. As a worst case preliminary, the modeling assumes the air volumes inside the steel decks are sealed and do not interact with the ambient air either passively or actively. Thus the modeling did not utilize any flow links acting on the air volumes around the steel deck plates. If necessary, flow links would be added in subsequent modeling to determine the effect of fan forced ventilation on the roof temperatures.

4. Results

Figure 9 shows the surface temperature of the **two-deck** roof for three different coatings; None (asphalt only), White Paint, and Lo-Mit Paint.

- The white painted roof drops below ambient air temperature about one hour before sundown;
- The asphalt roof begins to drop below the ambient profile about an hour after sundown;
- The Lo-Mit painted roof passes through the ambient profile four hours after sundown.

Figure 10 shows how the temperature of the air cells in the two-deck roof vary with time for the three different roof surface coatings.

- Air cells in the steel deck below the white coated surface cool the fastest. The air cell temperature profile for the white coated surface drops below ambient four hours after sundown;
- Air cells for the uncoated (plain asphalt) surface cool below ambient air at midnight;
- Air cells for the Lo-Mit coated surface never drop below the ambient air temperature.

Figure 11 shows the surface temperature of the **single-deck** roof for the three different candidate coatings.

- The maximum daytime and minimum nighttime temperature values remain the same as those for the two-deck roof of Figure 9;
- The white covered single deck surface behaves the same as the white covered two deck surface;
- The asphalt covered single deck surface cools about an hour faster than the asphalt covered two deck roof;
- The Lo-mit covered single deck roof cools two hours faster than the Lo-m’t covered two-deck roof.

Figure 12 shows how the temperature of the air cells in the single-deck roof vary with time for the three different roof surface coatings. Because an equivalent thickness of insulation has been removed from between the deck steel and the facility room air (Figure 1) and placed atop the deck (Figure 6), the deck air cell temperatures become equivalent to the facility room air temperature.

- The roof air cell temperatures for all coatings never deviate more than 2°C from the temperature of the room air inside the facility (21°C).

5. Conclusions

- White paint is the only surface coating that will drive the outer surface temperature of either candidate roof design below the ambient air temperature profile before sundown, and thus prevent buoyant flow off the roof during the nighttime hours;
- Provided the roof is white coated, no force ventilation of the air cells in the two-deck roof will be required;
- Because force ventilation will not be required, the complexity and additional expense of the two-deck roof design will not be required;
- A white coated single deck option should be selected for the support facility roof.

Given a white coated single deck roof design, special consideration must be given to whether the insulation atop the single deck adjacent to the enclosure can withstand the impact of ice falls. The addition of an additional stiff membrane or barrier atop the insulation near the enclosure will be required. The use of a suspended open steel deck grate is suggested as a means of smashing up large chunks of ice which could otherwise damage the upper roof membrane. Emphasis must also be placed on how easily the material above the deck plate can be stripped in the event those sections of the roof above the plant room and workshop becomes the floor of future heated rooms in an expanded support facility. Finally, the roof must be well sealed about its outer perimeter to prevent the air constrained within the steel deck from rising upwards at night.

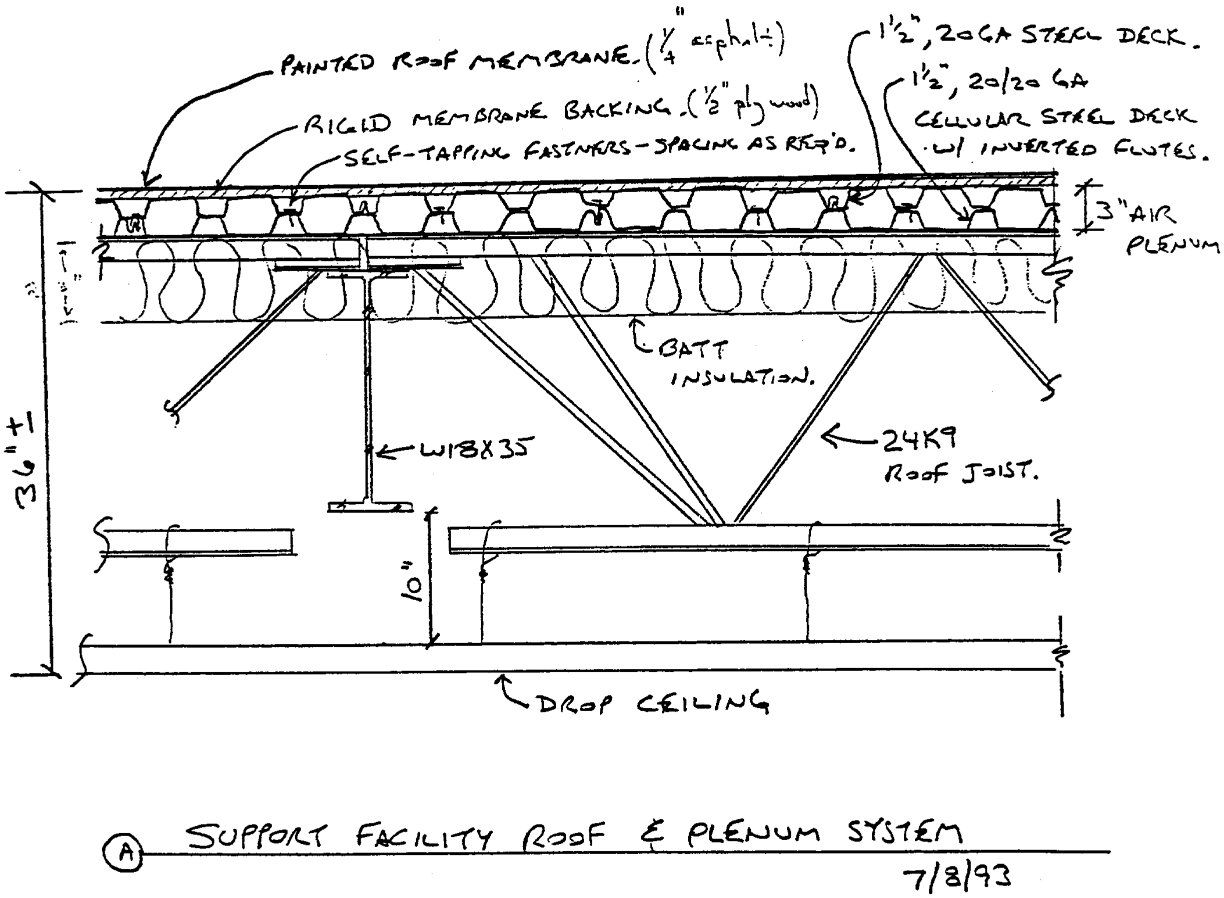
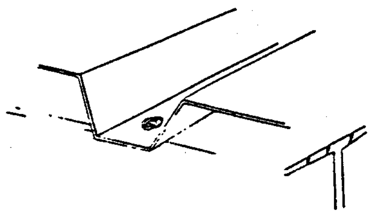


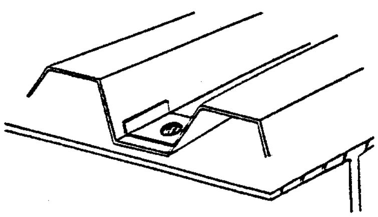
Figure 1. The “two-deck” Ventilated Roof

Attachments

WELDS TO SUPPORT

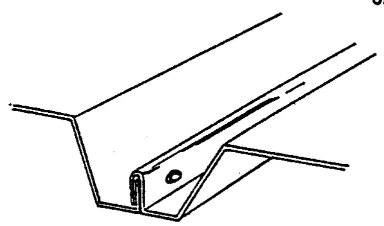


HSB-36, SYSTEM 80 AND N-24 DECK
PUDDLE WELD
Effective Minimum 1/2" Diameter or 3/8" x 1" Long
(No Weld Washer Used)

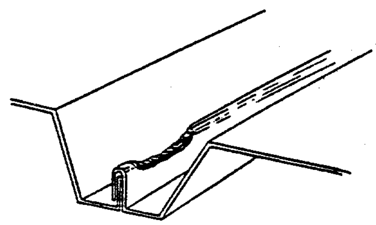


VERCOR DECK
PLUG WELD
Through 3/8" Diameter Hole In 14 GA Weld Washer

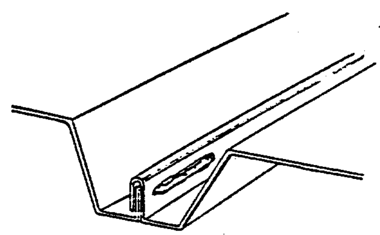
SIDE LAP FASTENING



BUTTON PUNCH
3/16" Diameter Button Protrudes Noticeably Interlocking Units



TOP SEAM WELD
Clinch First To Get Contact Of Lips
1 1/2" Long Weld Must Engage Top Of Inner Leg



SIDE SEAM WELD
Clinch First To Get Contact Of Lips
1 1/2" Long Weld Must Engage Inner Leg And Have Fusion Top And Bottom

The performance of the roof deck diaphragm depends on the quality of the welds to supports and the side lap attachments. Each welder should demonstrate his ability to produce quality welds. In a test, if a piece of deck welded to the support should be pried apart, the deck should tear and the weld should be sound.

To test a button punch connection, an average sized man should be able to stand (not jump) on the flute adjacent to the attachment without it coming apart.

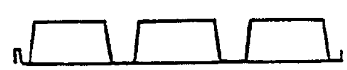
Cellular Deck

Lower deck for "two-deck" roof

TYPE HSB-36 CD
(also available 30" & 24" wide)

GAGE	WEIGHT (Lbs./Sq.Ft.)	$I (IN^4)$	$S (IN^3)$
20/20	3.9	.38	.31
18/20	4.4	.52	.46
20/18	4.4	.41	.31
18/18	5.1	.57	.47
18/16	5.7	.61	.48
16/16	6.3	.77	.66

TYPE N-24 CD

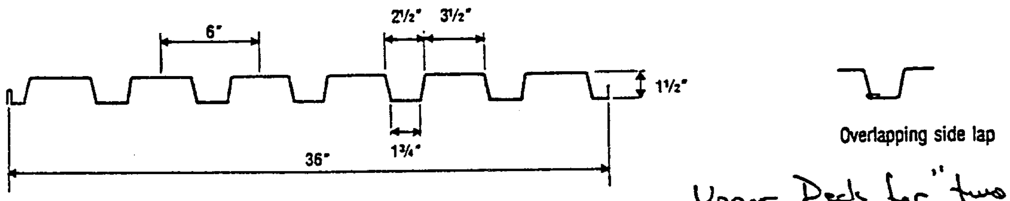


GAGE	WEIGHT (Lbs./Sq.Ft.)	$I (IN^4)$	$S (IN^3)$
20/20	4.2	1.4	.60
18/20	5.0	2.0	.89
20/18	4.8	1.5	.61
18/18	5.7	2.1	.91
18/16	6.2	2.2	.92
16/16	7.1	2.9	1.3

Figure 2. Steel Deck Details

Type HSB-36

High Shear B Deck-36" Wide
Verco's New Standard B Deck
Higher lateral load capacity
Also available 24" or 30" wide with button punch or overlapping side lap on special order



Upper Deck for "two-deck" roof
Deck for single deck roof

Gage	Weight (Lbs./Sq. Ft.)		I	+S	−S	2" End Bearing Allowable Reaction (lbs)
	Painted	Galvanized	(In⁴)	(In³)	(In³)	
22	1.8	1.9	.183	.209	.209	1,280
20	2.2	2.3	.233	.271	.271	1,740
18	2.8	2.9	.338	.395	.395	2,500
16	3.4	3.5	.440	.502	.502	3,000

VERTICAL LOADS (Lbs./Sq. Ft.) HSB-36 AND HSB-36 WITH SHEARTRANZ® — **PAINTED OR GALVANIZED**

	Gage		Span												
			5'-0"	5'-6"	6'-0"	6'-6"	6'-8"	7'-0"	7'-6"	8'-0"	8'-4"	8'-6"	9'-0"	9'-6"	10'-0"
Simple Span	22	s	105	86	73	62	59	53	46	41	38	36			
		Δ	95	71	55	43	40	34	28	23	20	19			
	20	s	131	108	91	78	74	67	58	51	47	45	40		
		Δ	115	88	68	53	49	43	35	28	25	24	20		
	18	s	179	148	124	106	101	91	80	70	65	62	55	50	45
		Δ	164	123	95	75	70	60	48	40	35	33	28	23	20
	16	s	227	188	158	134	128	116	101	88	81	78	70	63	56
		Δ	204	153	118	93	89	74	60	50	44	41	35	30	25
Two Spans	22	s	110	91	77	65	62	56	49	43	40	38	34		
		Δ	—	—	—	—	—	—	—	—	—	—	—		
	20	s	140	116	97	83	79	71	62	55	50	48	43	39	
		Δ	—	—	—	—	—	—	—	—	—	—	—	—	
	18	s	185	153	128	109	104	94	82	72	67	64	57	51	46
		Δ	—	—	—	—	—	—	—	—	—	—	—	—	—
	16	s	230	190	160	136	129	117	102	90	83	79	71	63	57
		Δ	—	—	—	—	—	—	—	—	—	—	—	—	—
Three or More Spans	22	s	138	114	96	82	78	70	61	54	50	48	43		
		Δ	—	—	—	81	75	65	53	43	38	36	30		
	20	s	176	145	122	104	99	89	78	68	63	61	54	48	
		Δ	—	—	—	101	94	81	65	54	48	45	38	32	
	18	s	232	191	161	132	127	118	103	90	83	80	71	64	58
		Δ	—	—	—	—	—	112	91	75	66	62	52	45	38
	16	s	288	238	200	170	162	146	128	112	103	99	89	80	72
		Δ	—	—	—	—	162	140	113	94	83	78	65	56	48

See page 14, item 1 on how to use this table.

Figure 3. Steel Deck Details

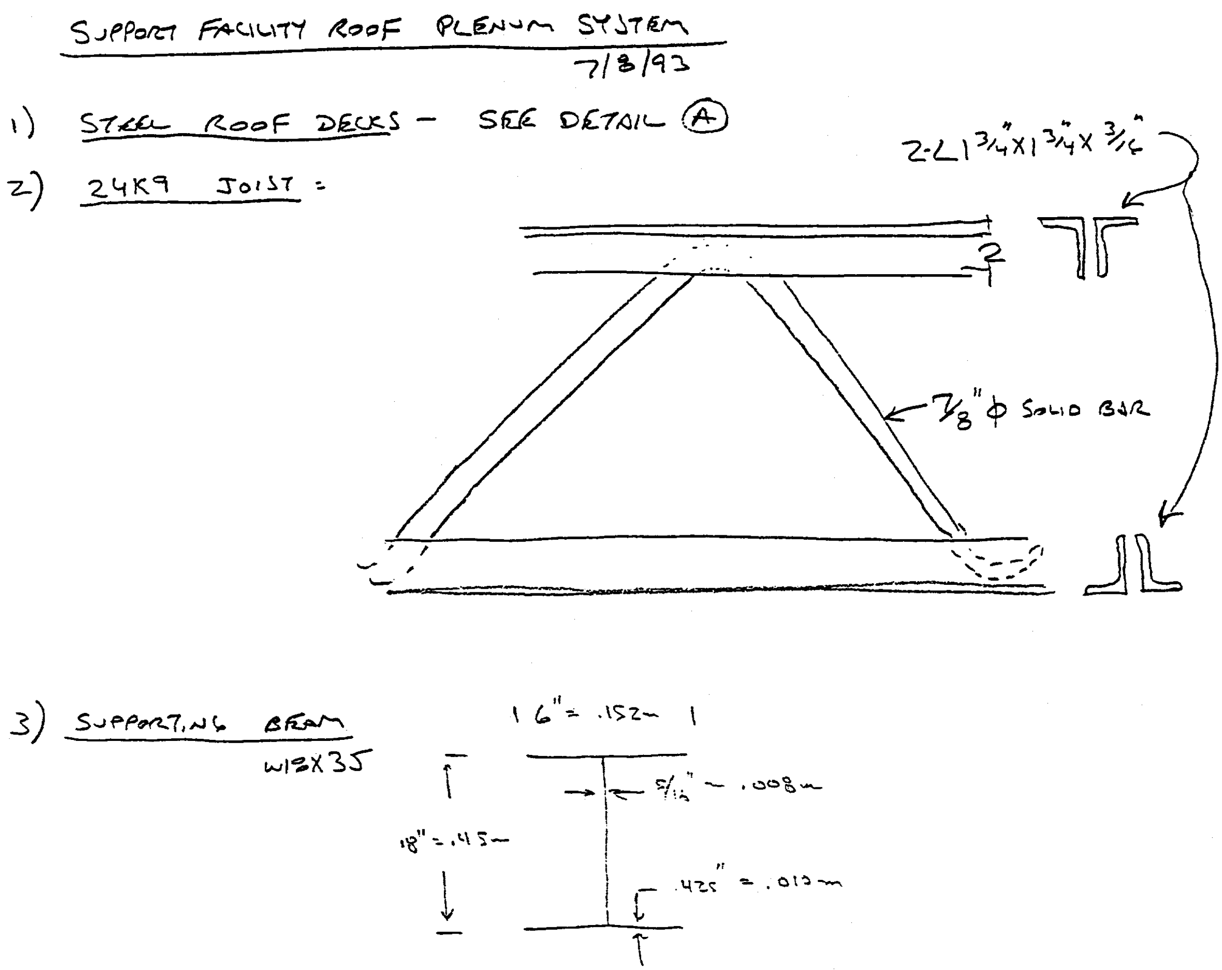


Figure 4. Joist and Support Column Details.

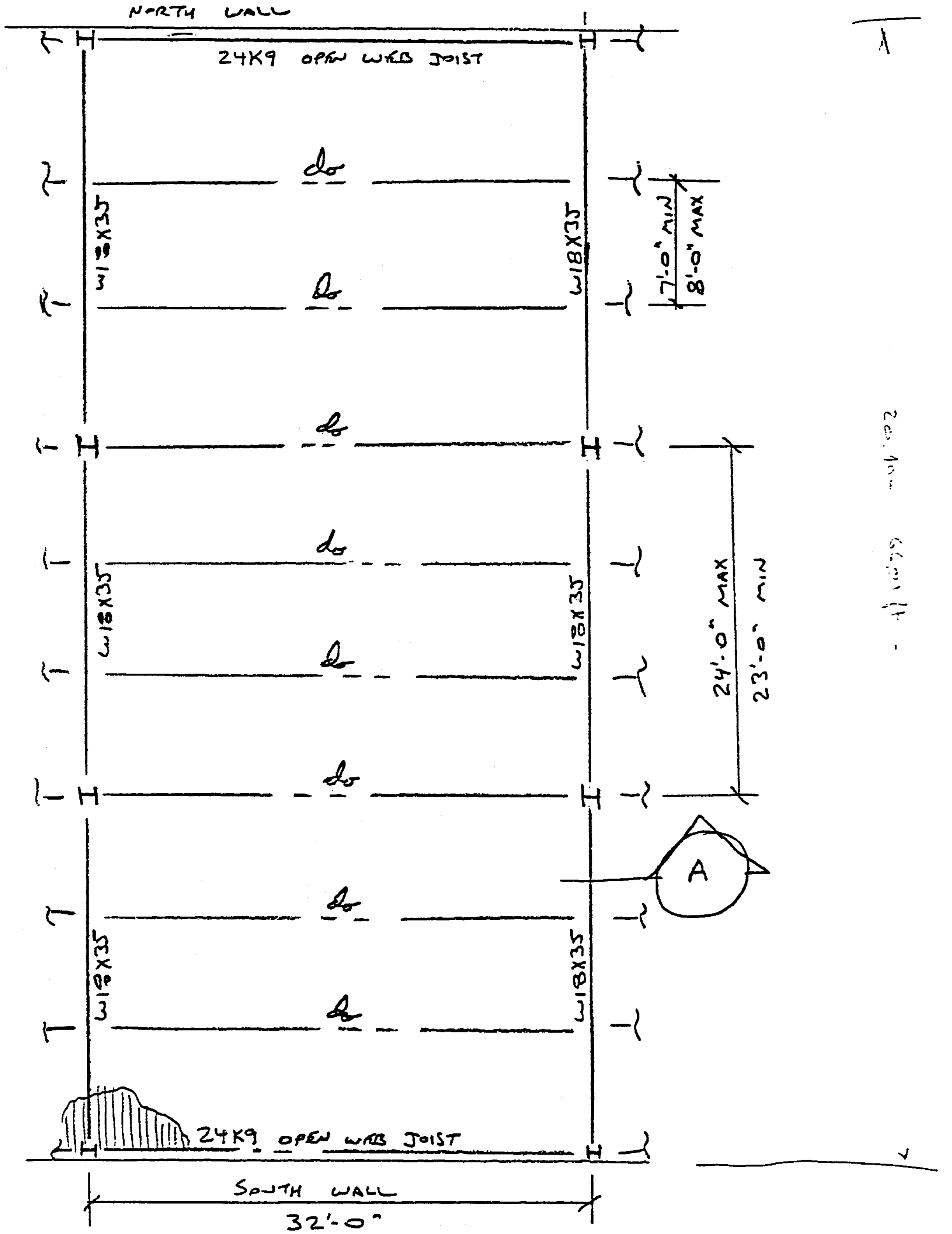


Figure 5. Joist and Support Column Details

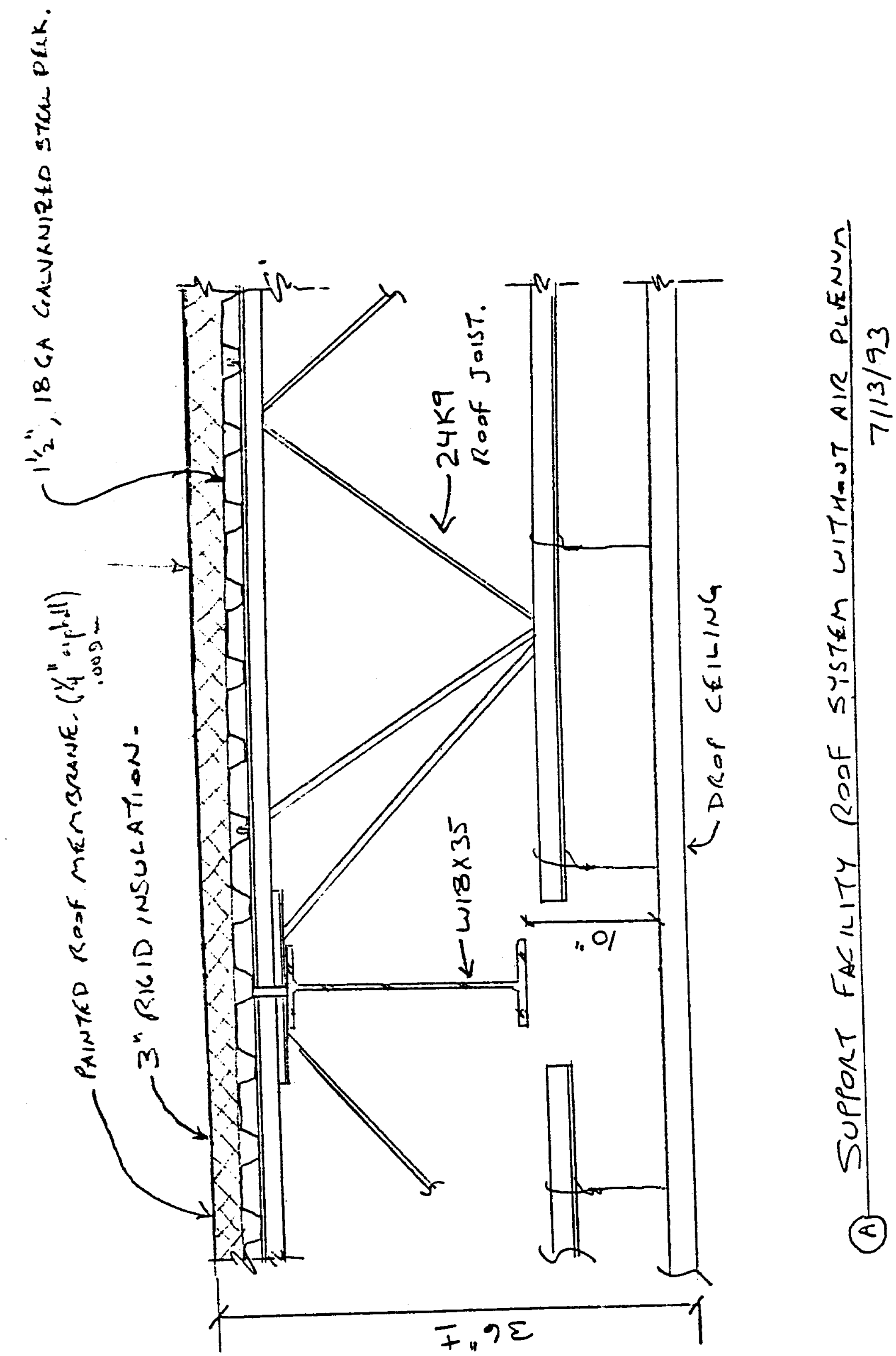


Figure 6. The Single Deck Roof.

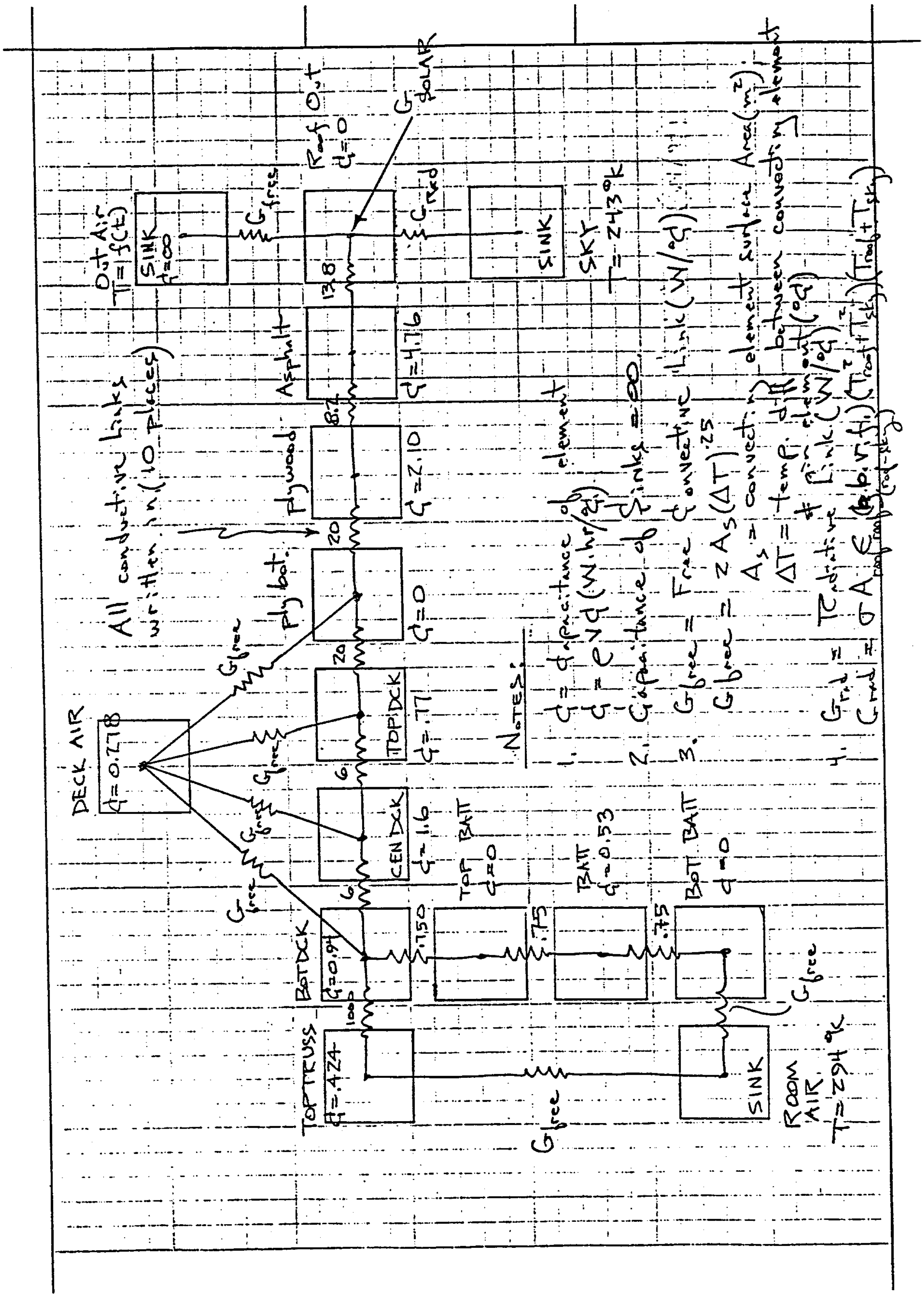


Figure 7. Two Deck Roof Thermal Circuit

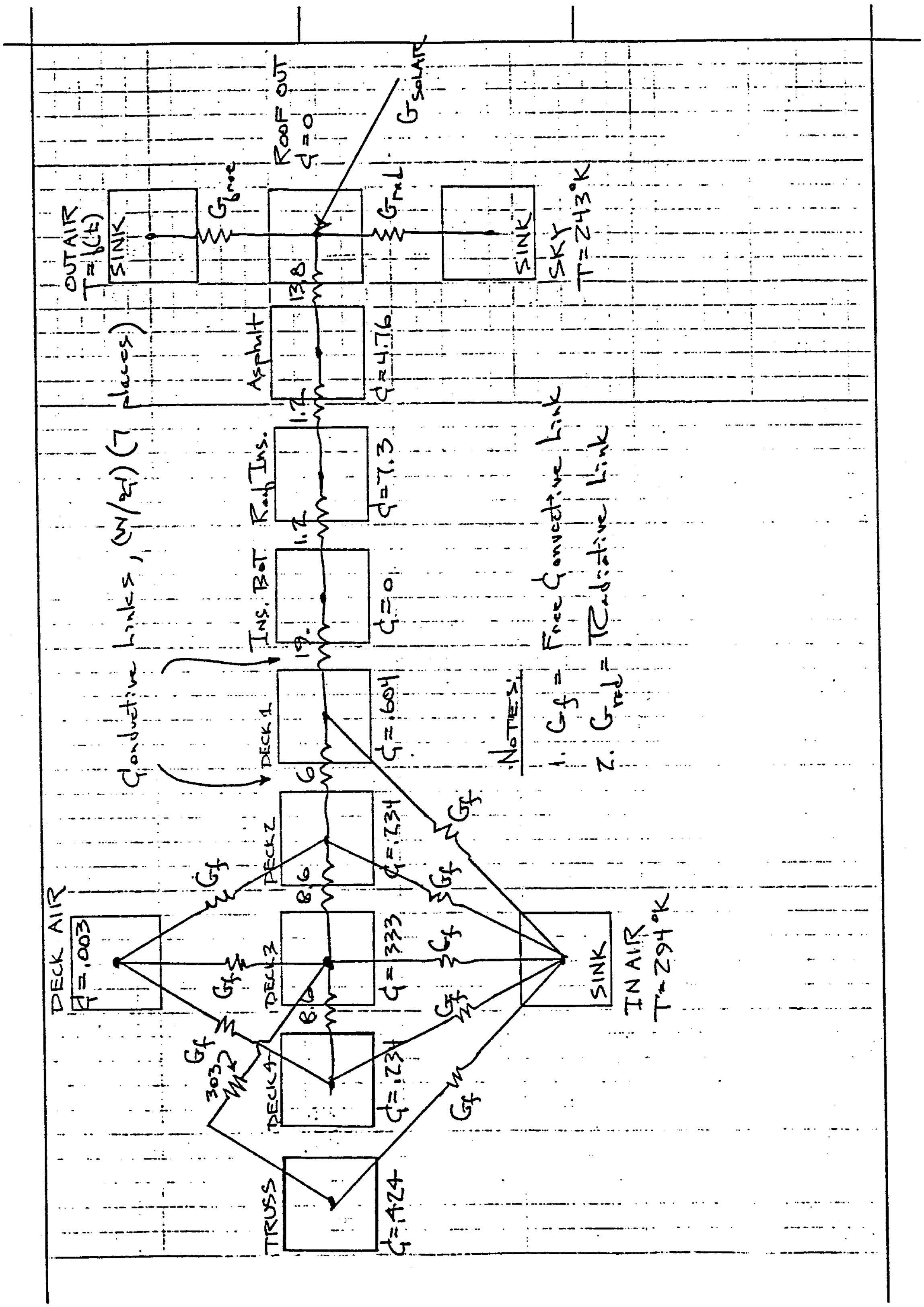


Figure 8. One Deck Roof Thermal Circuit

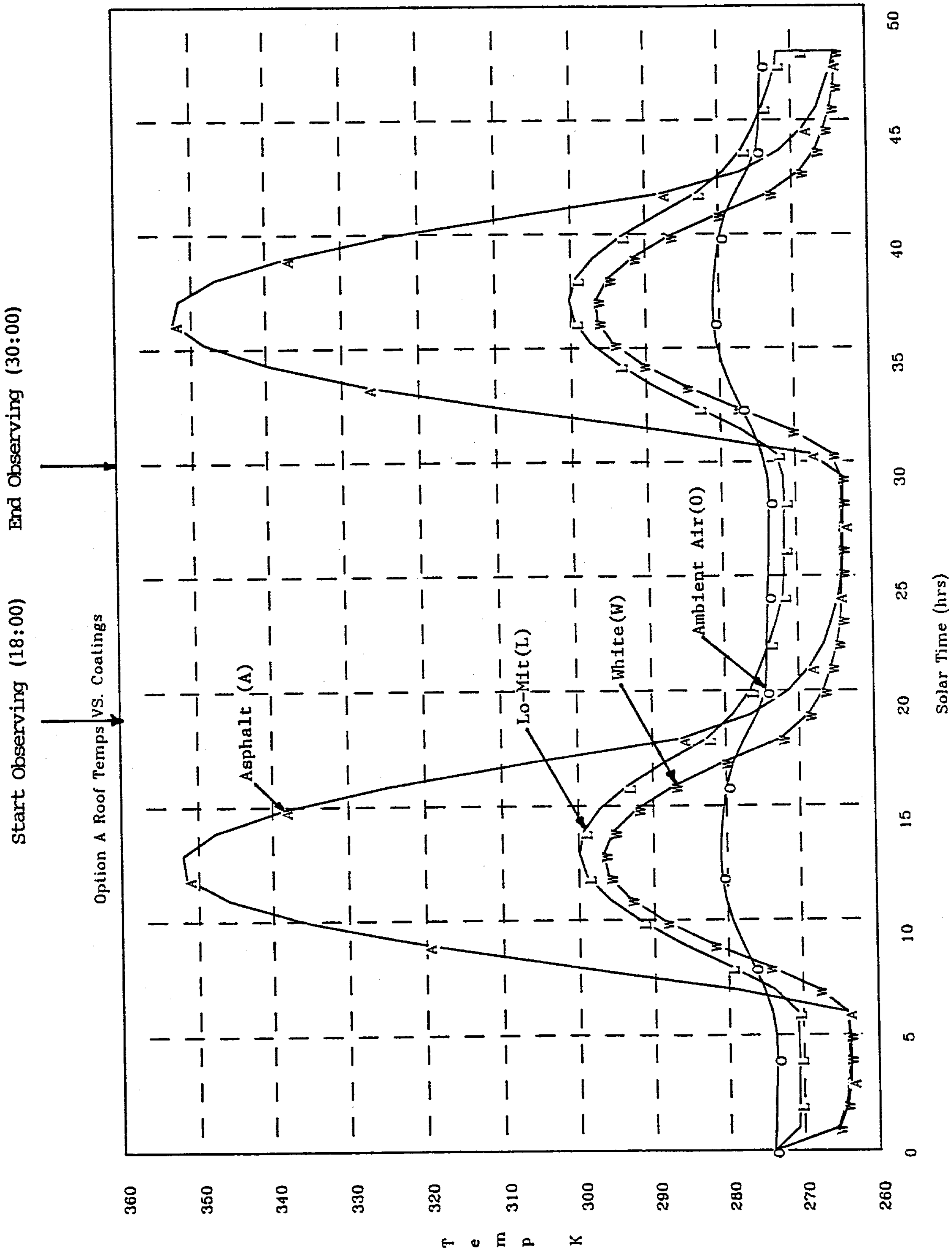


Figure 9. Two Deck Roof Surface Temperatures

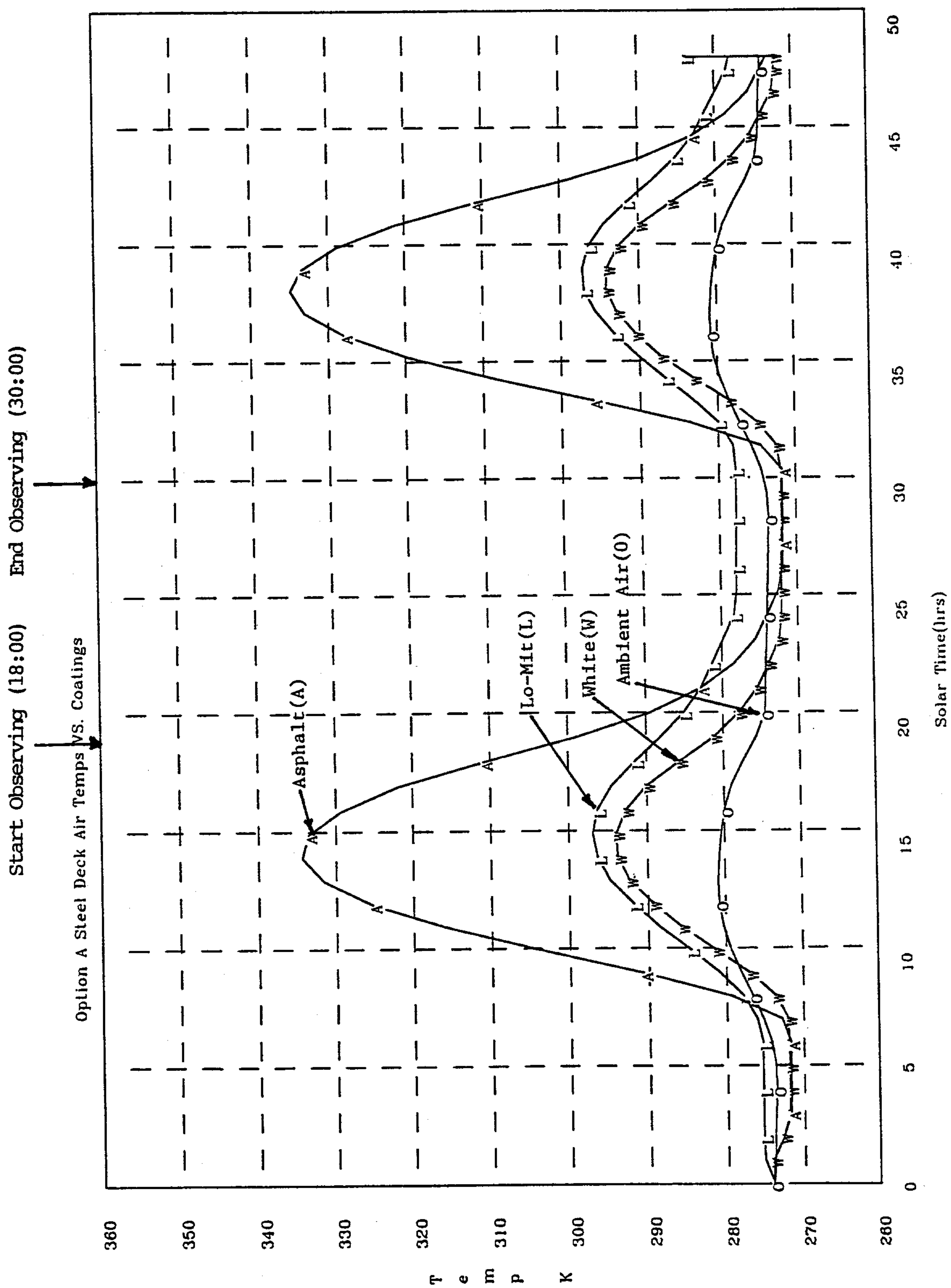


Figure 10. Two Deck Roof Air Cell Temperatures

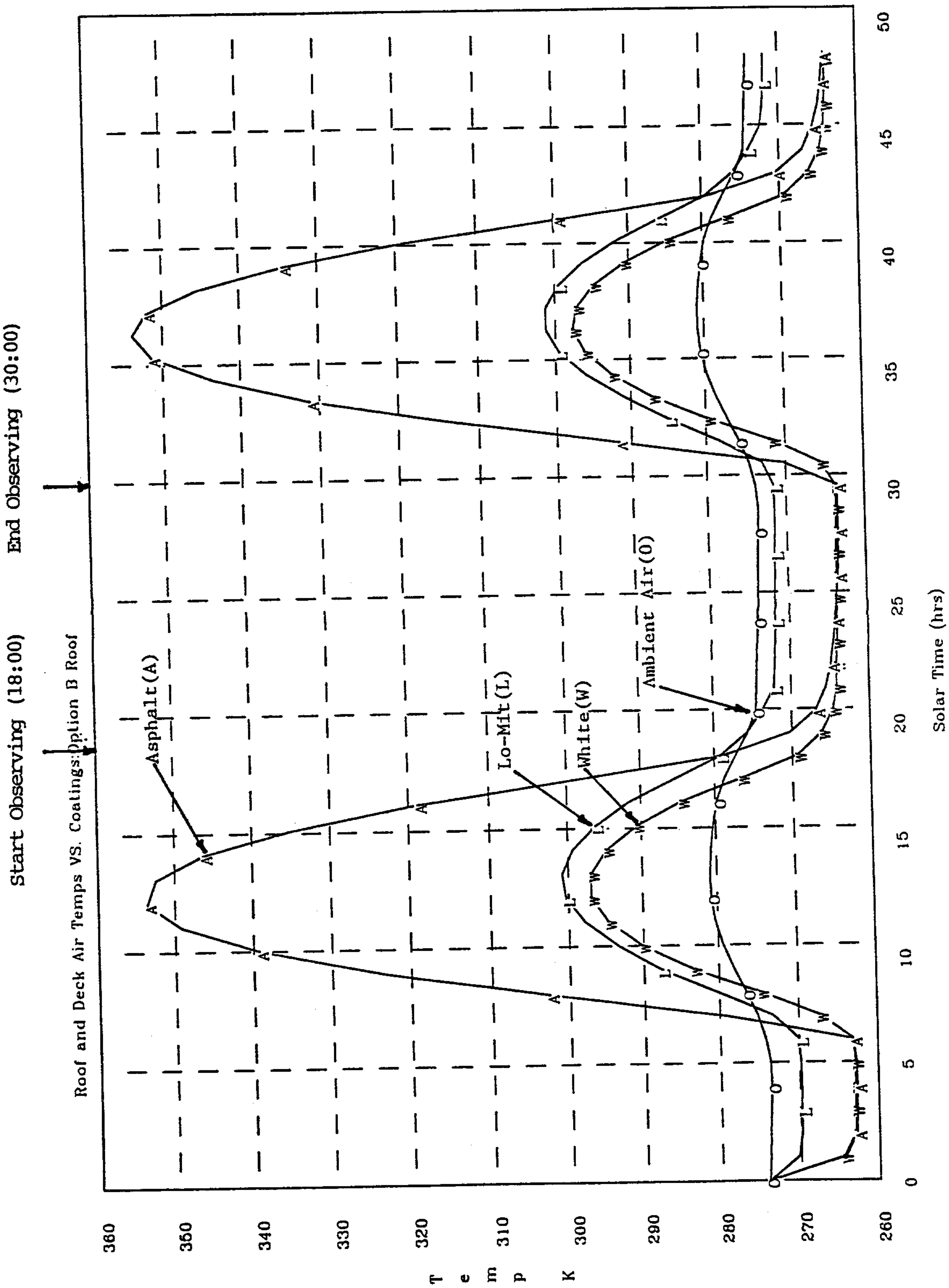


Figure 11. Single Deck Roof Surface Temperatures

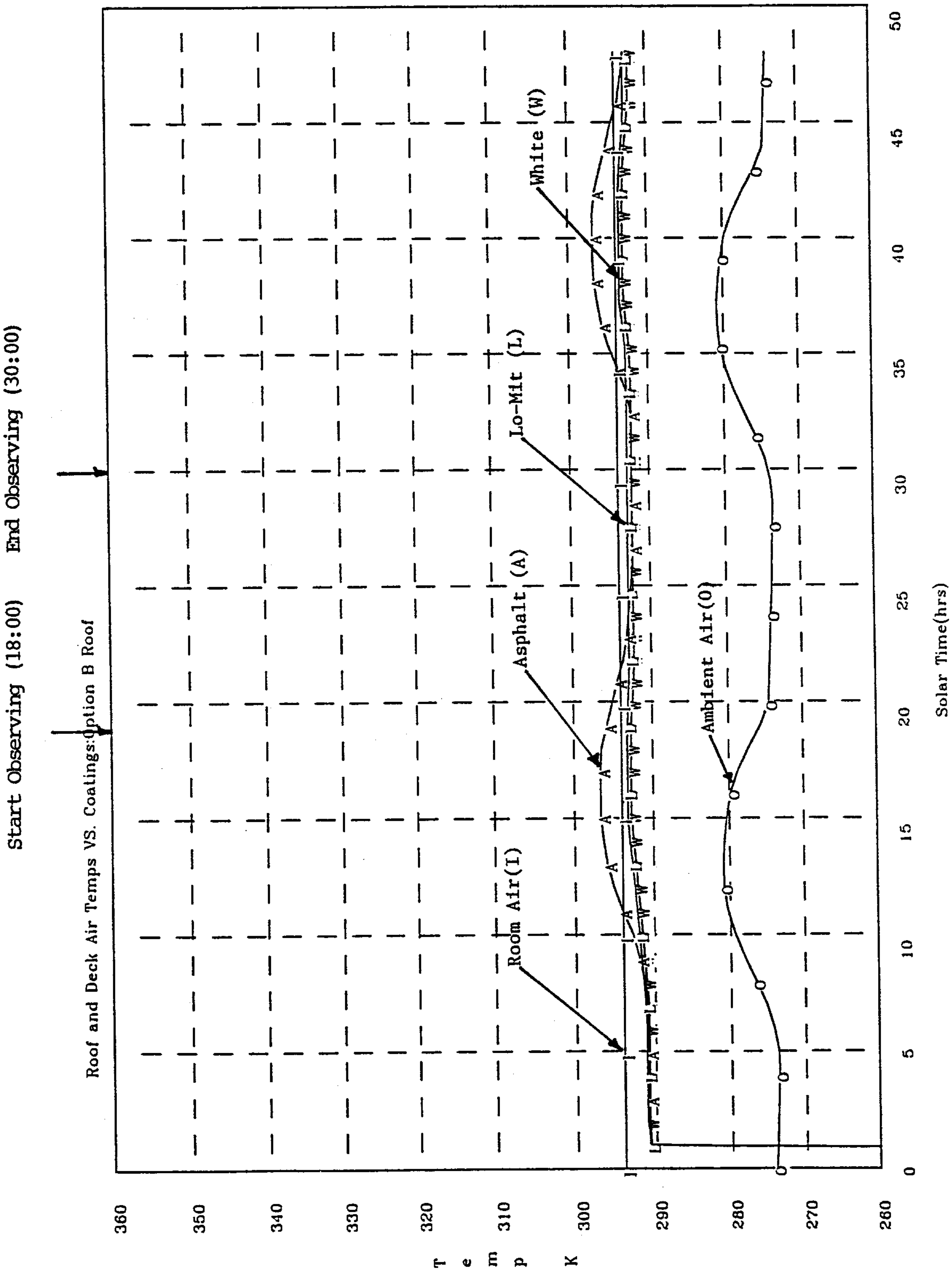


Figure 12. Single Deck Roof Air Cell Temperatures