NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

December 16, 1999

SYSTEMS GROUP CHAIRMAN FACTUAL REPORT ADDENDUM FOR BOEING/AIR FORCE CENTER WING TANK FUEL HEATING STUDY

A. ACCIDENT: DCA96MA070

Location : East Moriches, New York

Date : July 17, 1996

Time : 2031 Eastern Daylight Time

Airplane : Boeing 747-131, N93119
Operated as Trans World Airlines (TWA) Flight 800

B. SYSTEMS GROUP

Chairman : Robert L. Swaim
National Transportation Safety Board
Washington, D.C.

C. SUMMARY

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). All 230 people aboard were killed. The airplane was being operated as a 14 Code of Federal Regulations (CFR) Part 121 flight to Charles De Gaulle International Airport (CDG) at Paris, France, as Trans World Airlines (TWA) flight 800. Wreckage from the airplane was recovered from more than nine square miles of ocean. Reconstruction of portions of the wreckage found evidence of an explosion in the center wing fuel tank (CWT).

The Air Force Safety Center, Directorate of Engineering and Technical Services, informed the Safety Board in March 1999 of the existence of a 1980 Boeing study about Air Force E-4B[1] fuel tank heating. The Safety Center provided the Safety Board with pages from the

[1] The E-4B is a military variant of the commercial 747 and has the CWT volume of the 747-200 (and subsequent) airplanes. The E-4B CWT volume shown in the study is 110,812 pounds, which is about 17,000 gallons (at 6.51 pounds per gallon). The September 1990 TWA 747 Systems Handbook shows that the CWT volume for the 747-

first volume of the study on April 30, 1999. The Air Force E-4B/C-18/T-43 Engineering Branch provided the Safety Board with a copy of the complete study on June 29, 1999. The four volume study was titled "CENTER WING TANK FUEL HEATING STUDY" (Document No. D226-20582-1, -2, -3, -4) and had a release date of March 14, 1980.

The complete study was almost 900 pages in length and most of volumes two through four were tabular listings of numerical data that the 64 page first volume summarized in text and charts. The first volume contained sections for an Abstract, Introduction, Analysis, Design Modification Study Results, Conclusions, and References. The fourth volume also contained copies of notes that had been taken during the tests.

This addendum to the Group Chairman Factual Report includes the 64 pages of volume one and examples of the notes found in volume four.

Robert L. Swaim
TWA 800 Systems Group Chairman
JP 12/17/99

100 CWT is 12,890 gallons. The additional fuel volume is contained in an area that was a dry bay in the 747-100, located between the spanwise beam 3 and the forward spar. The E-4B CWT temperature probe is located near the center of the rear wing spar.

DEPARTMENT OF THE AIR FORCE
Oklahoma City Air Logistics Center
Tinker Air Force Base Oklahoma

MEMORANDUM FOR NATIONAL TRANSPORTATION SAFETY BOARD
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1. The E-4B program office has no objection to the National Transportation Safety Board request to place the following document into a Public Docket that pertains to the July 17, 1996, accident involving TWA Flight 800:

2. Center Wing Tank Fuel Heating Study, Document No. D226-20582-1, -2, -3, -4, prepared under Air Force Contract No. 159628-74-C-0127, marked ORIGINAL RELEASE DATE 3-14-80.

3. Should there be any questions concerning the above, please contact Hal Nolan, Tom Parsons, or the undersigned at (405) 736-5023.

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E-4B/C-18/T-43 Engineering Branch
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PREPARED UNDER
- [x] CONTRACT NO. F19628-74-C-0127
- [ ] IR&D
- [ ] OTHER

DOCUMENT NO. D226-20582-1 (Vol. I) MODEL E-4B

TITLE CENTER WING TANK FUEL HEATING STUDY
(VOLUME I OF IV)

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ABSTRACT

The requirement that the E-4B be capable of world wide remote deployment to support the NEACP mission leads to a requirement for understanding fuel temperature as a function of the environment during ground operation over a 48-hour period. This document presents the results of a study to define the resultant fuel temperatures under the extremes of the mission requirement. Operational constraints are defined in terms of fuel load limitations for the aircraft. Recommendations to reduce the severity of the operational limitations include hot weather testing to reduce analysis conservatism and insulation of the center wing tank base to reduce the effect of pack bay heating.

KEY WORDS

Thermal Analysis

Command Post

Fuel Heating Study

Center Wing Fuel Tank

Ground Operation

Remote Deployment

Self-Contained Operation

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1.0 Introduction

The requirement that the E-4B aircraft be capable of self-sustained ground operation for a 48-hour period represents a severe constraint not placed on the original aircraft design.

Under environmental extremes (the 125^{o}F MIL-STD-210A hot day) with average air temperatures of 103^{o}F and a high solar load on the wing, wing tank fuel temperatures could be expected to reach 112^{o}F. With the Liquid Cooling System and one SHF operating, temperatures in excess of 120^{o}F were predicted.

As the Functional Area Specification allowed use of ground water for LCS heat rejection under environmental extremes, the CDR presentation (Nov 1976) showed acceptable performance for the wing tanks and insufficient justification for recertification of the allowable fuel temperatures to higher values for JP-4.

Subsequent concerns related to center wing tank fuel temperatures which were impacted by the addition of the 4th air cycle machine in the air conditioning equipment bay in the fairing directly under the fuel tank. These concerns led to the placement of a fuel temperature gage on the aircraft for the center wing tank.

DT and E testing, however, was conducted with minimum ground operation times and under moderate ambient temperature conditions. Under these conditions no problems were experienced.

The question of the existence of a potential problem remained due to reports of JAL commercial aircraft operating out of Hawaii experiencing loss of CWT fuel feed during the ascent to altitude.

IOT and E environmental testing at Howard Air Force Base (January 1979) demonstrated fuel temperatures in all tanks in excess of the 110^{o}F allowable JP-4 fuel limit. These temperatures also appeared in excess of the expected fuel temperatures for the reported conditions. This, however, was confused by fuel temperature gauge inaccuracies estimated to be on the order of 12^{o}F.

At Air Force direction Boeing initiated TCP-92 (and subsequently TCP-102) to provide a detailed analysis of the CWT fuel heating problem. The technical work statement for TCP-92 follows:

11.9.1 CENTER WING TANK FUEL OVERTEMPERATURE STUDY

11.9.1.1 General Requirements

Perform a study of the overheating of the fuel in the Center Wing Tank during a deployed 48 hour Ground Alert Operation under MIL-STD-210 Hot Day conditions.

The purpose of this study will be the identification of aircraft operational procedures and hardware modifications which will extend the duration of the aircraft ground alert deployment beyond its present limitations.

This study will also address potential Operational Procedures that may be applied to the E-4A Aircraft.

11.9.1.2 Task Objective

Perform a study of the overheating of the fuel in the center wing tank during a deployed 48 hour Ground Alert operation under MIL-STD-210 Hot Day environmental conditions. The objective of this study will be the identification of

a Aircraft Operational procedures and
b Hardware modifications

which will extend the duration of aircraft operation before a center wing tank fuel overheat condition occurs. In addition to identifying the procedures and modifications, the study will quantify the duration of time gained before overheating occurs.

11.9.1.3 Ground Rules

An analytical model of the center wing tank will be developed with sufficient detail to characterize thermal interactions with the pack bay, wheel well, and main wing adjacent fuel tanks.

The Ground Alert Operation Scenario will encompass the following elements:

a MIL-STD-210 Hot Day Profile with:
   1. 125^{O}F max air temperature
   2. 105^{O}F max air temperature
   3. 85^{O}F max air temperature

b Fuel supplied to the aircraft at 90^{O}F under all conditions

11.9.1.3 Ground Rules (Continued)

c Water supplied to the aircraft at average air temperature when considered

d Fuel loading

(1) Aircraft lands with minimum fuel reserves
(2) All wing tanks filled to capacity
(3) Center wing tank filled with:

(a) 10,000 lb
(b) 55,000 lb
(c) 110,000 lb

(4) Ground Alert operation uses fuel from tank #2
(5) When tank #2 drops to 5000 lb below tank #3, fuel is transferred from CWT to top off tank #2.
(6) Every 24 hours the CWT is refueled to initial fuel loading.

e Electrical Loads

(1) SHF on continuously with minimum rf transmitted power level
(2) VLF off

f The use of alternative fuels to JP-4 is not to be studied.

g Preference is to be given to procedures and alternatives which do not use ground water, but the use of ground water is not to be ruled out.

h Main Wing Tanks (#1 through #4) are not to be studied other than as required to provide a boundary condition on the Center Wing Tank.

11.9.1.4 Study Concepts

Options which will be considered are to include:

a Insulation of the fuel tank base

b Insulation of high temperature pneumatic ducts within the pack bay

c Baffling in the pack bay to provide an interface air layer between the pack components and the fuel tank. The "cool" air layer could be provided by:

(1) Forward Lobe System Draw Air Exhaust
(2) Blowers installed in the pack bay
(3) Directed discharge from the packs

d Installation of blowers in the pack bay wing box to increase air circulation in the pack bay

e New fuel pumps for the center wing tank coupled with recertification of the aircraft to a take-off temperature limit greater than the current 110°F.

f Operation of the forward lobe draw system blowers at high speed to provide a greater cool air flow to sweep through the pack bay.

g Operation of the aircraft with the pack bay doors open to increase air circulation in the pack bay.

As these ground rules were established before the study, they were intended as guidelines. Some modification of the guidelines has resulted as the study progressed. Additionally a second deployment to Panama (December 1979) has resulted in test data (TCP-102) which has been used in this study to validate the thermal model.

The initial look at new fuel pumps coupled with recertification to higher fuel temperatures indicated that the existing boost pumps were capable of recertification to higher fuel temperatures (130°F). This effort was broken out of this study and has been worked as WR-071.

The results of the study conducted under TCP's -92 and -102 are presented in the following sections in an abbreviated format. Extensive appendices (contained in Volumes 2 through 4) document the details of the thermal model, the deployment to Panama, and a summary of the pertinent computer data.

2.0 Analysis

The 747 Aircraft wing envelopes 5 large fuel tanks. The outboard mains are contained within the visible wing essentially between the inboard and outboard engines. The inboard mains essentially span the wing between the wing/fuselage intercept and the inboard engines. The center wing tank lies within the common boundary of the wing and the fuselage. The fuel tank capacities are as follows:

outboard mains	27,859 lbs. (each)
inboard mains	80,171 lbs. (each)
center wing tank	110,812 lbs.

The center wing tank is bounded; across the front spar by the forward lobe, on the upper surface by the main deck floor support structure, across the rear spar by the wheel well, on the lower skin by the air conditioning equipment bay, and on the sides by the bulkhead between the center tank and the inboard wing mains.

Figure 2.1 illustrates the general location of the center wing tank and addresses sources of heating for the fuel. The front spar and upper surface of the tank are exposed to the air conditioned aircraft cabin. The rear spar is exposed to the wheel well which is open to ambient air under the aircraft. The major head load appears to be due to the high temperature in the air conditioning equipment by acting over the base of the tank. The final heat transfer path considered is that between fuel tanks, both by conduction transfer along the spars and by convection currents at the intertank bulkheads. In the analysis to be subsequently discussed, the center wing tank (CWT) was warmer than the wing mains, thus the wing tanks served to provide a cooling path for the CWT. Note, however, the cooler the wing tank fuel, the more effective will be this mode of cooling.

Heat transfer interactions for the wing tanks involve all heat transfer mechanisms:

a) convection interactions with the ambient environment (air temperature) and with the CWT fuel.

b) conduction interaction with the CWT fuel through the wing spars and skin structure.

c) radiation interaction with the sun (heating), the sky (cooling) and the concrete runway.

d) internal heating due to fuel pump operation, hydraulic heat exchanger operation and liquid cooling system operation.

2.0 Analysis (Continued)

The purpose of the analysis conducted under TCP-92 is the modeling of the CWT and its interactions with its environment for the purpose of fuel temperature prediction under all combinations of operating modes and ambient environments.

The analysis will be presented in sections as follows:

a) Development of the thermal model

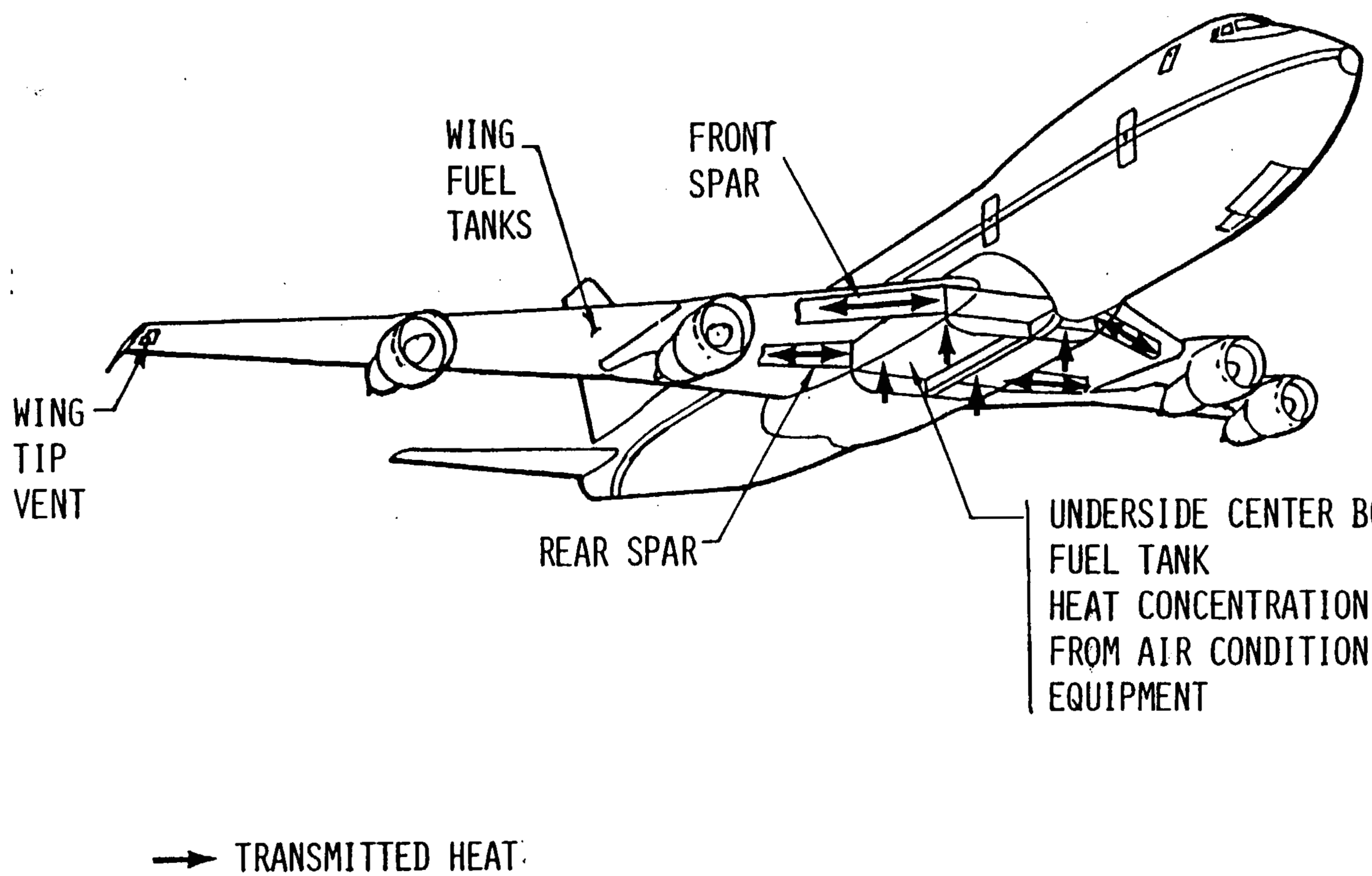
b) Verification of the thermal model through the use of the Panama Deployment Test data

c) Boundary conditions used with the model for prediction purposes, and

d) The summarized results of the analyses.

FIGURE 2.1

E-4 FUEL TANK SURFACES AFFECTED BY HEAT



2.1 Thermal Model Development

Figures 2.2 and 2.3 illustrate the complexity of structural detail associated with the center wing section fuel tank. In order to reduce the complexity of the thermal model and yet retain all significant heat transfer modes, the rear right hand quadrant of the tank (as shown in Figure 2.4) has been remodeled.

Pentinent elements of the model include:

144 structural nodes
5 boundary nodes
3 fuel nodes

1005 conductive/convective elements
2 radiative elements
3 sources

Appendix A (Volume II) contains a detailed account of the formulation of the model. Included in that appendix are:

a) extensive references to the drawings

b) detailed breakdowns of the nodal areas

c) weight distributions and capacitance calculations

d) detailed breakdowns of the conductor network

e) conductor calculations

f) coding for the model and

g) coding for the variable fuel load subroutine.

Boundary conditions are handled as follows:

a) forward lobe and main deck cabin are taken as a fixed temperature with convection interaction with the tank structure

b) wheel well temperature is taken as a variable (from a table which follows the ambient air temperature profile) and is convectively coupled to the rear spar

c) pack bay temperature is taken as a variable (from a table which follows the ambient air temperature profile) and is convectively coupled to the tank lower skin

2.1 Thermal Model Development (Continued)

d) air temperature is input as a table driven variable which follows the MIL-STD-210A profile and is convectively coupled to the upper and lower wing surface.

e) ground temperature is input as a table driven variable which follows the same profile as the MIL-STD-210A air temperature profile and is radiatively coupled to the wing lower surface

f) solar flux is input as a table driven variable which also follows the air temperature profile but is offset in time so as to lead the air temperature profile. Solar load is input to the wing upper surface as a source term.

g) sky temperature is taken as a fixed temperature with a radiation interaction with the upper wing surface.

The values assigned to boundary conditions will be presented in a subsequent section. Once the model was completed, the upcoming deployment to Panama provided an opportunity for additional experimental work in order to guide validation of the thermal model.

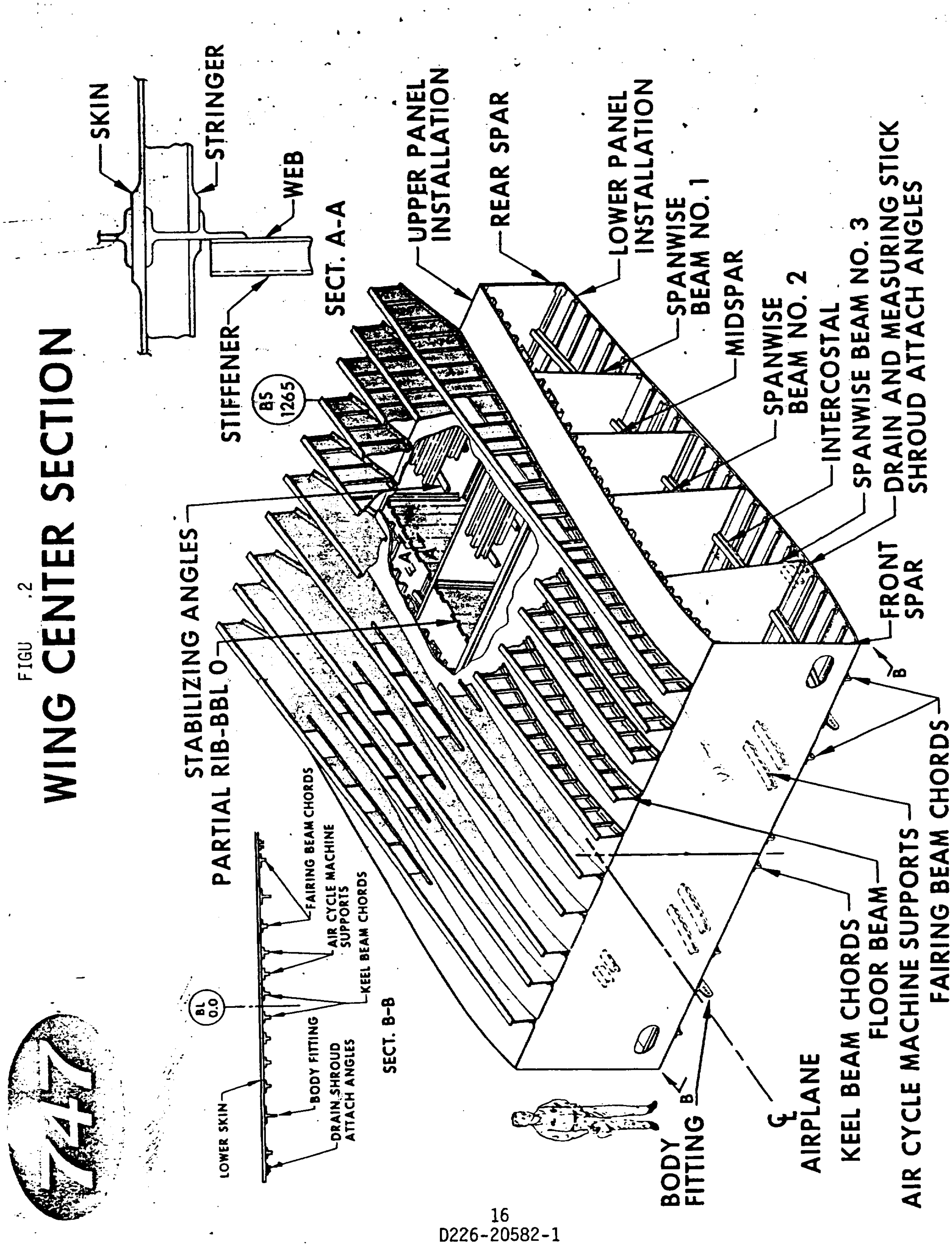
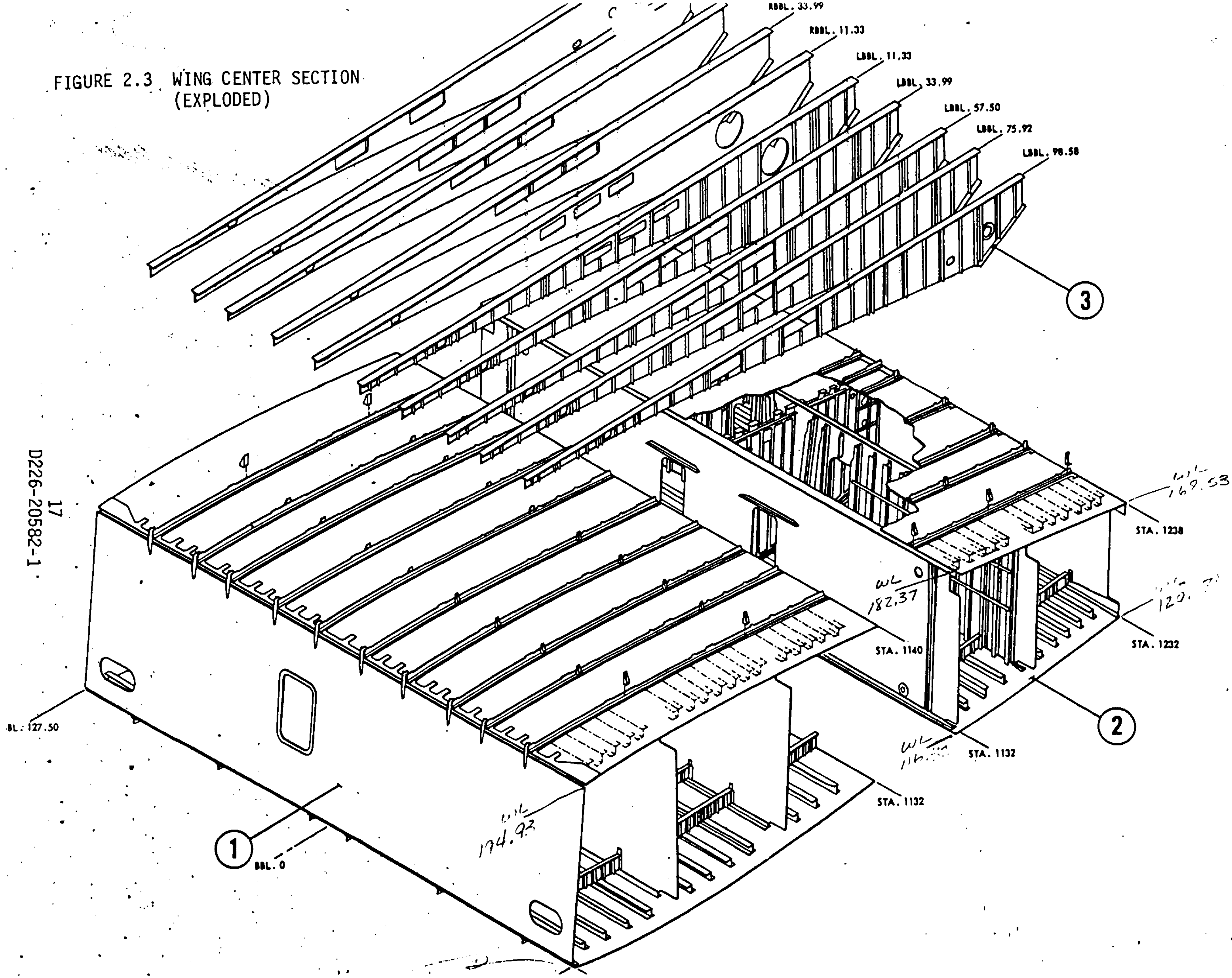
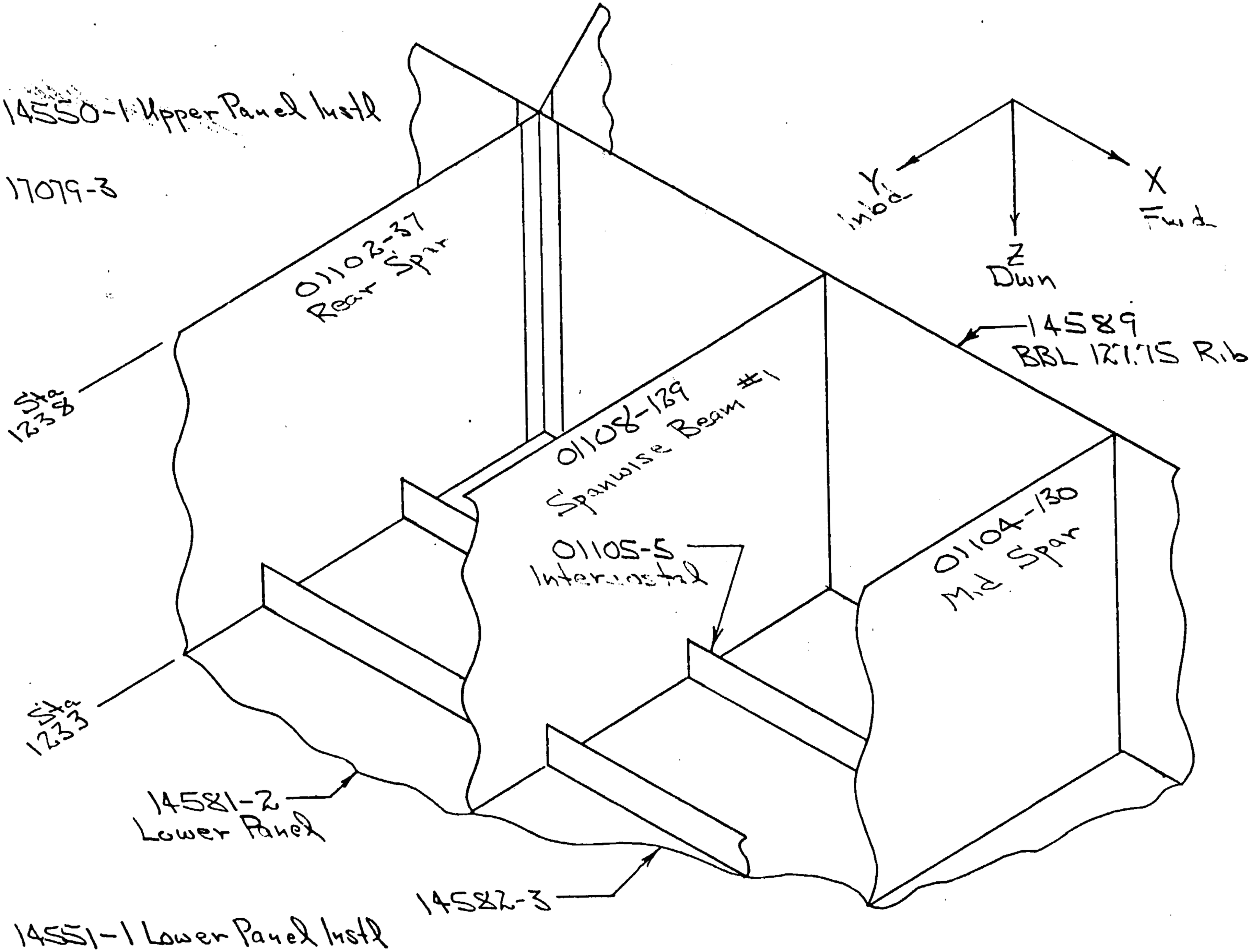

FIGU .2
WING CENTER SECTION
747
SKIN
STRINGER
WEB
STIFFENER
SECT. A-A
UPPER PANEL INSTALLATION
REAR SPAR
LOWER PANEL INSTALLATION
SPANWISE BEAM NO. 1
MIDSPAR
SPANWISE BEAM NO. 2
INTERCOSTAL
SPANWISE BEAM NO. 3
DRAIN AND MEASURING STICK SHROUD ATTACH ANGLES
FRONT SPAR
BS 1265
STABILIZING ANGLES
PARTIAL RIB-BBL 0
FAIRING BEAM CHORDS
AIR CYCLE MACHINE SUPPORTS
KEEL BEAM CHORDS
BL 0.0
BODY FITTING
DRAIN SHROUD ATTACH ANGLES
LOWER SKIN
SECT. B-B
FAIRING BEAM CHORDS
AIR CYCLE MACHINE SUPPORTS
FLOOR BEAM
KEEL BEAM CHORDS
℄ AIRPLANE
BODY FITTING
B
A

FIGURE 2.3 WING CENTER SECTION
(EXPLODED)



JB 9/26

FIGURE 2.4 WING CENTER SECTION (MODELED)



2.2 Model Verification

The data sheets and logs recorded during the deployment to Panama are incorporated into the report as Appendix C (Volume IV).

The significant findings or events relative to thermal modeling and verification of the thermal model are itemized as below.

Measurements were made under the fuselage and wing of the aircraft below the center wing tank and the inboard mains. The air temperature under the wing tanks was 24°F above the ambient air temperature. Similarly, the air temperature under the air conditioning equipment bay was 32°F above the ambient air temperature. This increase is due to the pack heat exchanger discharge heat being exhausted in this area and forming a trapped pocket of hot air under the center section of the aircraft.

Measurements were made in the pack bay below the base of the center wing tank. A strong gradient was observed in the pack bay and temperatures well above the expected were recorded.

The model was subsequently revised to reflect

a) the above temperature increases in boundary conditions and

b) the sequence of events and environmental conditions experienced in the Panama deployment.

Figures 2.5 and 2.6 depict the comparison between the test data and the analysis over the 70 hour history of the Panama test.

Figure 2.5 evaluates the CWT fuel temperature. Agreement is generally good. The following comments seem appropriate:

a) At the 12 hour mark a sudden torrential rain (0.67 inches) caused measured temperatures to fall below predicted values. No effort has been made in the model to account for energy removal by evaporation of that water.

b) Refueling occurred at the 24 hour mark.

c) Refueling occurred at the 42 hour mark.

d) A fuel transfer occurred at the 59 hour mark as the wing tank fuel had heated sufficiently to cause an overfilled condition to exist. When fuel began to spill from the wings, fuel was transferred into the center wing tank.

e) At the 63 hour mark a second torrential rain (0.94 inches) again caused measured temperatures to fall below the predicted value. Notice the similarity to test/analysis deviation at the 12 hour mark.

2.2 Model Verification (Continued)

Figure 2.6 evaluates the inboard tank fuel temperatures. Again agreement is generally good. The following comments seem appropriate:

a) Sunrise at the 5, 29, and 53 hour points are marked on the plots. Similarly sunset at the 17, 41, and 65 hour points are noted. On the wing tanks these should be significant events, however, the cloud cover associated with the rainfall events has diminished the effect of the solar load variation.

b) After both rainfall periods the test data shows an offset from the analysis due to the energy required to reevaporate water.

c) Refueling (conducted into the CWT) had an indetectable impact on the inboard wing tanks.

d) At the 42 hour mark when the LCS heat load was switched into the fuel tanks, a dramatic impact occurred. The dashed line illustrates the expected rise for LCS heat load into the fuel. Poor agreement would have resulted with the test data. The solid line shown was generated by doubling the LCS load into the fuel tanks. The test data has been checked to verify that the LCS load was distributed between all four wing tanks.

The only change in operating characteristics to occur at this point was addition of LCS heat into the fuel. Remembering that the fuel temperature probe reports fuel temperature at a specific point in the tank and the analysis shows bulk fuel temperature, one might deduce that with the LCS operating a different circulation pattern exists within the fuel tank. This results in a higher than average temperature at the probe location.

In an effort to show agreement between analysis and test, the model has been revised to show a doubled LCS load into the fuel. As this is the only measurement the flight engineer has, this can be assumed representative of what the flight engineer will see in service.

In conclusion, the model can be shown to agree with test data once:

a) pack bay temperatures were increased to measured values

b) local air temperatures are increased to measured values, and

c) LCS heat loads are increased to reflect the measurement point - rather than the fuel average temperature.

The necessary boundary conditions used in the analysis are discussed in the following section.

FIGURE 2.5-1 CWT FUEL TEMPERATURE (PANAMA - DECEMBER 1979)

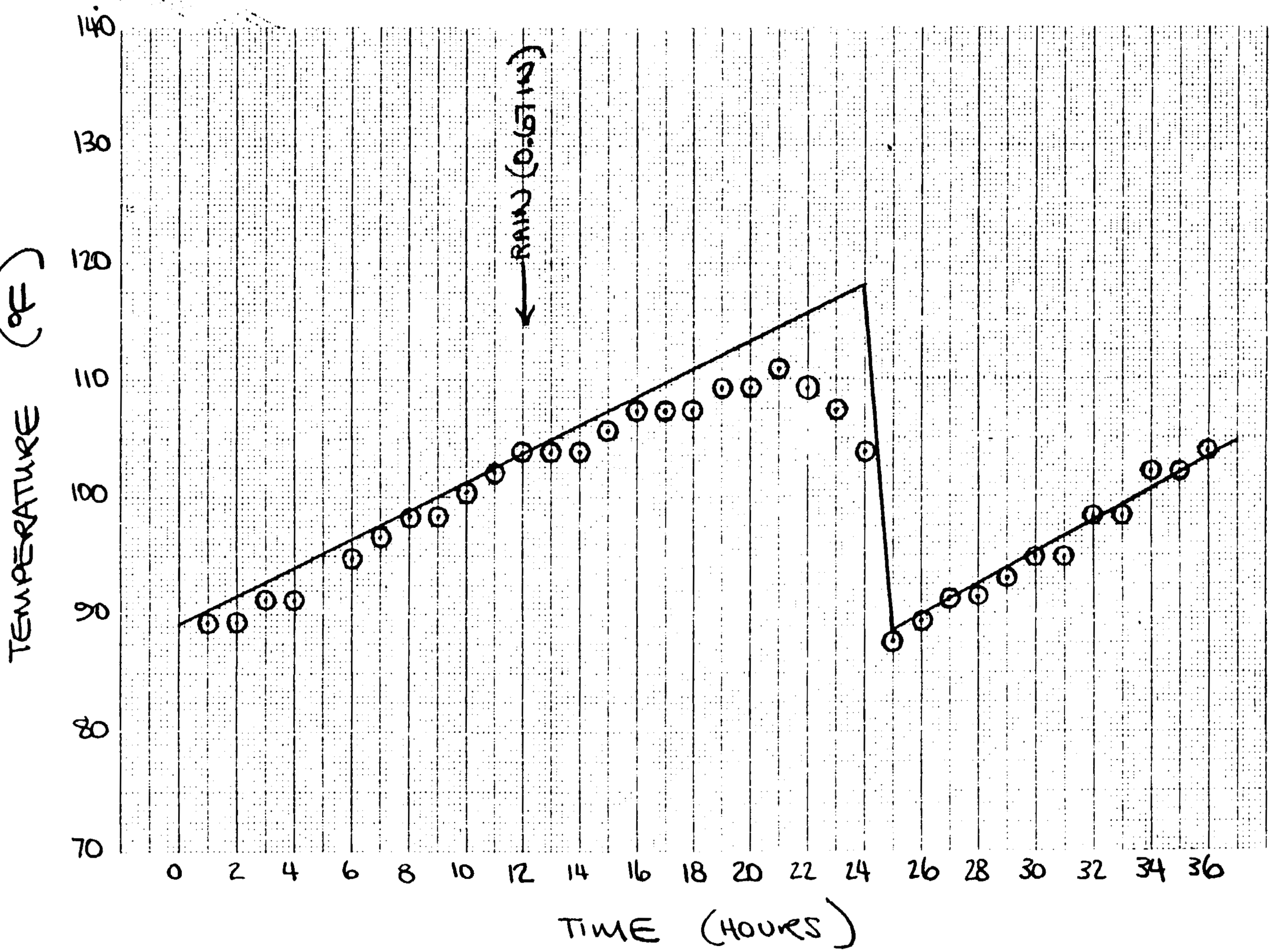


FIGURE 2.5-2

CWT AT PANAMA (DEC 1979)

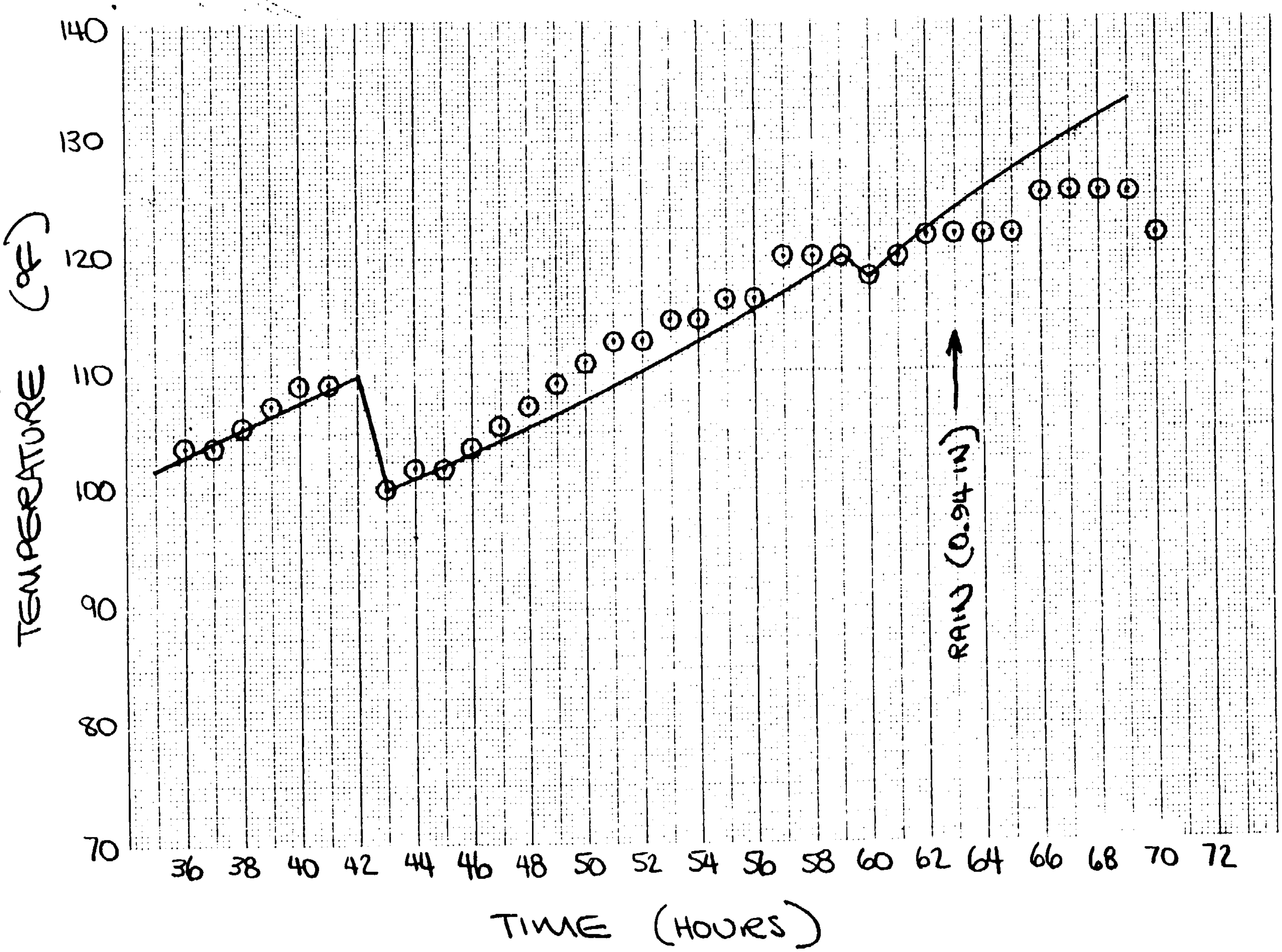


FIGURE 2.6-1 INBOARD MAIN TANK FUEL TEMPERATURE (PANAMA - DECEMBER 1979)

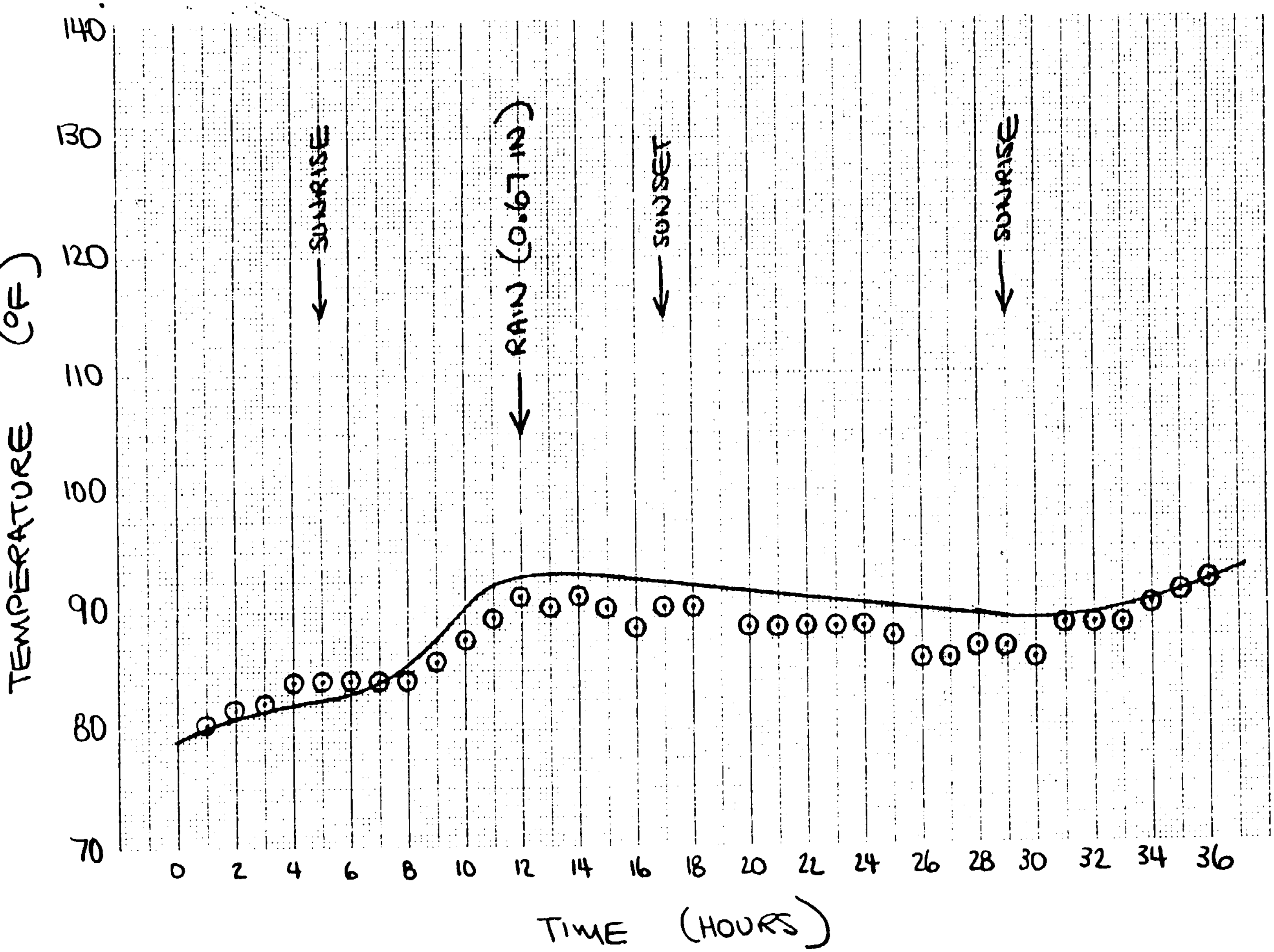
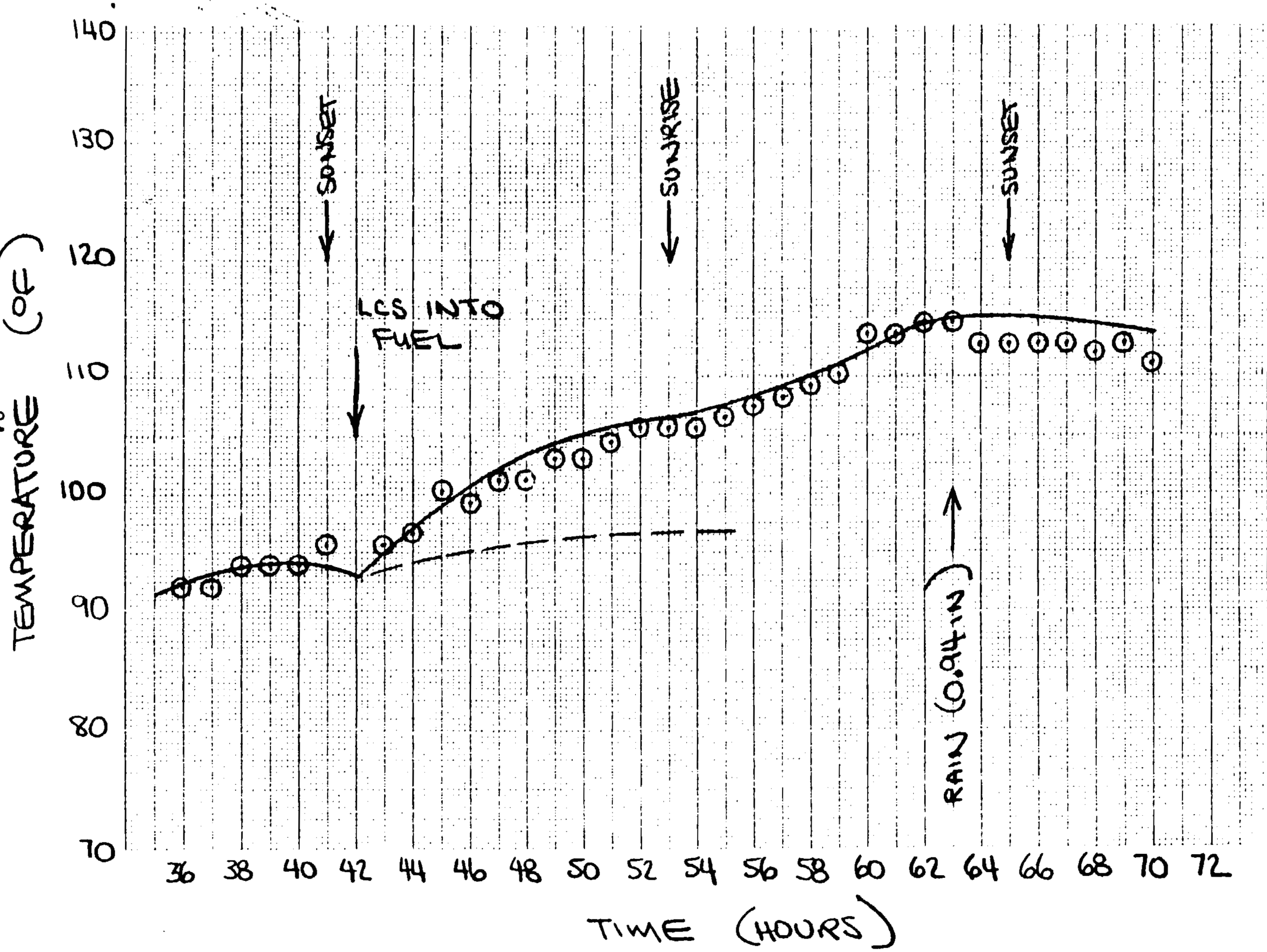


FIGURE . .o-2

TANK (2/3) AT PANAMA (DEC 1979)



2.3 Boundary Conditions

Where possible boundary conditions have been taken from either MIL-STD-210A or from the statement of work groundrules for TCP-92.

Air Temperature

The air temperature profile shown in Figure 2.7 is taken from MIL-STD-210A for the hot (125^{o}F) day. This profile was used for all days. For every 10^{o}F the peak temperature was reduced, the minimum temperature was reduced by 5^{o}F. Once the ambient air temperature was fixed, it was increased by 12^{o}F around the wing to accommodate local heating from the air cycle machine discharge.

Surface Temperature

The ground temperature profile shiwn in Figure 2.7 is modeled to follow the air temperature profile. The maximum and minimum temperature values were scaled from a Minuteman study, conducted in Yuma, Arizona, relative to air temperature. Again, for every 10^{o}F in peak temperature reduction, a 5^{o}F decrease was taken in the minimum. The temperature decrease in ground (concrete surface) temperature linearly follows the decrease in air temperature. That is, if the peak air temperature decreases 10^{o}F, the peak ground temperature also decreases 10^{o}F.

Sky Temperature

An effective sky temperature of 10^{o}F was assumed for the 85-125^{o}F range of peak day temperatures. An effective sky temperature of 45^{o}F was assumed in the humid environment cases (Panama test simulation).

These sky temperatures were taken to be consistent with the air conditioning design analysis presented in G7101.06.26.

Pack Bay Temperature

Based on the measurements taken at Panama and an examination of the impact of pack bay temperature on the CWT fuel temperature, the pack bay temperature under the tank was taken as ambient air temperature + 95^{o}F.

Aircraft Compartment Temperature

The main deck cabin and forward lobe compartment air temperatures were assumed to be 85^{o}F and to remain constant throughout the 48 hour time period.

Solar Flux

The solar load profile is shown in Figure 2.7 as is the profile of the solar load reflected off the ground surface up onto the bottom of the wings.

2.3 Boundary Conditions (Continued)

Solar Flux (Continued)

The solar flux peak value of 105 watts/ft^2 is taken from MIL-STD-210A. For humid environments (Panama test correlation) a peak value of 90 watts/ft^2 was used (also taken from MIL-STD-210A).

The solar load profile was intended to lead the air and ground temperature profiles by two hours. However, a five hour lead worked into the analysis without being detected until late in the analysis phase. A discussion of the small error induced is contained in paragraph 2.4.3 (Parametric Studies).

Solar Absorptivity

A solar absorptivity of 0.35 was assumed as typical of an aged white paint.

Solar Reflectivity

A solar reflectivity of 0.35 was taken as typical of reflection off concrete surfaces.

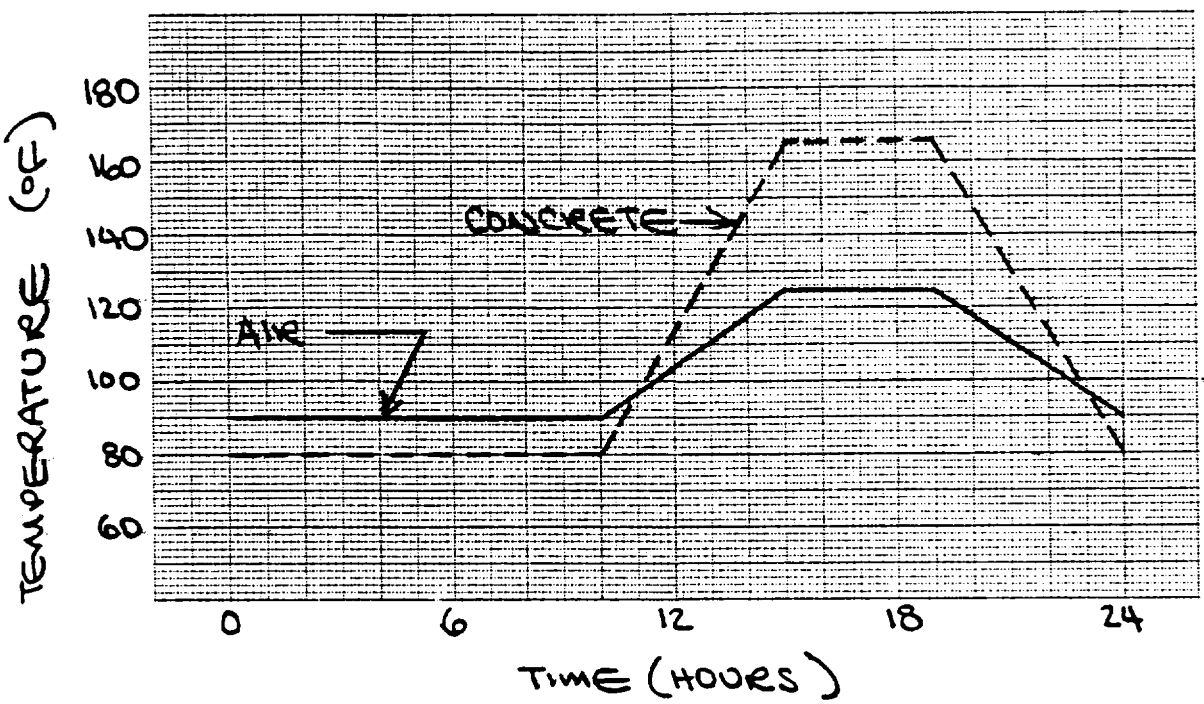
Fuel Load

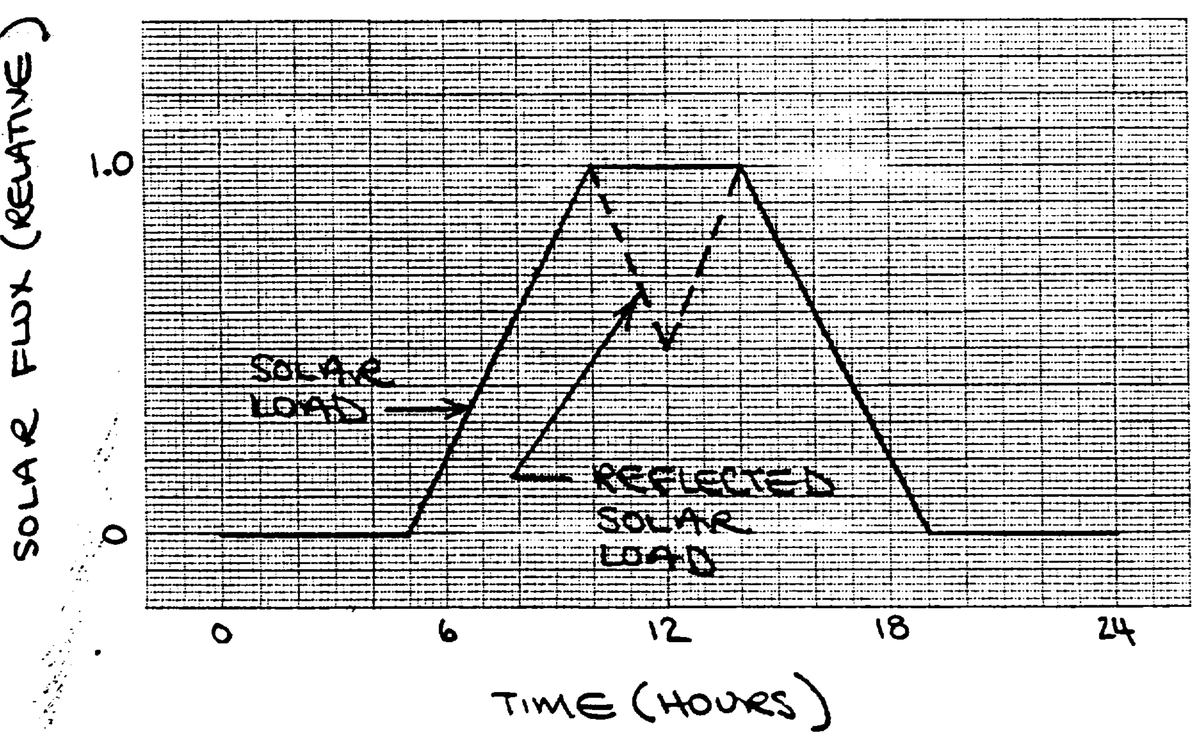
The fuel burn rate used was taken from the test data at Panama (January, 1979) and was 3500 pounds per hour. The wing tanks were assumed to remain full and the CWT had varying fuel weights under the ground rules of the study.

The initial fuel temperature was assumed to be onloaded at 90°F unless otherwise noted.

The impact of variation in these boundary conditions is discussed in paragraph 2.4.3 (Parametric Variation). The model, as described previously, after validation through the Panama test experience, and in conjunction with the just described boundary conditions was used to predict performance under widely ranging ambient conditions. Those performance predictions are described in the following paragraphs.

FIGURE 2.7 ENVIRONMENTAL BOUNDARY CONDITIONS





2.4 Analysis Results

The results of the analysis will be discussed in three sections:

a) Delivered Configuration
The analysis presented in this section pertains to the delivered aircraft configuration.

b) Insulated Configuration
The analysis presented in this section predicts performance for an aircraft with insulation added to the exterior base of the CWT.

c) Parametric Studies
Sometimes called sensitivity studies, the analysis presented in this section presents performance changes with changes in assumed boundary conditions.

Appendix B (Volume III) contains copies of three typical computer runs. Appendices D, E and F (Volume IV) contain a summary of a pertinent computer runs and selected fuel temperature reports.

2.4.1 Delivered Configuration

Considerable analysis has been conducted on the delivered configuration of the aircraft. The analysis has been directed toward the dual goal of understanding performance and developing operational techniques to prolong time on station under extreme environmental conditions.

Figure 2.8 depicts the maximum fuel temperature attained in the CWT and inboard main tanks for a range of ambient peak air temperature days. For example, on two successive 105°F days, the maximum fuel temperature in the CWT reached 140°F and the maximum temperature in the inboard wing mains reached 132.5°F.

From Figure 2.8 one may deduce that the CWT fuel temperatures exceed 130°F on all days with peak temperatures above 89°F. Similarly the inboard wing main fuel temperatures exceed 130°F on all days with peak temperatures above 101°F.

Note that the data of Figure 2.8 is for self-contained operation with the LCS heat dissipating into the wing fuel tanks.

Figures 2.8.1 through 2.8.3 illustrate fuel temperature performance with time over the 48 hour period for 85, 95 and 105°F peak ambient air temperature. The discontinuity in CWT fuel temperature at the 24 hour mark is the result of refueling with 90°F fuel.

Figure 2.8 serves notice that with ambients above 89°F some action must be taken to reduce the CWT fuel temperatures.

2.4.1 Delivered Configuration (Continued)

Two options appear immediately:

a) don't fuel the CWT, in which case self-sustained operation can be continued until peak air temperatures of 101°F are reached, or

b) divert the LCS heat from the fuel tanks into the ground heat exchanger.

Figure 2.9 depicts the maximum fuel temperature attained in the CWT and inboard main tanks for the same range of peak ambient air temperatures. The data shown is for operation with the LCS heat dissipated in the ground water heat exchanger.

The CWT may now operate over a range of peak ambients up to 105°F without exceeding the 130°F fuel limit. Of greater importance, however, is the impact on the inboard main tanks. The inboard wing mains will operate to the MIL-STD Hot Day requirement (125°F day) without fuel overheats.

Figures 2.9.1 through 2.9.3 illustrate fuel temperature performance with time over the 48 hour period for 105, 115 and 125°F peak ambient air temperature days.

Figure 2.9 serves notice that with ambients above 105°F some action must be taken to reduce the CWT fuel temperature.

Figures 2.10 and 2.11 show the reduction achieved in maximum fuel temperature when the initial fuel temperature is reduced. The less than 2°F reduction over a 48 hour period indicates that significant gains are not to be achieved with reasonable reductions in initial fuel temperature.

All preceding studies have been conducted with a 110,812 pound fuel load in the CWT. Smaller fuel loads could heat more rapidly.

A study was conducted to define the allowable fuel load envelope. Figure 2.12 illustrates the result of this study. Small fuel loads can be burned off before the fuel reaches 130°F. Large fuel loads have sufficient mass to delay heating to temperatures above 130°F. However, as shown in the Figure, a considerable envelope exists within which acceptable operation is not possible.

As a result of this restrictive operational envelope, a study of the effect of insulating the tank base was conducted.

FIGURE 2.8 MAXIMUM FUEL TEMPERATURE WITH AMBIENT ENVIRONMENT VARIATION

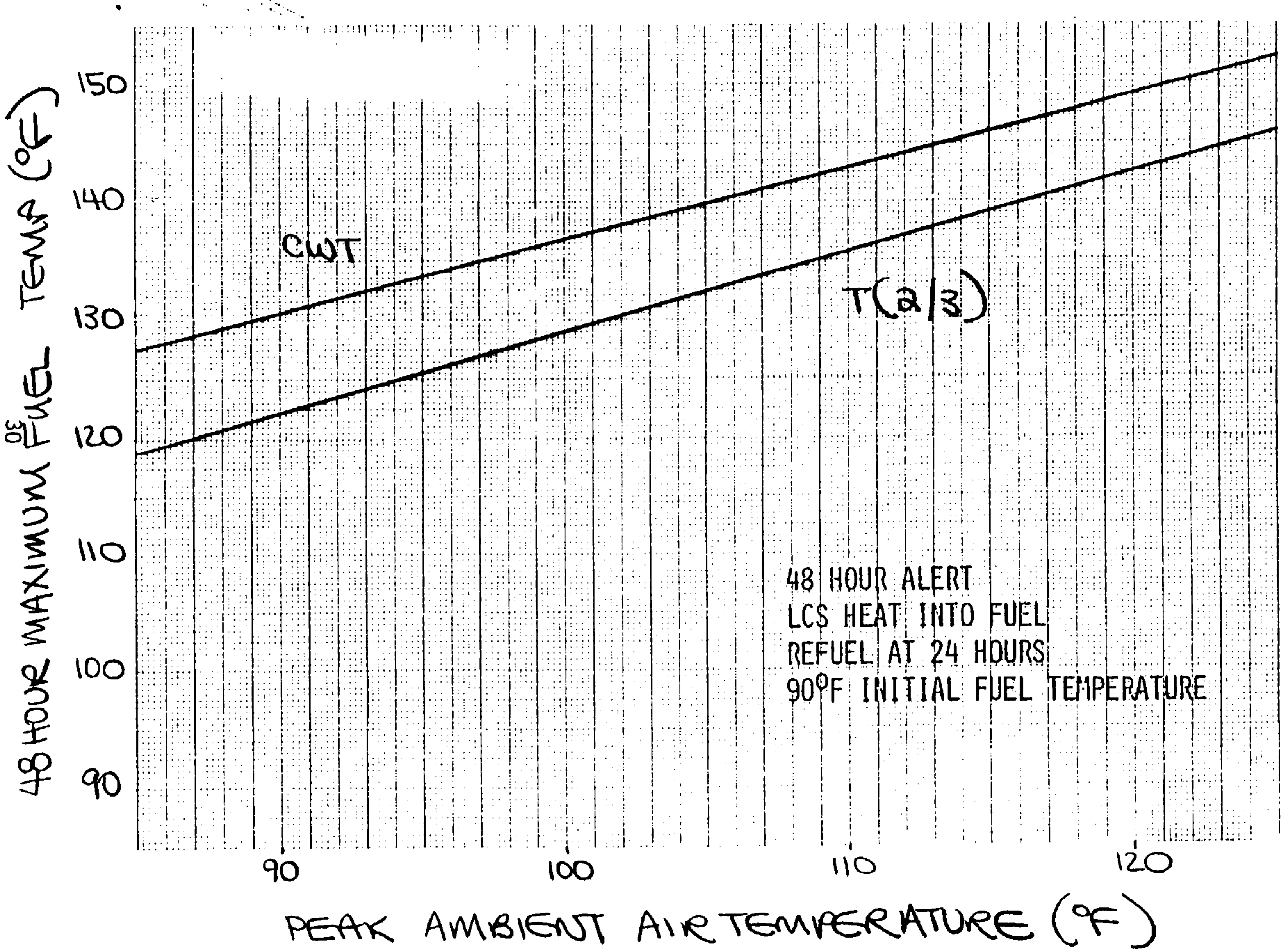


Figure 2.8.1

Fuel Temperature Variation with Time (85°F Peak Air Temperature)

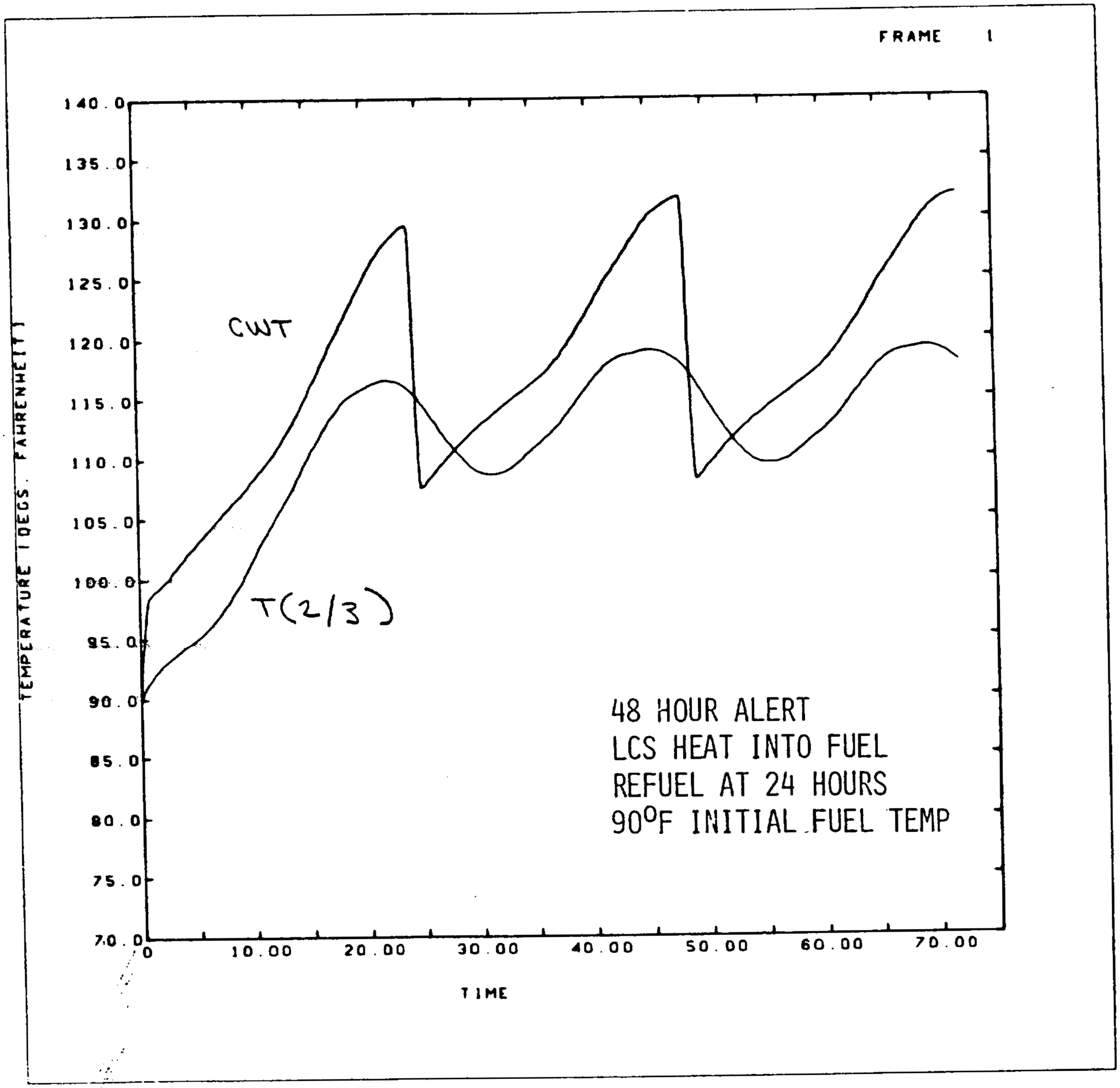


Figure 2.8.2

Fuel Temperature Variation with Time (95°F Peak Air Temperature)

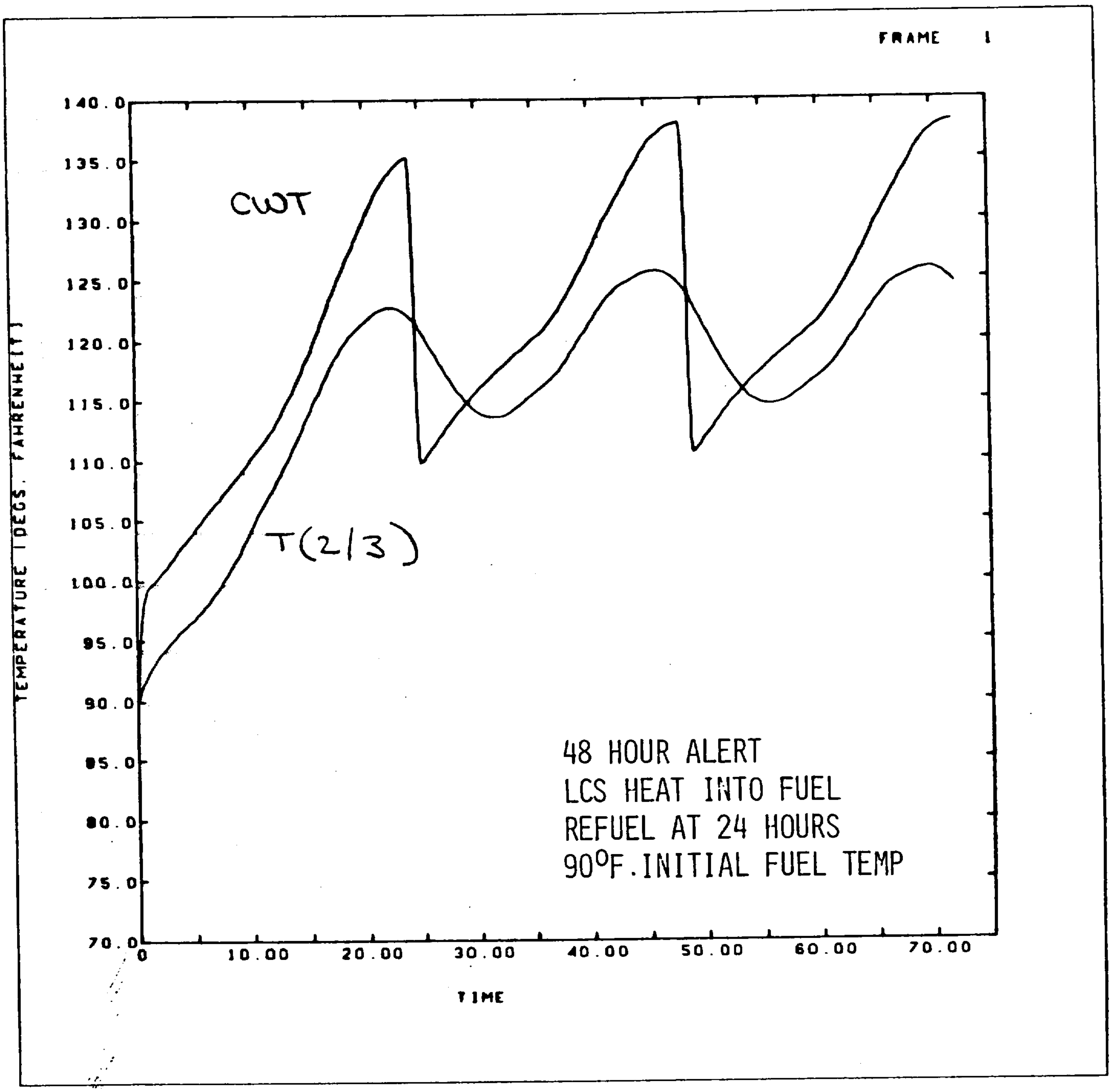


Figure 2.8.3

Fuel Temperature Variation with Time (105°F Peak Air Temperature)

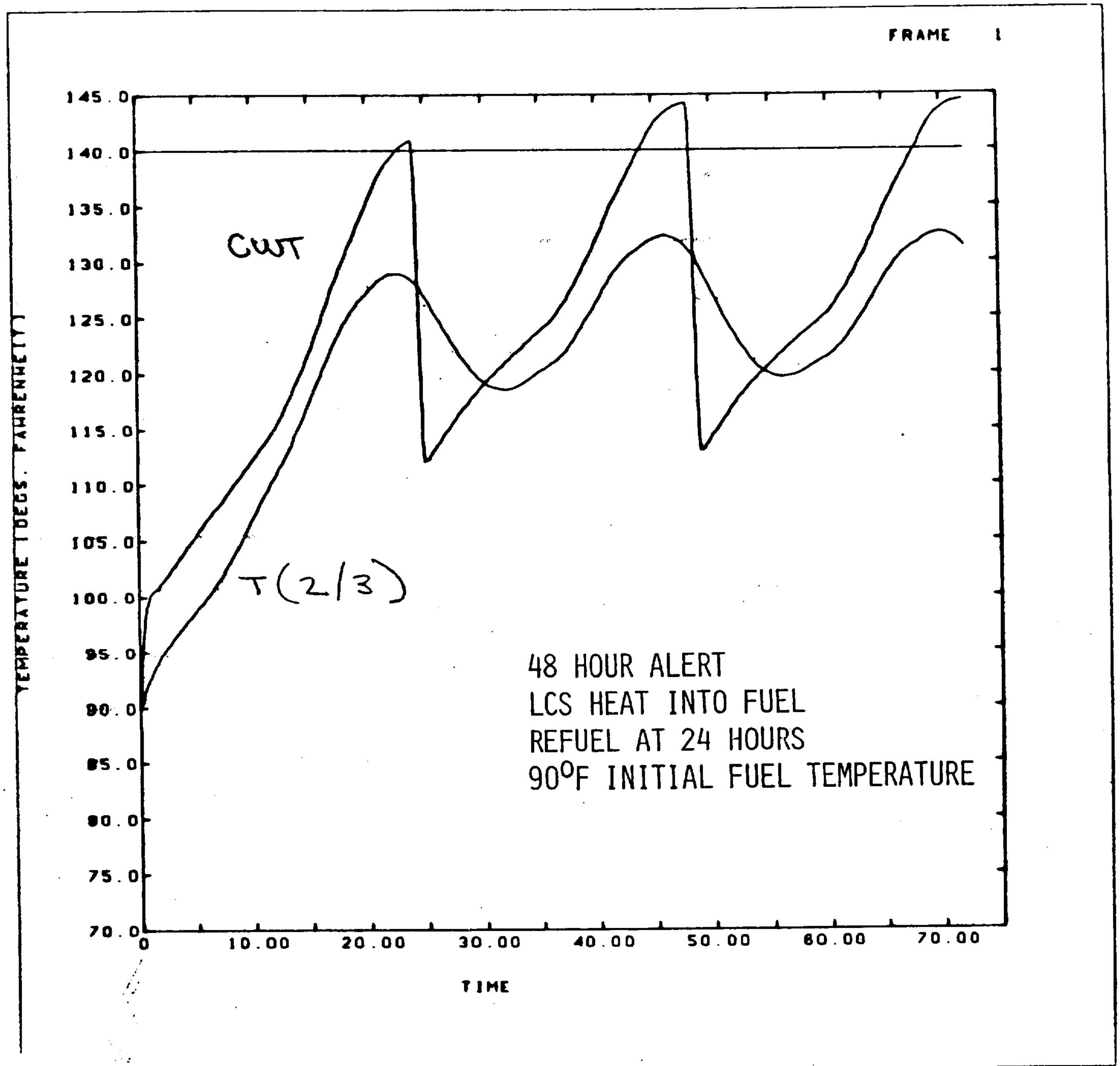


FIGURE 2.9 MAXIMUM FUEL TEMPERATURE WITH AMBIENT ENVIRONMENT VARIATION

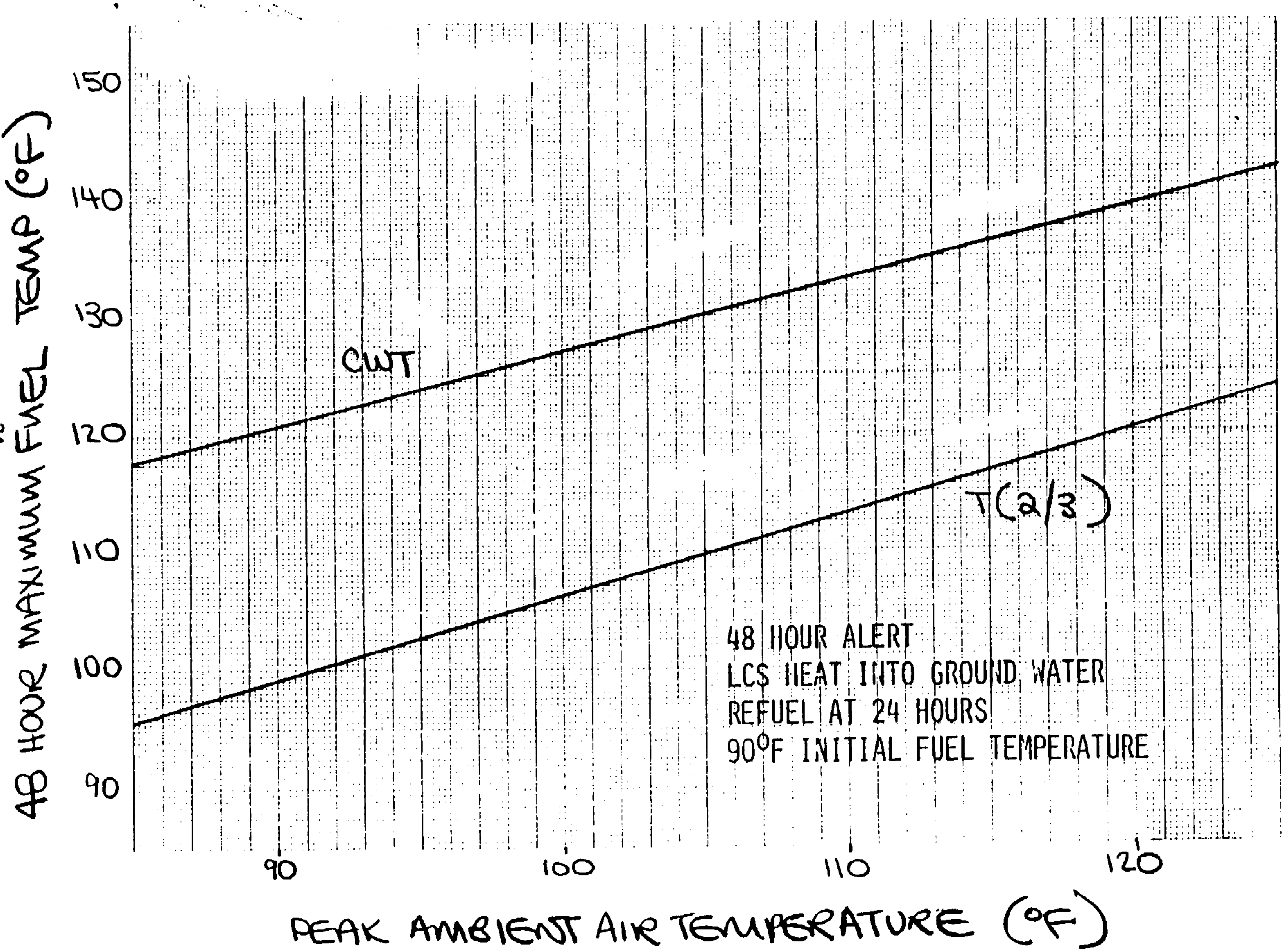


Figure 2.9.1

Fuel Temperature Variation with Time (105°F Peak Air Temperature)

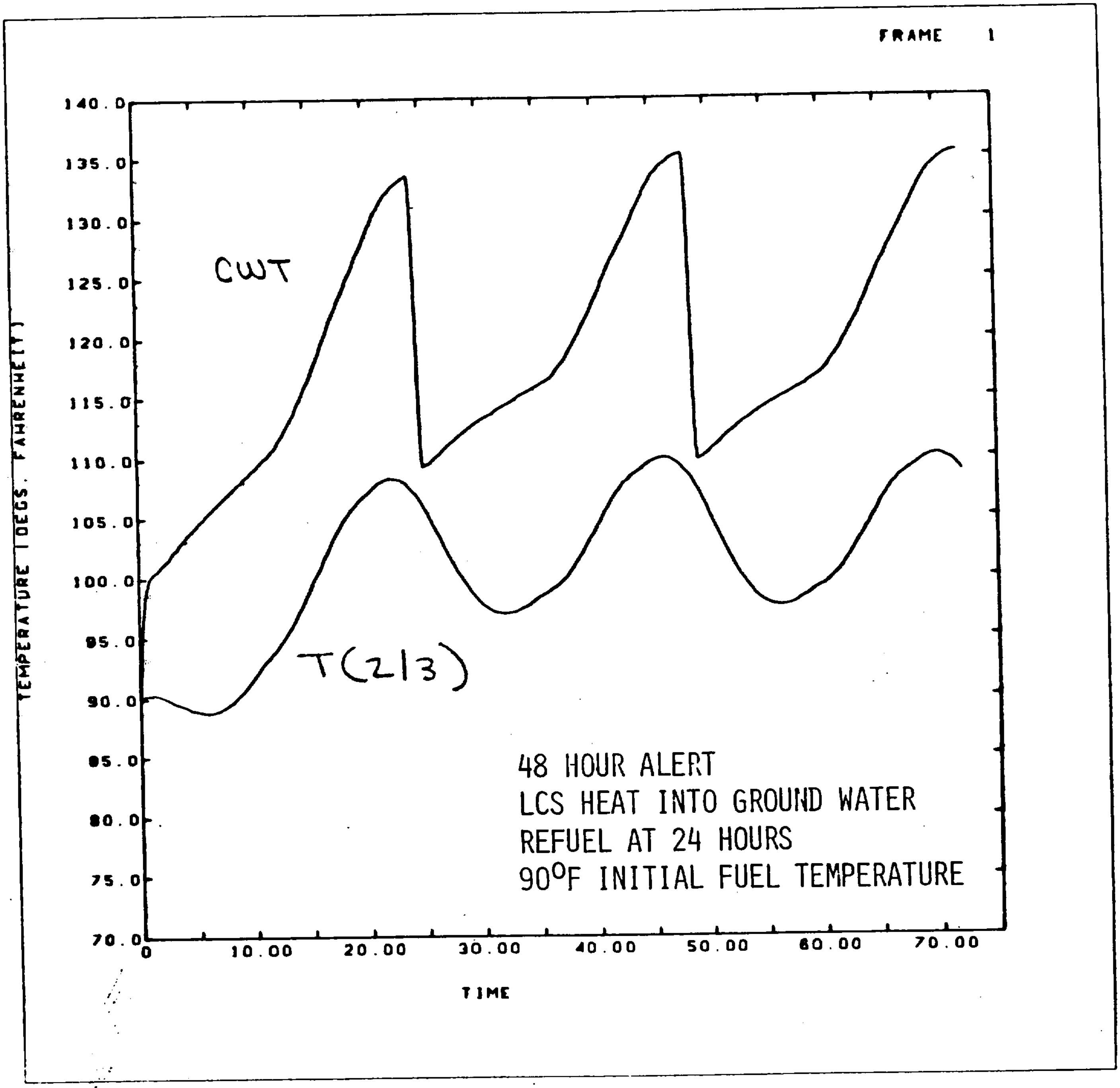


Figure 2.9.2

Fuel Temperature Variation with Time (115°F Peak Air Temperature)

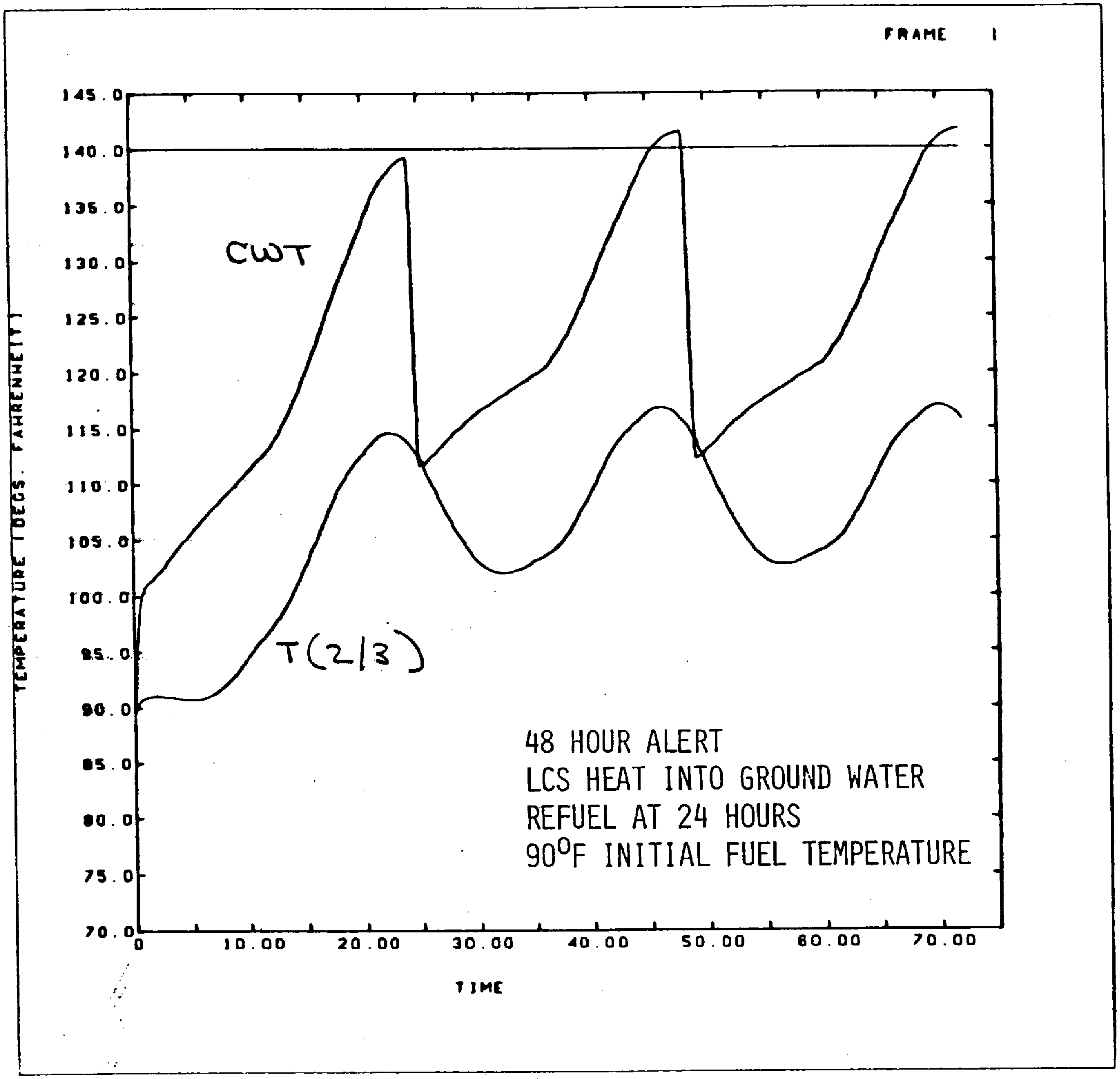


Figure 2.9.3

Fuel Temperature Variation with Time (125°F Peak Air Temperature)

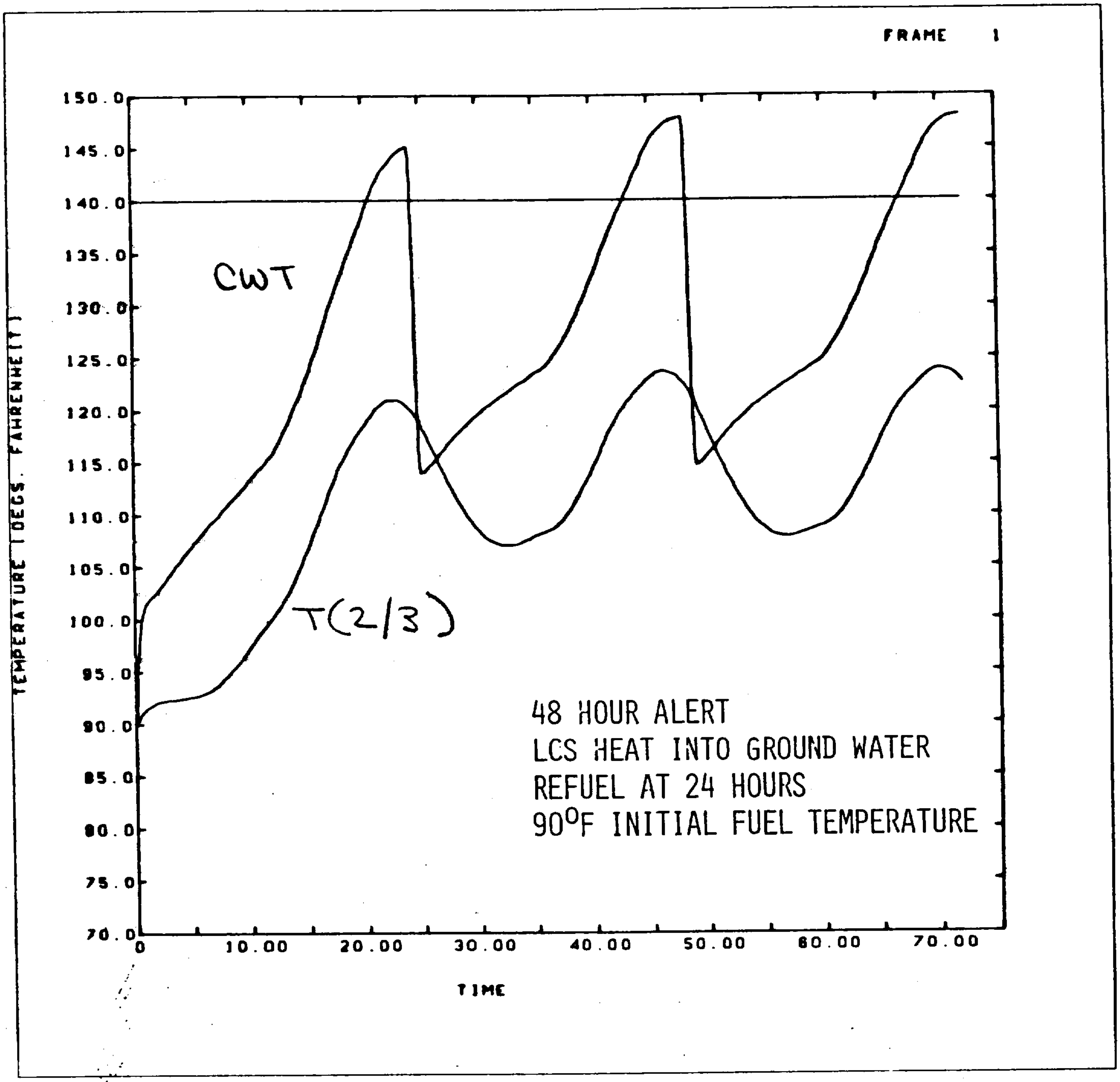


FIGURE 2.10

INITIAL FUEL TEMPERATURE EFFECT CWT

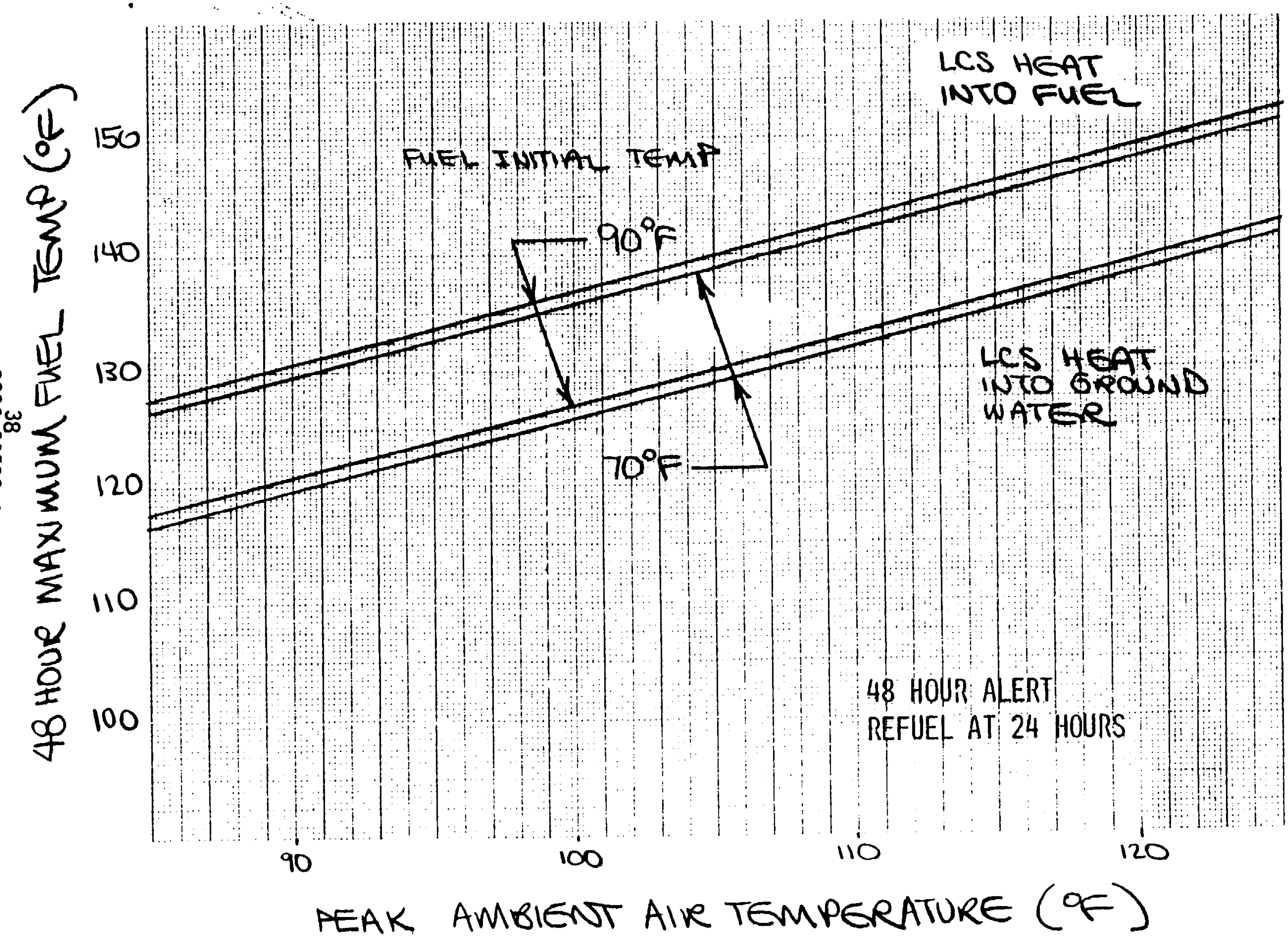


FIGURE 2.11

INITIAL FUEL TEMPERATURE EFFECT
WING MAINS (2/3)

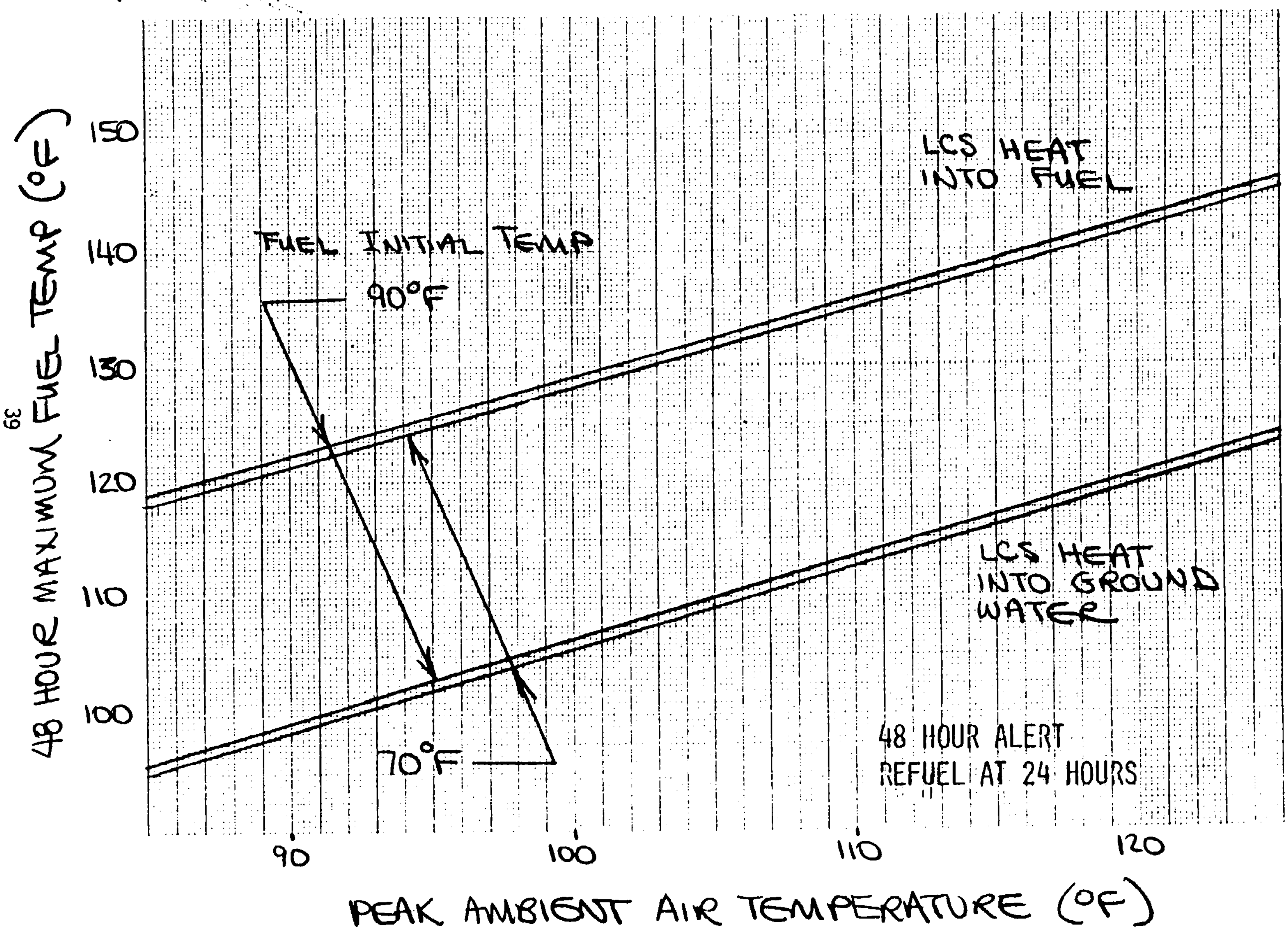
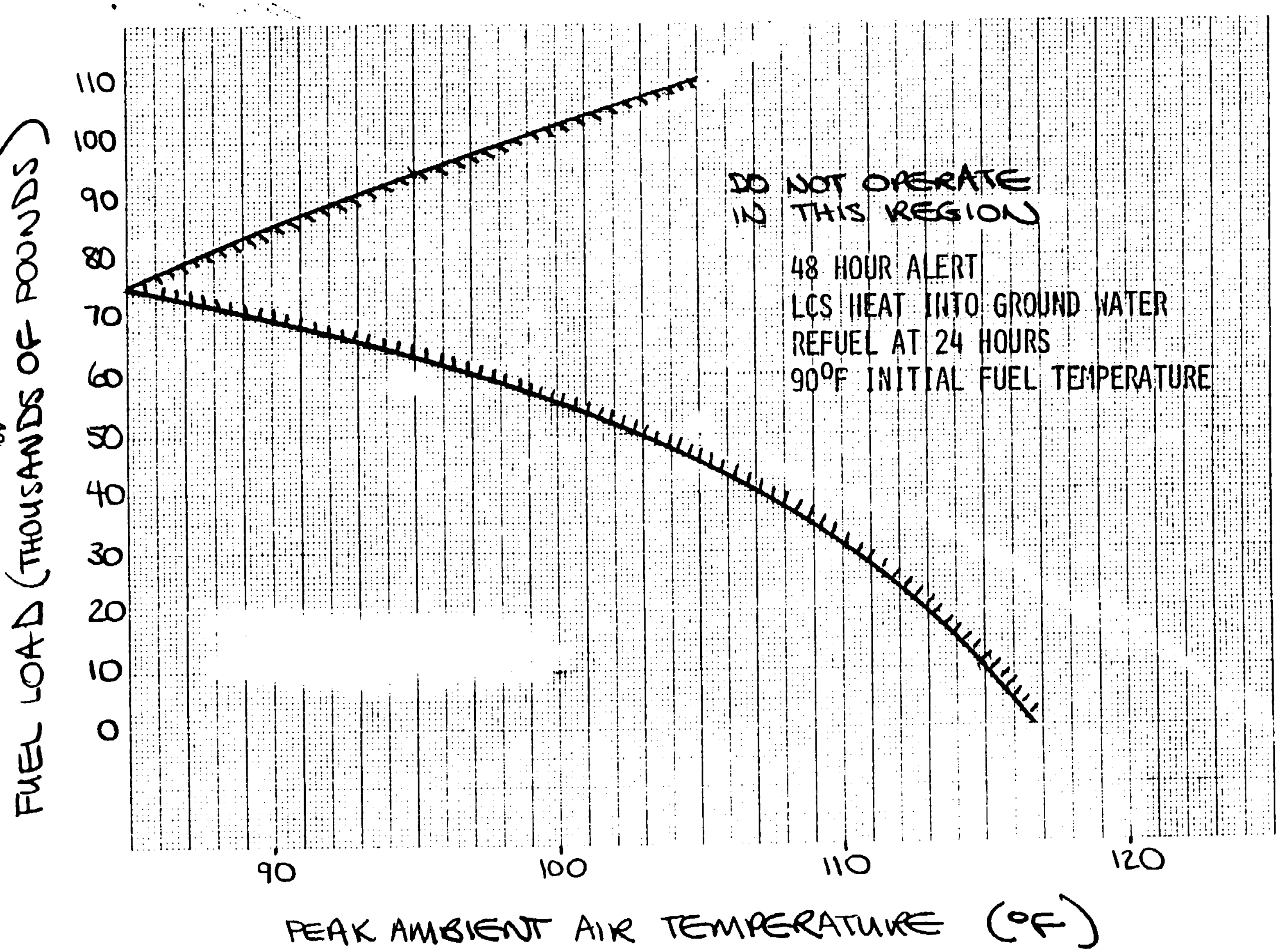


FIGURE 2.12

CENTER WING FUEL TANK ALLOWABLE FUEL LOAD



2.4.2 Insulated Configuration

The dominant source of heating into the CWT fuel is convective and conductive transfer from the air conditioning equipment bay. Uninsulated pneumatic ducting in the bay elevates the "pack" bay some 95°F over ambient air temperatures. This equipment bay encompasses the entire 144 ft^2 base of the CWT. Insulation over the base of the tank will serve to slow the rate of heat transfer into the fuel. Additionally, insulation of the pneumatic ducts will also serve to reduce the equipment bay air temperature.

Figure 2.13 illustrates the equipment bay configuration under the CWT.

Figure 2.14 depicts the maximum fuel temperature attained in the CWT. The study is shown with LCS heating into the fuel. Three curves are shown. The no insulation curve is repeated from Figure 2.8. The two insulated curves shown span the range from poor to good insulation effectiveness.

It is expected that even with insulation, the CWT will have overheats (self-sustained) when peak ambient air temperatures of 105°F are exceeded.

However, from Figure 2.8 it can be observed that self-sustained operation above peak ambient air temperatures of 101°F will cause problems with the inboard wing mains.

Figure 2.15 depicts the maximum CWT fuel temperature with the LCS heat load dissipated into the ground water system. Again, three curves are shown. The no insulation curve is repeated from the Figure 2.9 baseline analysis. Here we conclude that no overheats will occur for full tank loads all the way up to the 125°F MIL-STD hot day.

Figure 2.15.1 illustrates fuel temperature history with time over the 48 hour period for a 125°F peak ambient air temperature day.

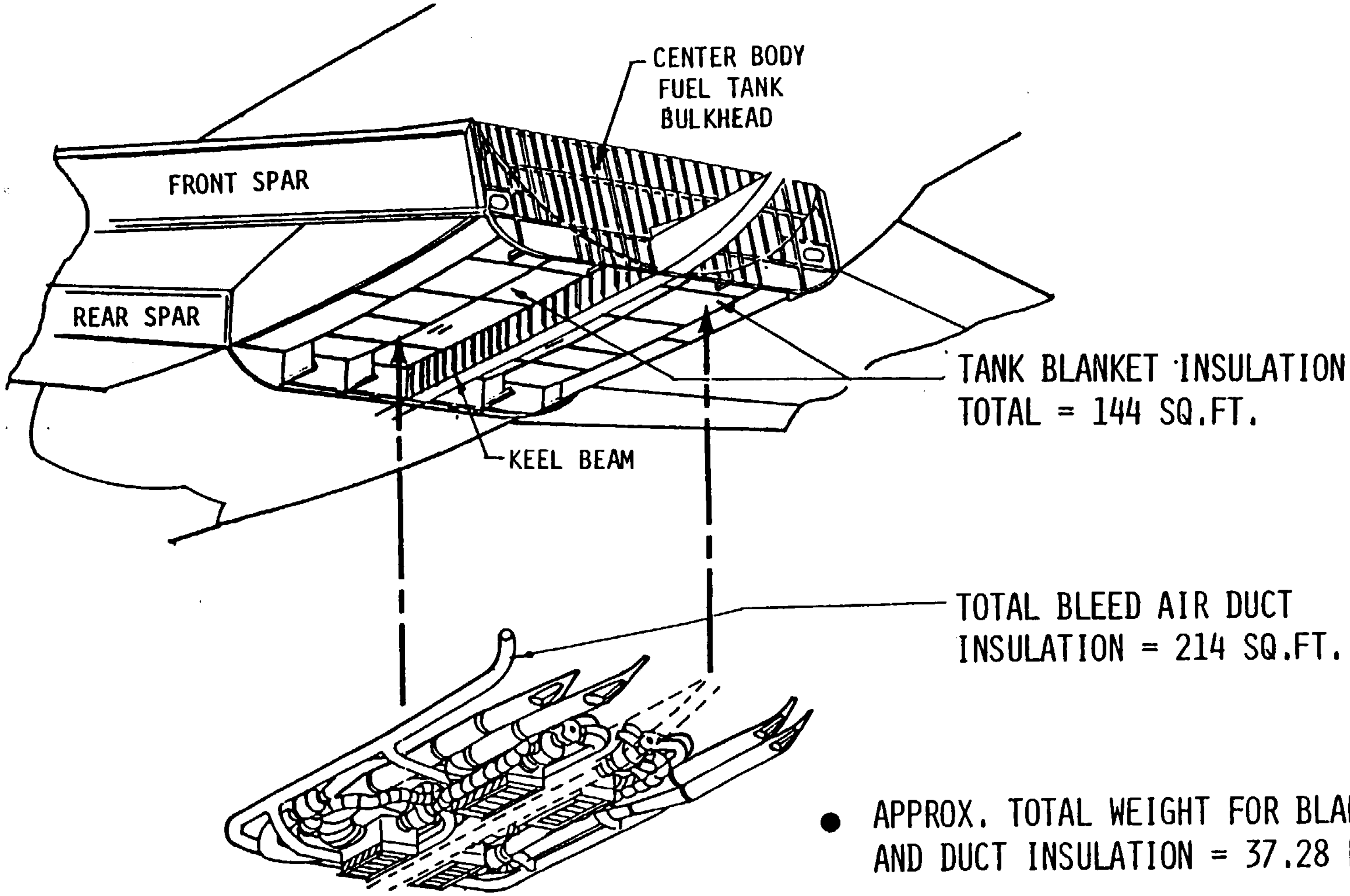
Figure 2.16 depicts the results of a study to define the allowable fuel weight envelope. Again, it is seen that restrictions must be placed on certain median fuel loads. Comparison with Figure 2.12 shows that the insulation of the tank considerably reduces the envelope of operational restriction.

Before concluding this study, an effort was made to examine the sensitivity of several of the assumed parameters.

FIGURE 2.13

E-4A CENTER BODY FUEL TANK INSULATION

SECTION 44



- APPROX. TOTAL WEIGHT FOR BLANKET AND DUCT INSULATION = 37.28 LB.

FIGURE 2.14

CENTER WING TANK FUEL TEMPERATURE

EFFECT OF INSULATION ADDITION

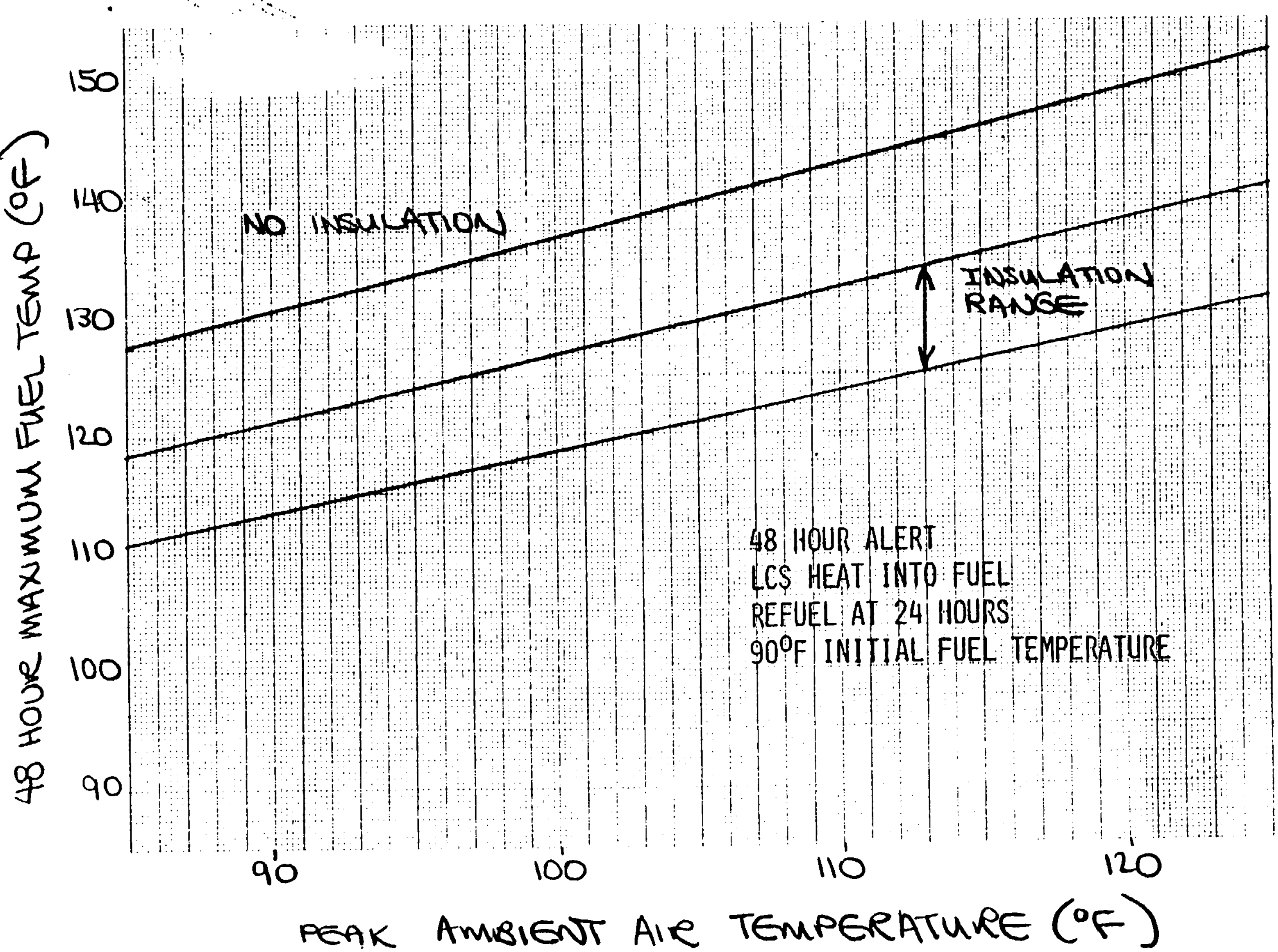


FIGURE 2.15

CENTER WING TANK FUEL TEMPERATURE

EFFECT OF INSULATION ADDITION

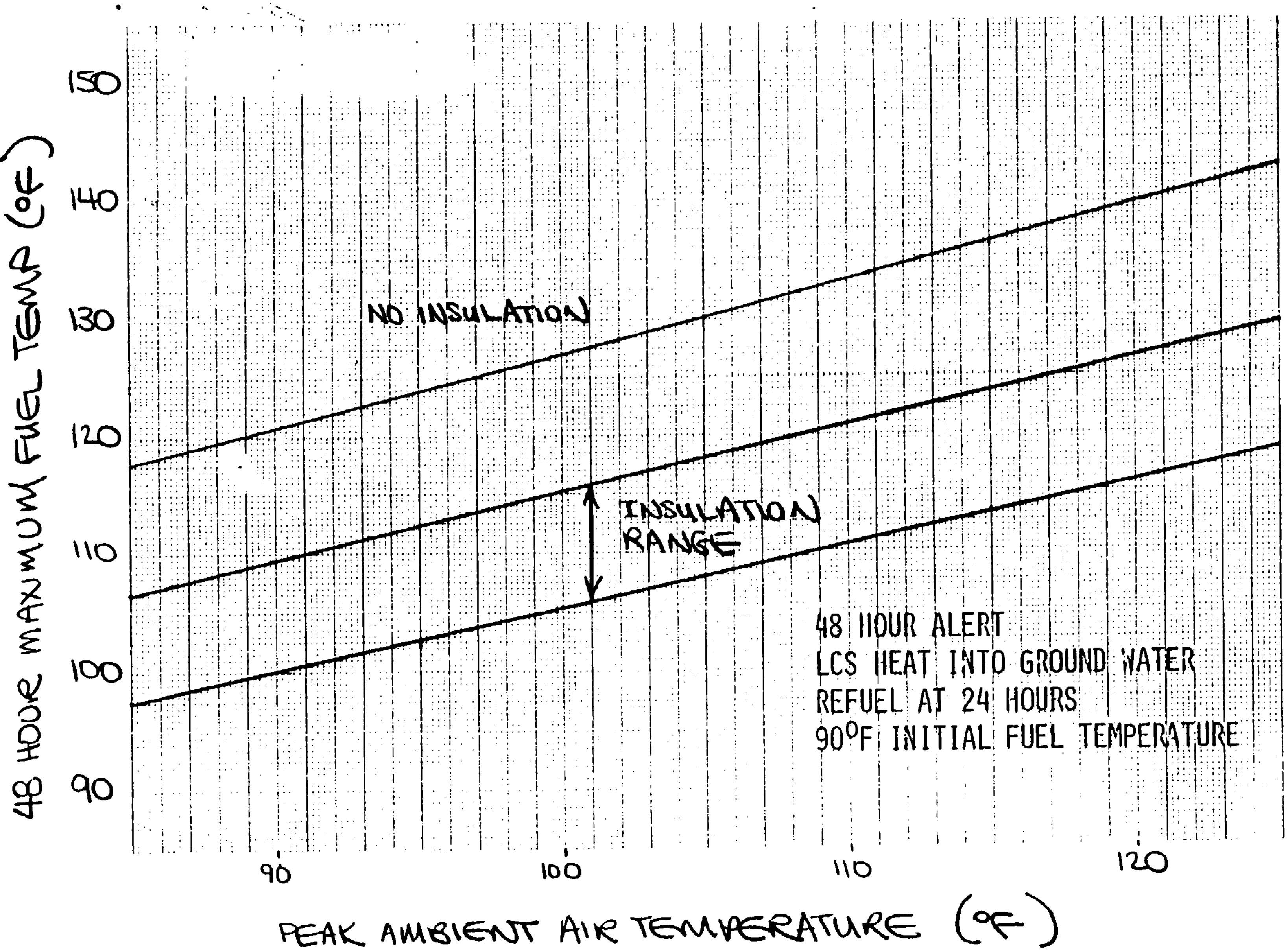


Figure 2.15.1

Fuel Temperature Variation with Time (125°F Peak Air Temperature)

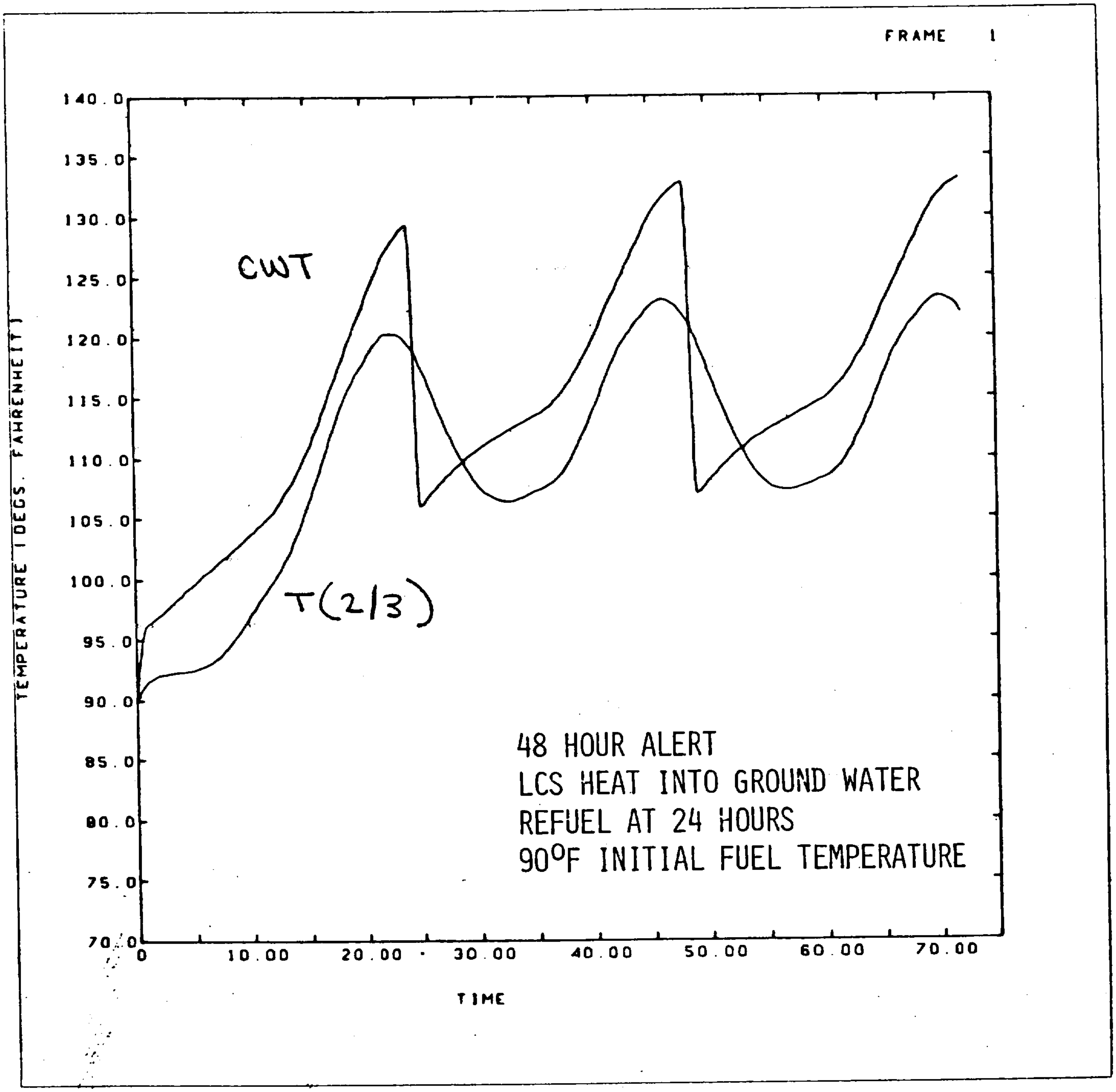
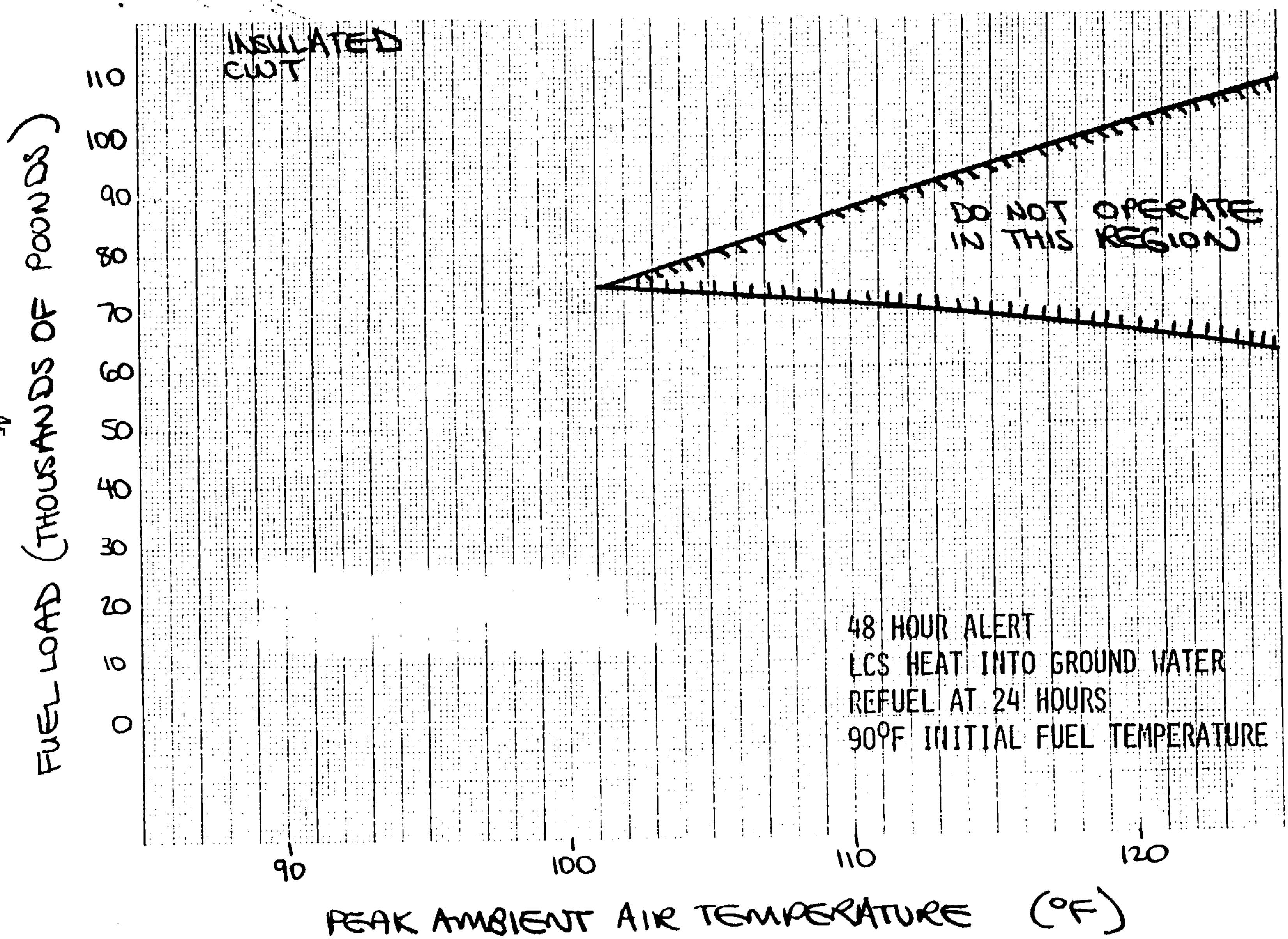


FIGURE 2.16

CENTER WING FUEL TANK
ALLOWABLE FUEL LOAD



2.4.3 Parametric Studies

Several of the assumed environmental boundary conditions have been investigated and the results are summarized in Table 2.1.

As expected, the inboard mains are sensitive to external environments (air and sky temperature, solar flux, and solar absorptivity) while the CWT is extremely sensitive to equipment (pack) bay temperature. The inboard mains react most strongly to ambient air temperatures.

Other parametric variations:

a) LCS load,

b) initial fuel temperature, and

c) CWT fuel load (quantity)

may be extracted from the data summary sheets of Appendix D.

Figure 2.17 shows the impact of varying the landing time relative to sunrise. The time shown in the Figure is number of hours from the start of the deployment to sunrise. The MIL-STD-210A profile on this plot would have sunrise at 12 hours. The time phasing of the MIL-STD day appears to be worst case for study.

Figure 2.18 shows the impact of varying the time lag between sunrise and ambient air temperature increase. Due to an oversight the models used in this study had lag times ranging from the intended 2 hours to 7 hours. From the Figure it can be seen that this would cause errors on the order of:

a) $0.4^{o}F$ for the CWT and

b) $4.0^{o}F$ for the inboard wing mains.

These numbers do not appear to be significant.

Table 2.1

SENSITIVITY STUDY
(125^oF BASELINE)
(48 HOUR MAXIMUM)

PARAMETER	INBOARD MAIN TANKS	CENTER WING TANK	UNITS
AMBIENT AIR TEMPERATURE	$\frac{\Delta T}{\Delta P} = \frac{-6.7}{-10}$	$\frac{\Delta T}{\Delta P} = \frac{-3.5}{-10}$	$(^oF)/(^oF)$
SKY TEMPERATURE	$\frac{\Delta T}{\Delta P} = \frac{1.6}{20}$	$\frac{\Delta T}{\Delta P} = \frac{0.7}{20}$	$(^oF)/(^oF)$
PACK BAY TEMPERATURE	$\frac{\Delta T}{\Delta P} = \frac{0.3}{20}$	$\frac{\Delta T}{\Delta P} = \frac{6.9}{20}$	$(^oF)/(^oF)$
SOLAR FLUX	$\frac{\Delta T}{\Delta P} = \frac{0.4}{20}$	$\frac{\Delta T}{\Delta P} = \frac{0.2}{20}$	(^oF)/(Btu/hr)
SOLAR ABSORPTIVITY	$\frac{\Delta T}{\Delta P} = \frac{0.9}{0.05}$	$\frac{\Delta T}{\Delta P} = \frac{0.5}{0.05}$	(^oF)

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FIGURE 2.17

FUEL TEMPERATURE VARIATION WITH RELATIVE LANDING TIME

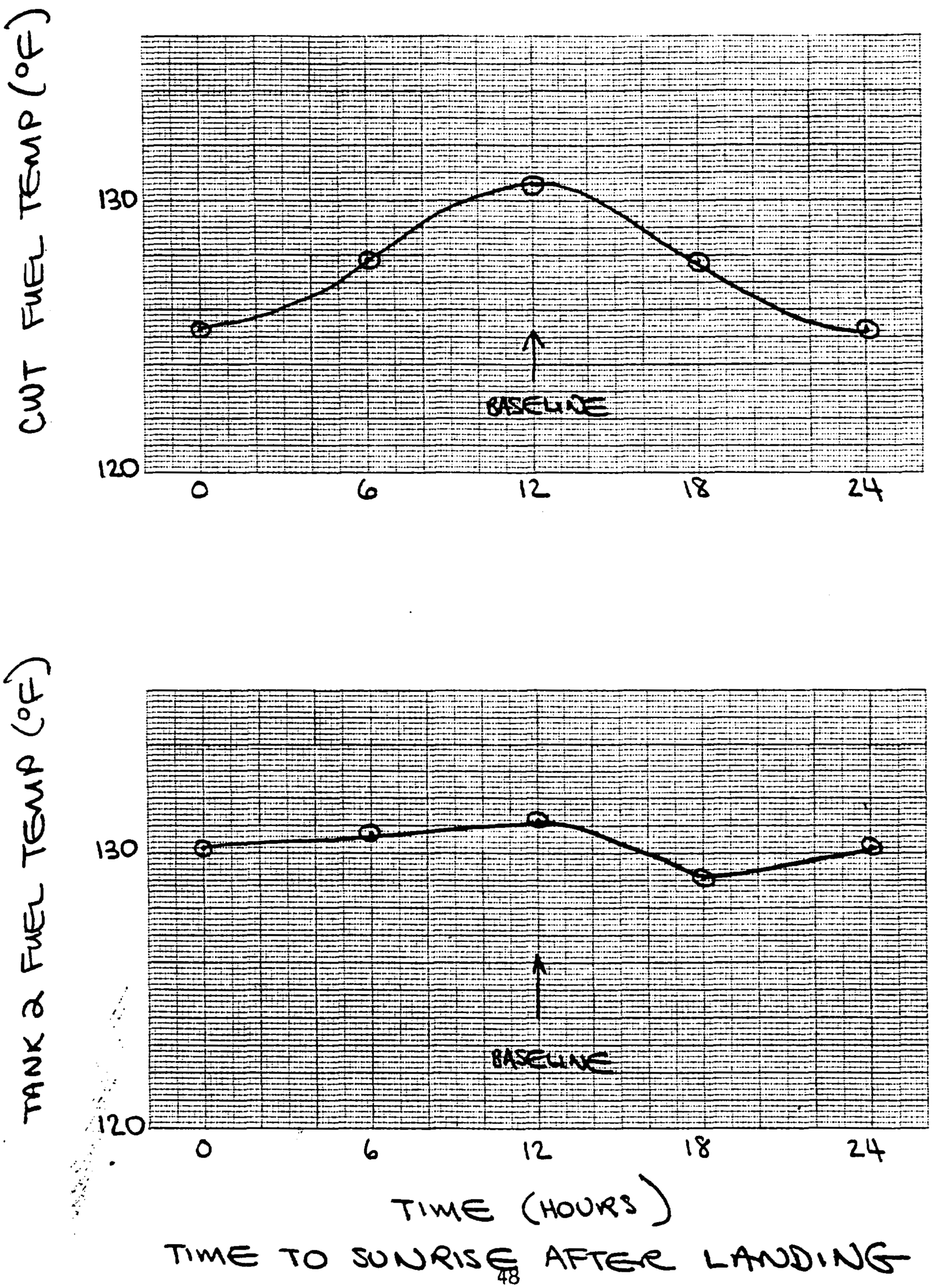
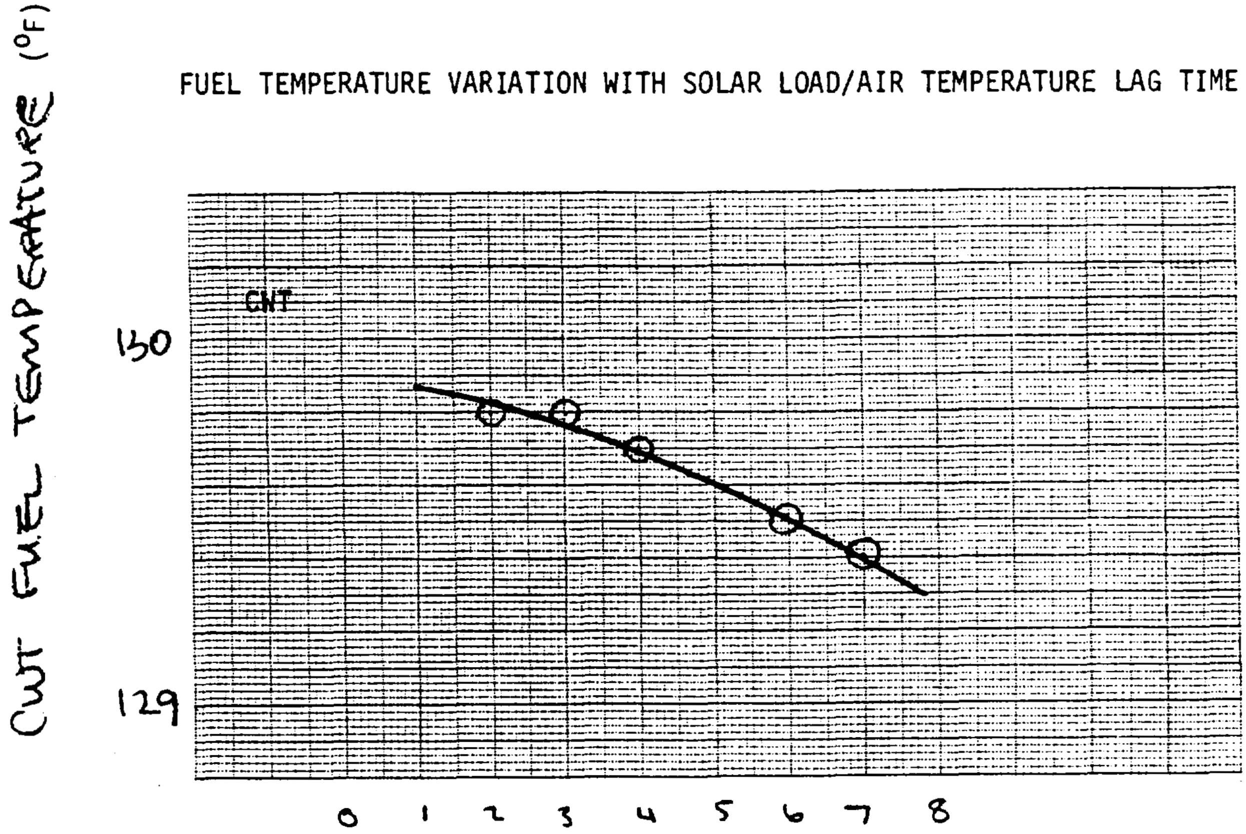
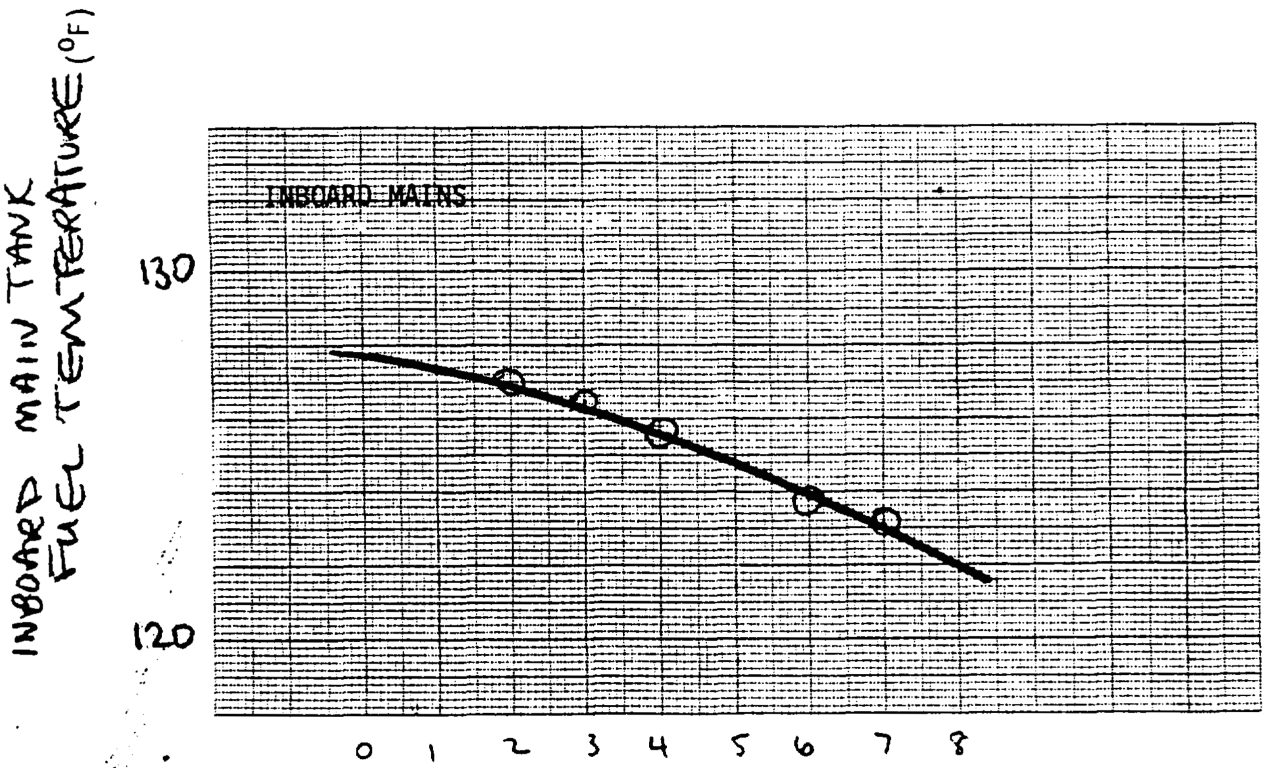


FIGURE 2.18

FUEL TEMPERATURE VARIATION WITH SOLAR LOAD/AIR TEMPERATURE LAG TIME





3.0 Design Modification Studies

A structural diagram of the center wing tank was prepared. It shows the basic geometry of the wing center section and adjacent structure, and identifies front, mid, and rear spars, spanwise beams, tank end ribs, BL 0 rib, floor beams, keel beams, fairing beams, intercostals, upper panels, lower panels, and wing-body fairing. It is documented as Layout LO-1000, and is shown here as Figure 3.1.

The following hardware modifications were considered:

a. Insulation of tank skin panels;

This modification would insulate approximately 400 square feet of the wing center section lower panels, by installing 22 insulation blankets with 40 yards of Velcro tape hook and pile, as shown in Layout LO-1002. See Appendix B. Additional weight would be approximately 26 pounds.

b. Insulation of bleed air ducts;

This modification would insulate approximately 93 feet of 7-inch-diameter bleed air ducts located beneath the center wing tanks. Sixteen blanket sections would be installed by tying circumferentially with fiberglass tape as shown in Layout LO-1001 in Appendix C. Additional weight would be approximately 13 pounds.

c. Cooling of center wing tank panel surfaces with forward lower lobe exhaust air;

This modification would direct exhaust air from the forward lower lobe along the bottom surfaces of the tank. Fiberglass panels would be used to form a channel under the CWT through which forward lobe exhaust air would be directed. Additional weight would be approximately 100 pounds.

Three additional concepts were considered:

d. Installation of blowers in the air conditioning pack bay;

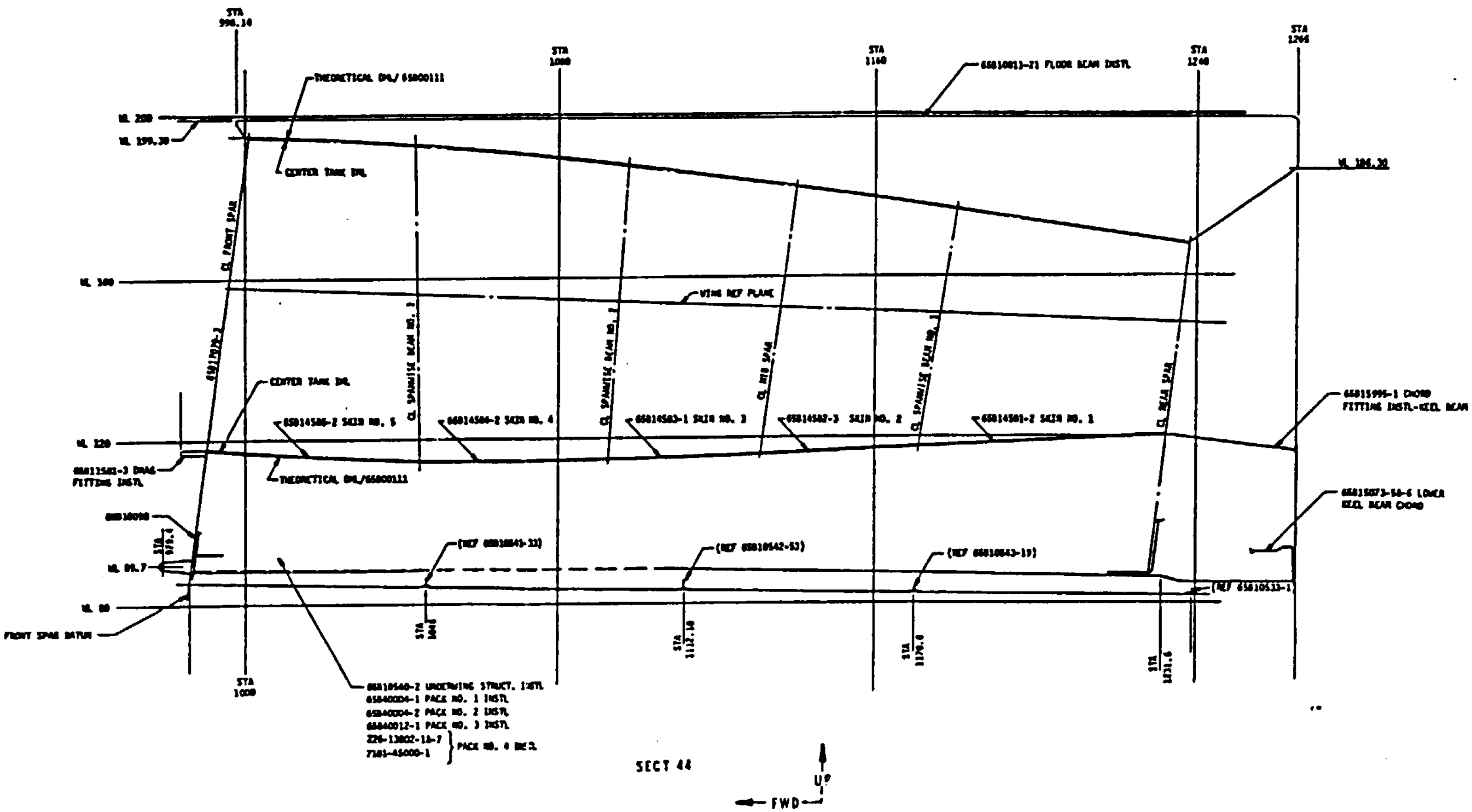
e. Baffling in the tank bay to utilize pack discharge air;

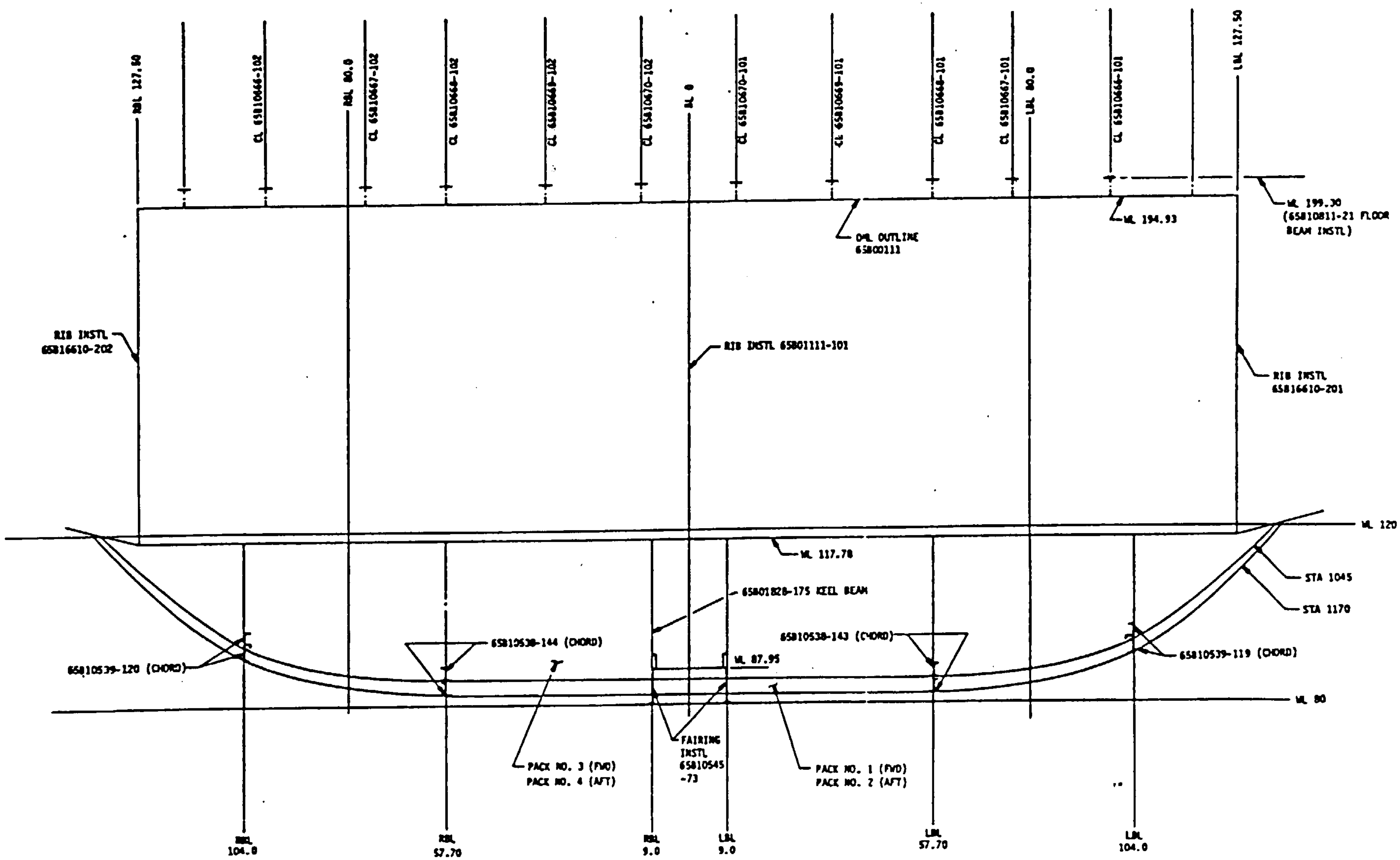
f. Installation of larger fuel pumps.

However, preliminary investigation of the wing center section structure indicated that implementation of Items d, e, and f would require extensive structural and electrical control modifications relative to implementation of Items a, b, and c. Study of those items, therefore, was not continued.

3.0 Design Modification Studies (Continued)

Work statements and conceptual design sketches were generated for the first three aircraft modification concepts. The work statements are presented in the following three sections.


STA 998.14
STA 1000
STA 1080
STA 1160
STA 1240
STA 1266
CENTER TANK DML
CL FRONT SPAR
WING REF PLANE
CL MID SPAR
CL REAR SPAR
FRONT SPAR DATUM
SECT 44
UP
FWD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CL 65810666-102
RBL 80.0
CL 65810667-102
CL 65810668-102
CL 65810669-102
CL 65810670-102
BL 0
CL 65810670-101
CL 65810669-101
CL 65810668-101
CL 65810667-101
LBL 80.0
CL 65810666-101
LBL 127.50
WL 199.30
(65810811-21 FLOOR
BEAM INSTL)
WL 194.93
OML OUTLINE
65800111
RIB INSTL
65816610-202
RIB INSTL 65801111-101
RIB INSTL
65816610-201
WL 120
WL 117.78
STA 1045
STA 1170
65801828-175 KEEL BEAM
65810538-144 (CHORD)
65810538-143 (CHORD)
65810539-120 (CHORD)
65810539-119 (CHORD)
WL 87.95
WL 80
PACK NO. 3 (FWD)
PACK NO. 4 (AFT)
FAIRING
INSTL
65810545
-73
PACK NO. 1 (FWD)
PACK NO. 2 (AFT)
RBL
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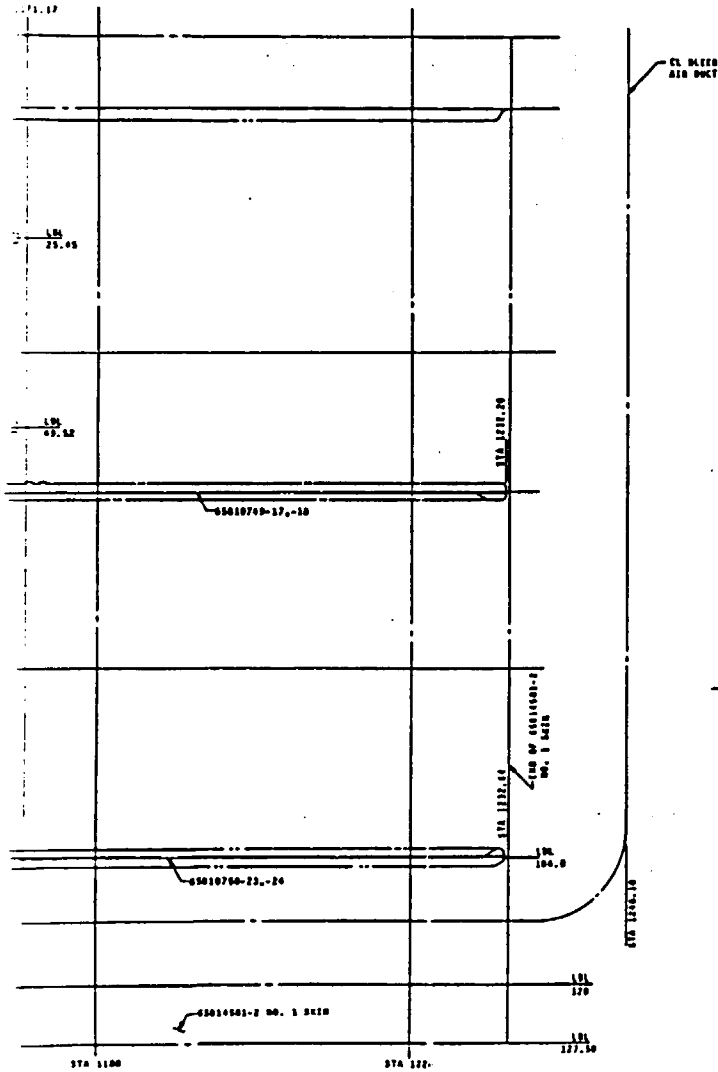
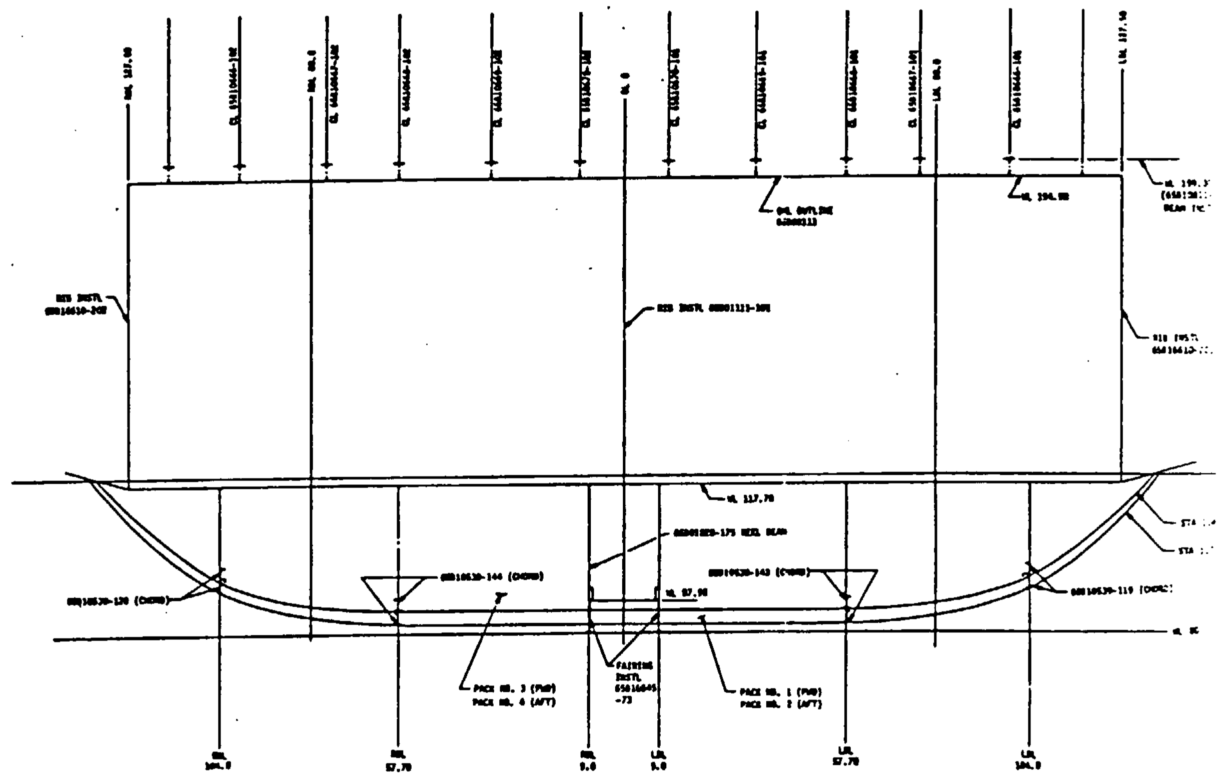
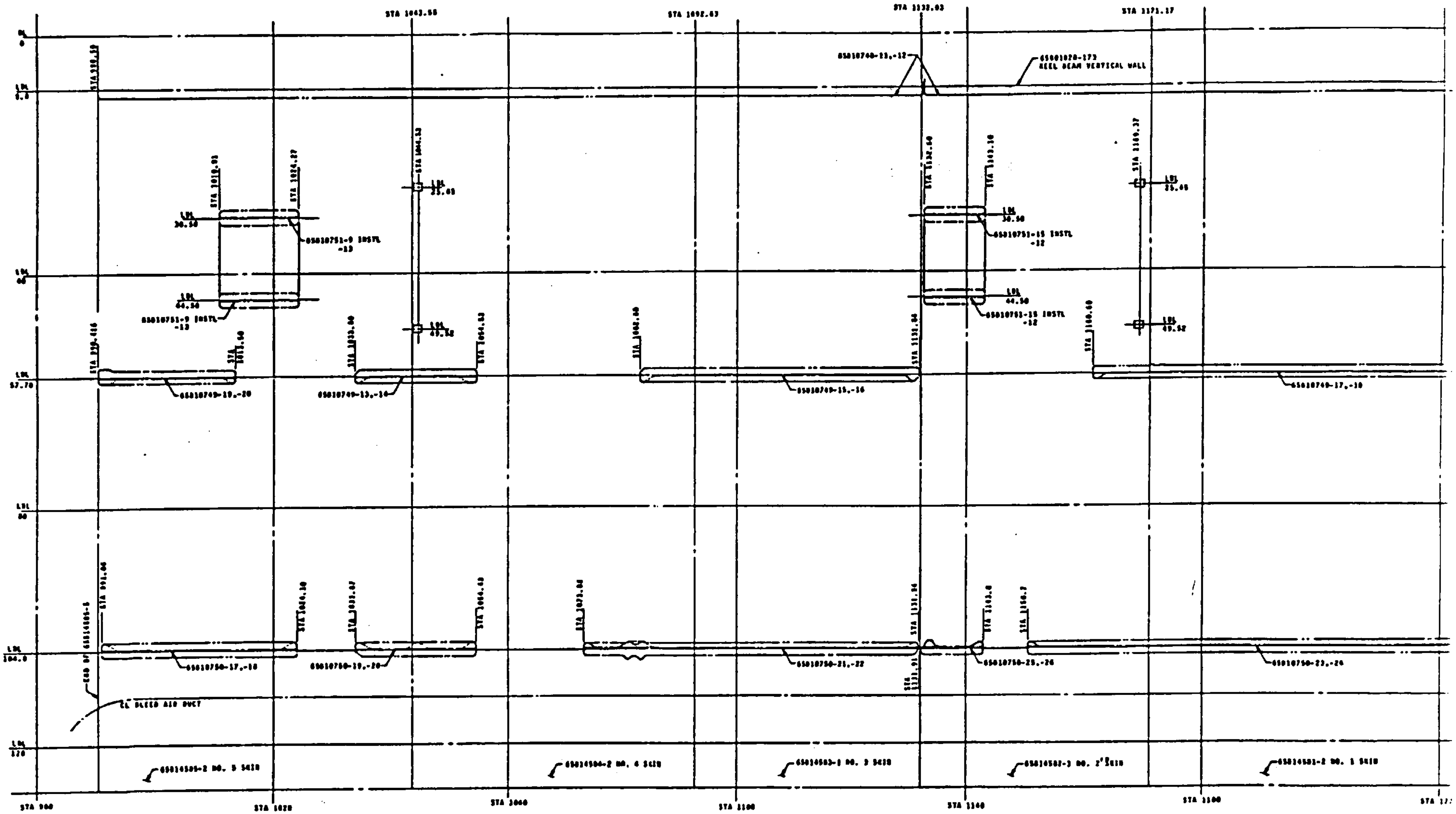
RBL
57.70
RBL
9.0
LBL
9.0
LBL
57.70
LBL
104.0
FRONT VIEW





FRONT VIEW



PLAN VIEW

FWD

3.1 Insulated Configuration (Tank Skin Panels)

GENERAL DESCRIPTION OF CHANGE:

Provide insulation blankets attached to approximately 400 square feet of tank skin panel surface.

DETAILED DESCRIPTION OF CHANGE:

1. Prepare rework drawings to install approximately 22 new insulation blanket assemblies, and add velcro tape to tank underside skin panels.

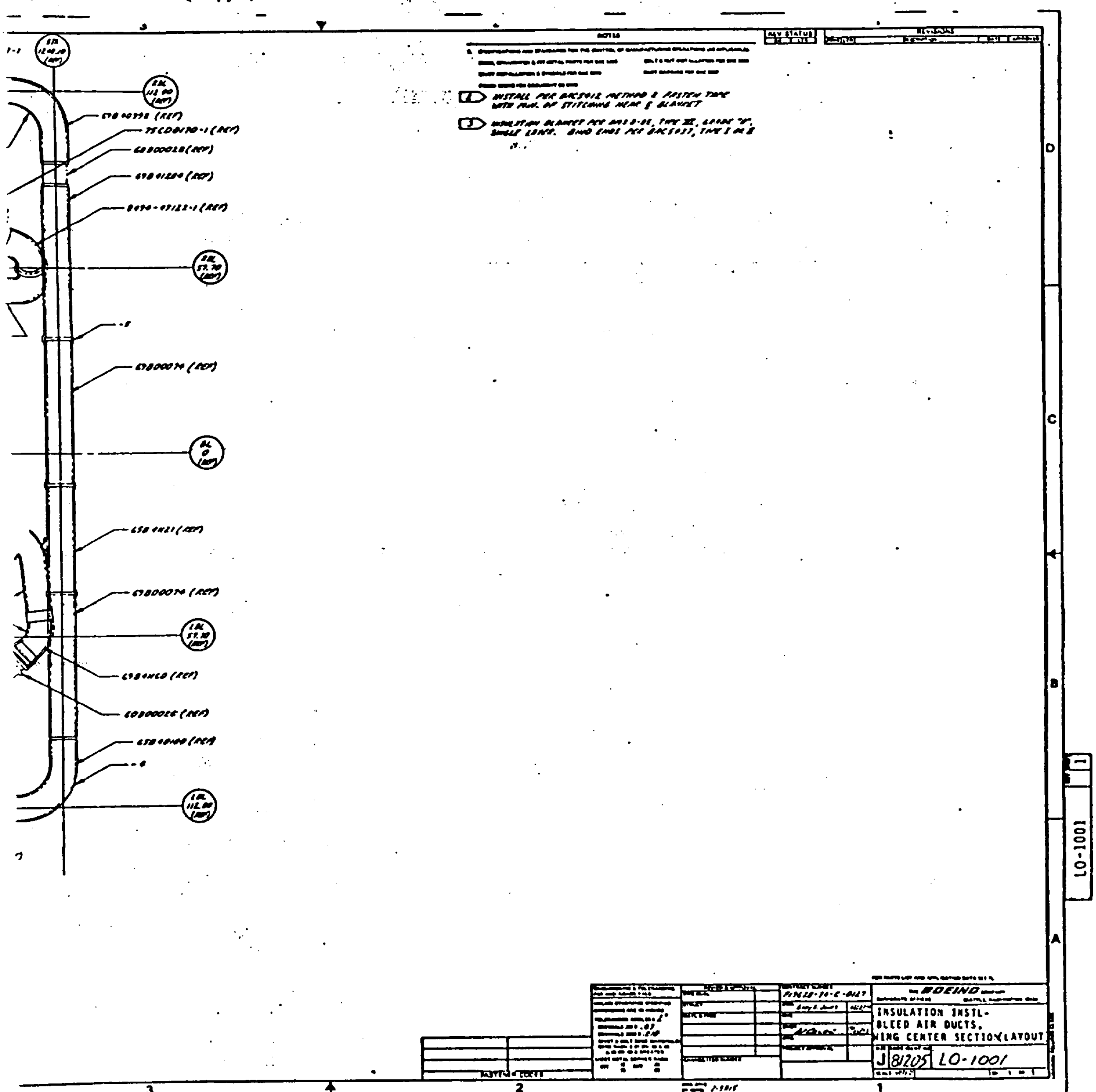
   a) Insulation batting material will be BMS 8-48 Type III, Class II, Grade 0.6 (1.00 ±.25 THK.), and covered with BMS 9-3 (112 or 113), Type B, Class 7 (plain Volan A .003 - .005 THK fiberglass).

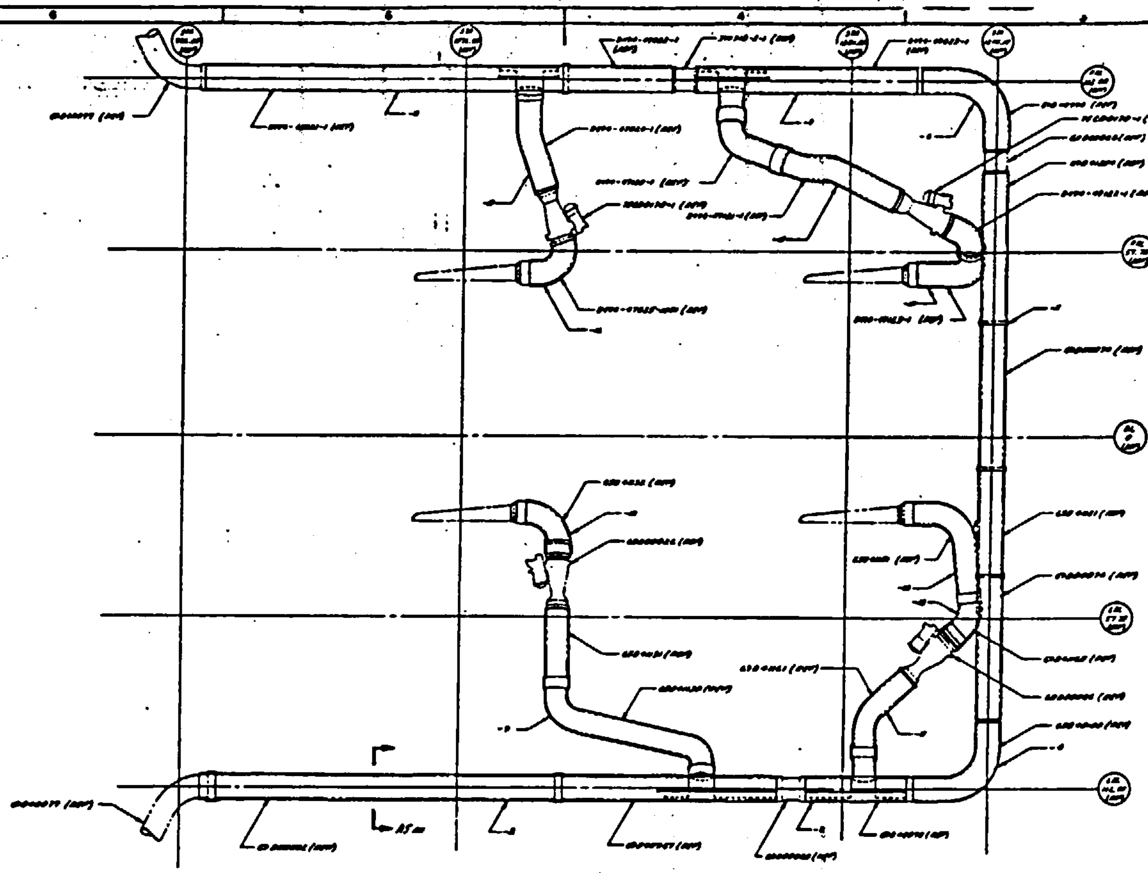
   b) Velcro tape pile (HAQ12-2-100 or equivalent) bonded to blankets per D6-2862 using BAC5010 Type 72, or type 48 adhesive.

   c) Velcro tape hook (HAQ12-1-200 or equivalent) bonded to tank skin per BAC5010 type 44.

REFERENCE:

Figure 3.2.


BOEING
INSULATION INSTL-
BLEED AIR DUCTS,
WING CENTER SECTION (LAYOUT)
J 81205 LO-1001
LO-1001
D
C
B
A
3
2
1



INSTL -1

PRELIMINARY
TABLE I

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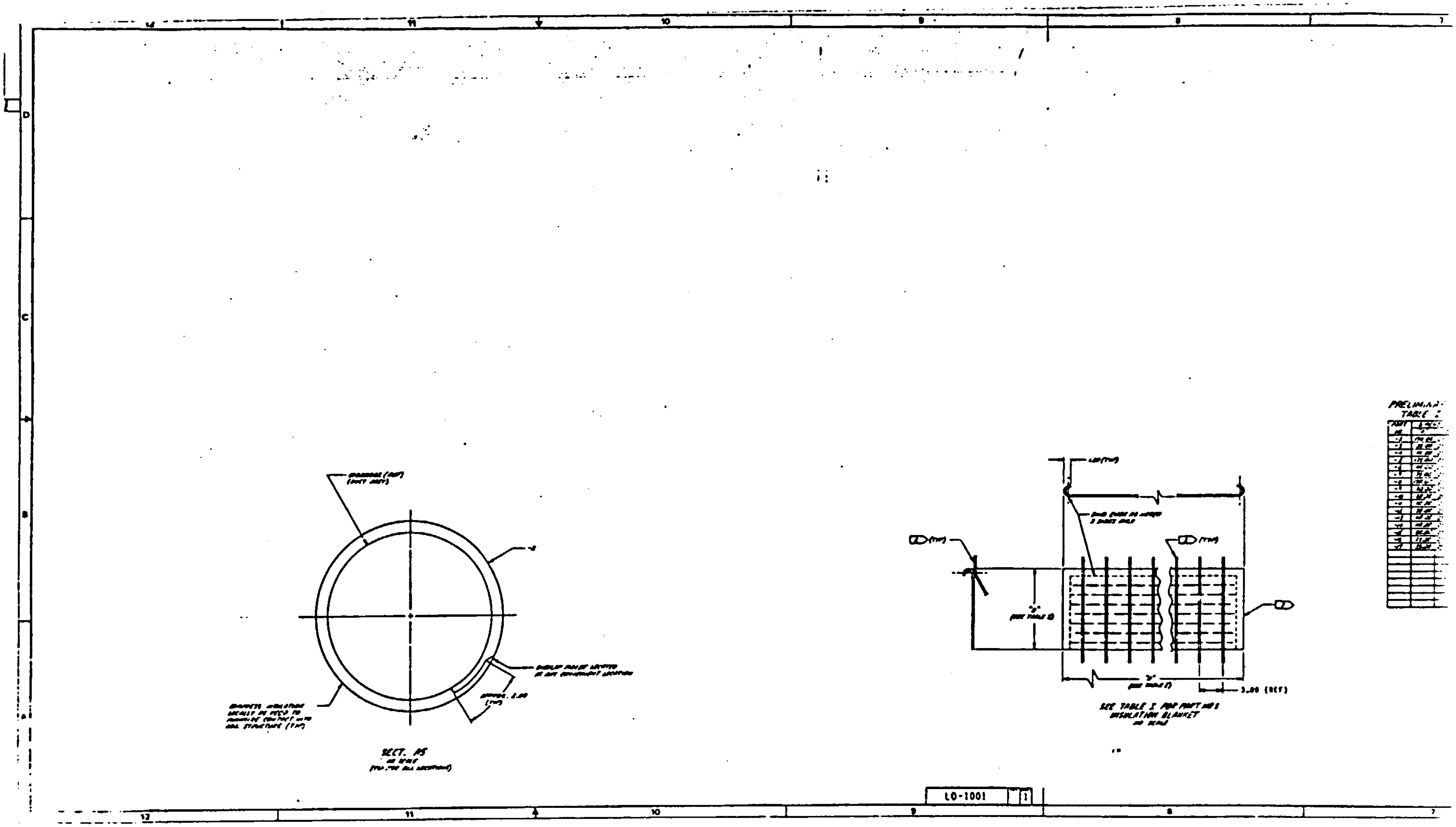
10-1001 | 1


SECT. AS
SEE TABLE I FOR PART NO'S
INSULATION BLANKET
3.00 (REF)
LO-1001
PRELIMINARY
TABLE I

3.2 Insulation of Bleed Air Ducts

GENERAL DESCRIPTION OF CHANGE:

Provide insulation blankets for approximately 100 feet of 7-inch diameter bleed air ducting located beneath the Center Wing Tank, between Station 990 and 1252.

DETAILED DESCRIPTION OF CHANGE:

1. Prepare rework drawings to install new insulation blanket assemblies per BMS 8-8E Type VII, Grade B to the following ducts:

69B00082	65B41121	8494-47824-1
69B40967	69B00074-7	8494-47825-1001
65B41130	69B41284	8494-47821-1
65B41132	69B40998	
69B40078	8494-47823-1	
69B41161	8494-47120-1	
69B41160	8494-47121-1	
65B41151	8494-47122-1	
65B40100	8494-47123-1	
69B00074-9	8494-47822-1	

(All blanket assemblies will have integrally sewn ties to eliminate clamp requirements.)

REFERENCE

Figure 3.3.

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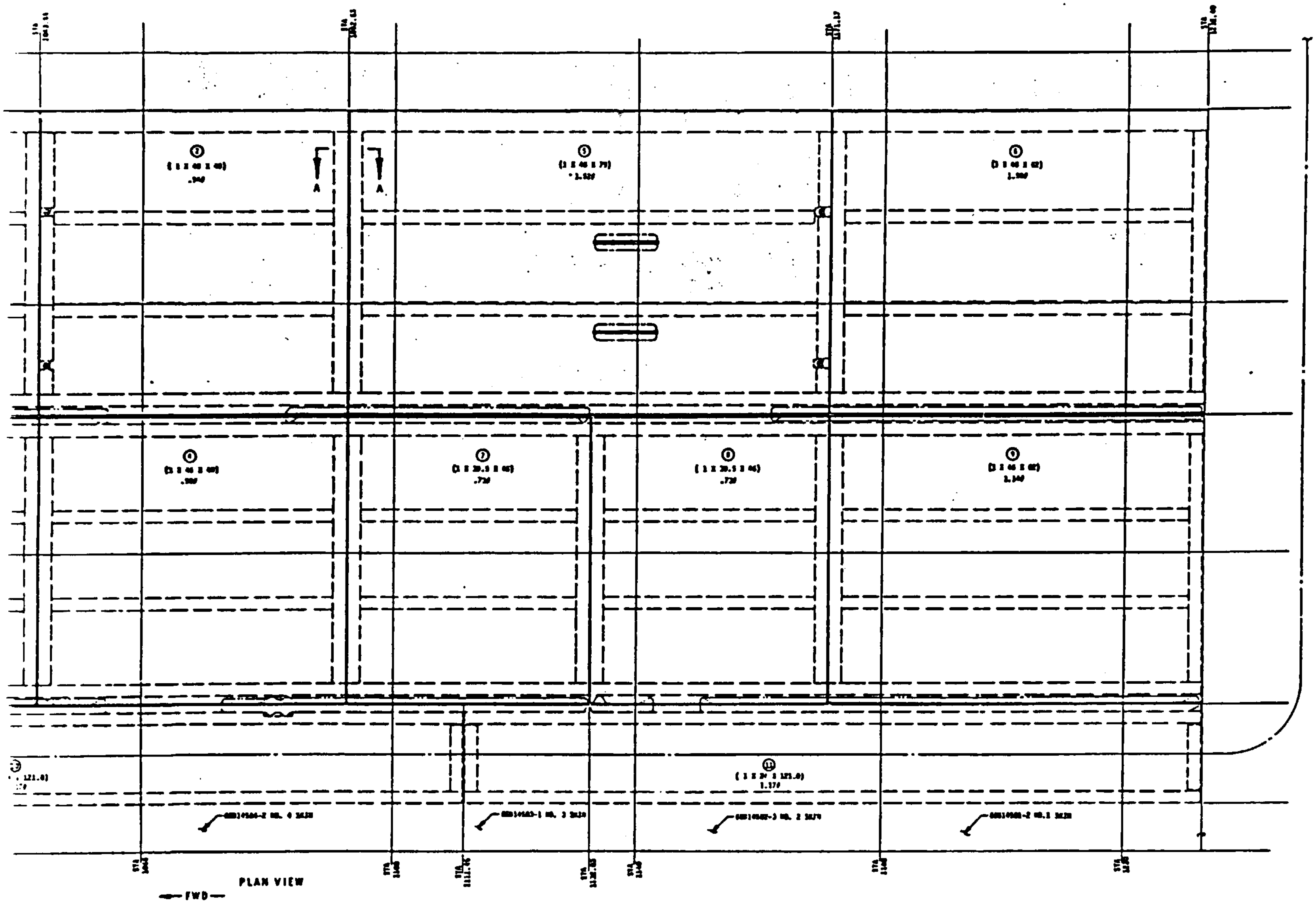
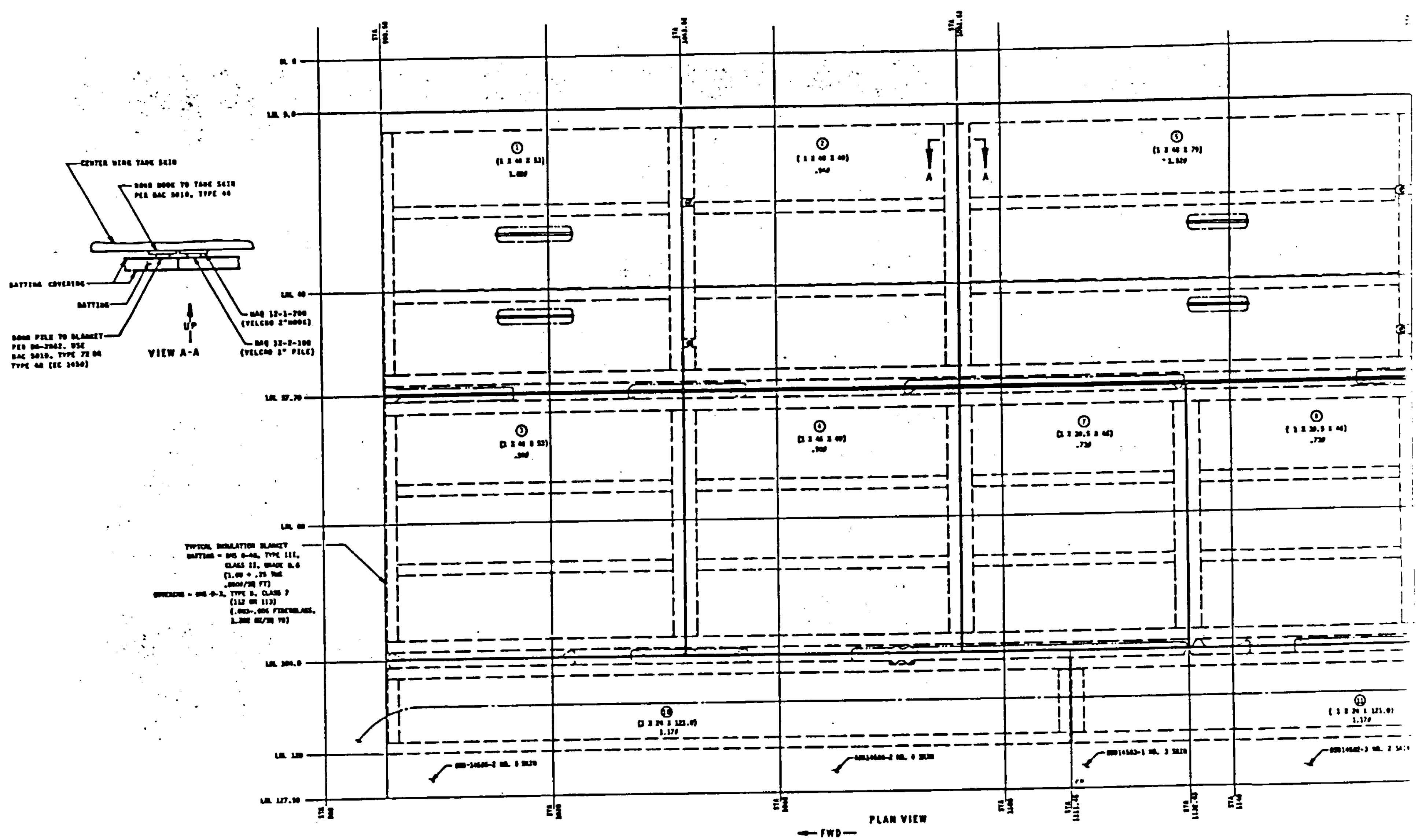


LO-1002
INSULATION INSTL-
LOWER PANELS,
WING CENTER SECTION
(LAYOUT)


VIEW A-A
PLAN VIEW
FWD

3.3 Cooling CWT Skin Panels

SUBJECT:

Center Wing Tank Underside Surface Cooling Using Area 10 Outflow Air

GENERAL DESCRIPTION OF CHANGE:

Provide airflow to underside surface of tank by ducting Area 10 outflow air to 10 rectangular shaped, three sided, fiberglass ducts, strategically bonded to the tank skin from Station 985.93 to Station 1232.64. Added weight will be approximately 100 pounds.

DETAILED DESCRIPTION OF CHANGE:

1. Prepare rework installation and assembly drawings to perform the following tasks:

    a) Remove the existing two 7101-42598 deflectors and install two new aluminum manifolds each containing seven 3-inch diameter hose stubs (L & RBL 45).

    b) Add four BACD40A12-336-8AZ (3.00 I.D. X 7 ft.), and three BACD40A12-480-8A2 (3.00 I.D. X 10 ft.) flexible hoses from each manifold to entrance stubs attached to new rectangular cooling ducts.

    c) Add five new fiberglass cooling ducts on L.H. and R.H. surfaces of the Center Wing Tank bottom panels. The ducts will be 2-ply structural laminate per BAC 5529 in hat section shapes with varying widths extending from station 985.93 to station 1232.64. Each duct entrance at station 985.93 will be a closed reinforced end containing tube stubs as required, and the exhaust exit at station 1232.64 will be open to the pack bay. All ducts will be attached to the tank underside by adhesive bonding per BAC 5010 type 44. Each duct run will be made from a minimum of three sections, to facilitate installation through the pack bay framework.

REFERENCE:

Figures 3.4 and 3.5.

FIGURE 3.4 CENTER WING TANK SURFACE COOLING

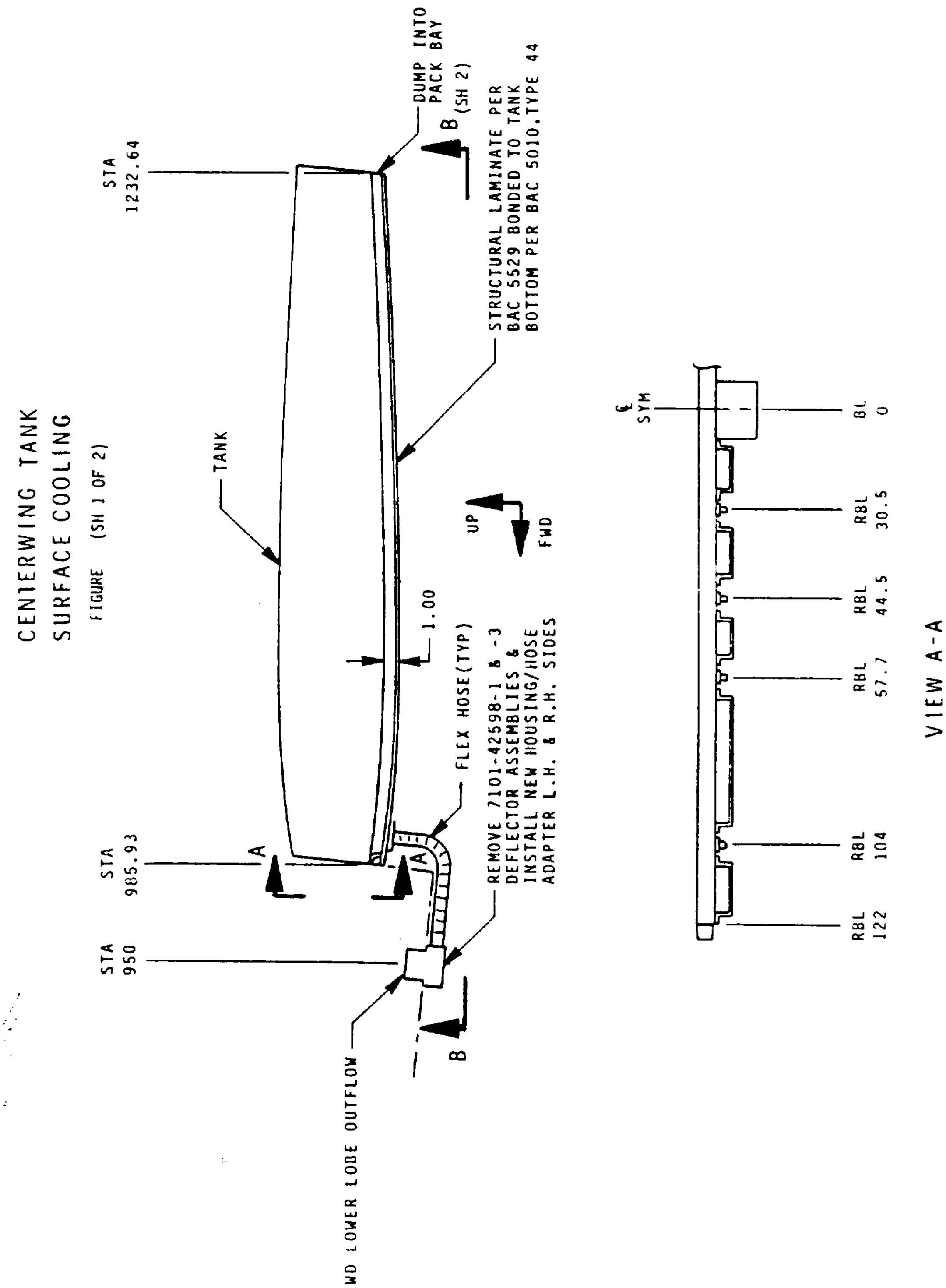
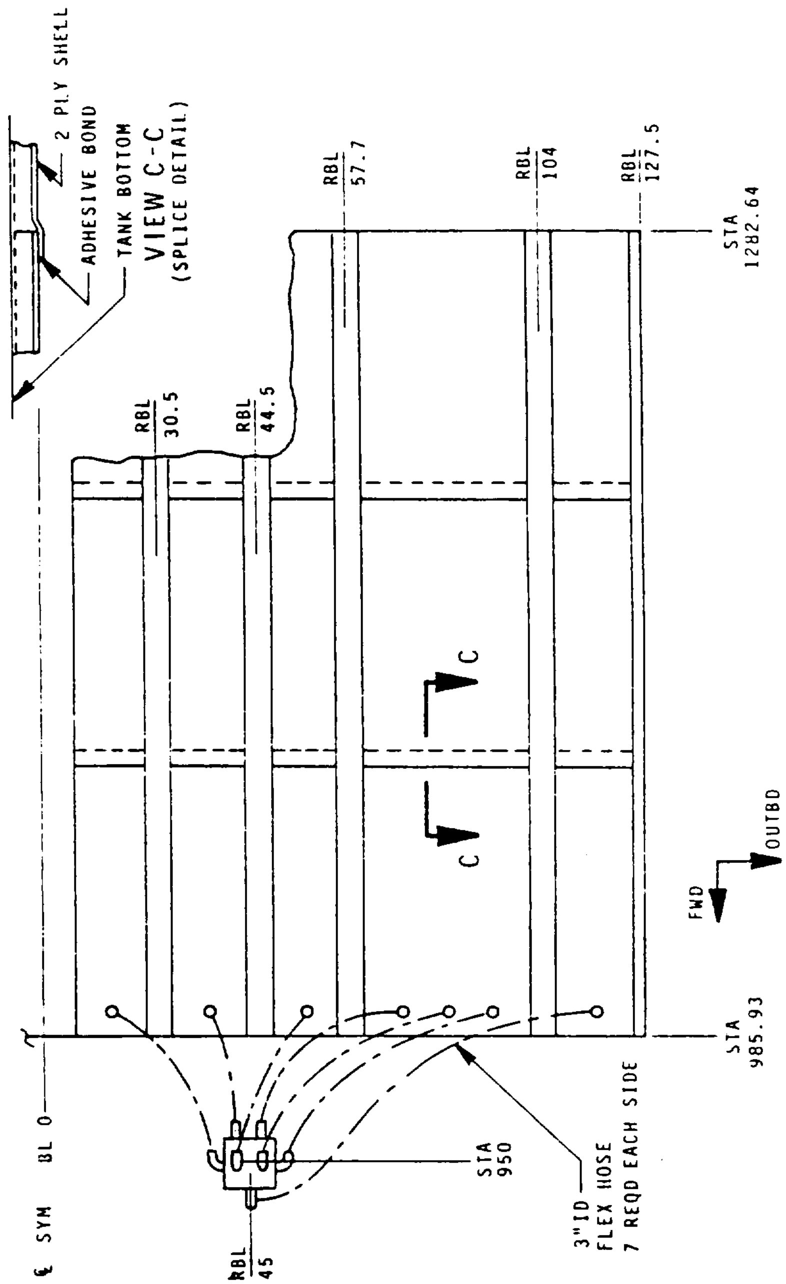


FIGURE 3.5 CENTER WING TANK SURFACE COOLING

CENTERWING TANK
SURFACE COOLING
FIGURE (SH 2 OF 2)



VIEW B-B (SH 1)

4.0 Conclusions

For the delivered aircraft, the conclusions of this study represent operational constraints. All constraints are valid for the E-4B configuration, those constraints related to LCS operation do not pertain to the E-4A configuration.

Remember also, that the operational constraints summarized herein are only related to the CWT and consider the wing tanks to be continuously filled. The operational constraints are summarized as follows:

a) If the center wing tank is filled every 24 hours, and fuel is burned at a rate sufficient to power the APU and one engine:

 1) the LCS heat must be dissipated in the ground heat exchanger on all days for which the peak ambient air temperature exceeds 89°F.

 2) on all days for which the peak ambient air temperature exceeds 104°F, a full fuel load will result in temperatures in excess of 130°F.

b) If the LCS heating is dissipated into ground water; the allowable fuel load restrictions of Figure 2.12 apply.

c) If LCS heating is dissipated into the fuel tanks; the allowable fuel load restrictions are considerably more severe than depicted in Figure 2.12.

In light of the restrictions imposed on the operation of the aircraft it is recommended that:

1) a hot weather test/deployment be conducted to a dry desert location with as high an ambient air temperature as possible.

   The purpose of this test is the removal of conservatism inherent in the analysis due to the assumption of local air temperature around the wing and pack bay temperature being a fixed temperature difference in excess of ambient air temperature.

2) Instrumentation for that test should include fuel tank temperature probes designed to examine gradients within the fuel tank with and without LCS circulation.

   This apparent stratification of fuel in the tanks made it necessary to double the LCS heat load in the analysis to assure that calculated fuel temperature agreed with temperatures that would be indicated to the flight engineer. Better understanding of these fuel temperature gradients may permit expanding the operational envelope through procedure and/or hardware changes.

4.0 Conclusions (Continued)

3) The bottom skin of the CWT and the accessible pneumatic ducts within the pack bay sould be insulated to reduce the operational constraints to be imposed on the aircraft.

5.0 References

1. ESD/YST letter to the Boeing Company, dated February 09, 1979; Subject: CONTRACT F19628-74-C-0127, OVERHEAT OF CENTER WING FUEL.

2. MIL-STD-210A, CLIMATIC EXTREMES FOR MILITARY EQUIPMENT, Change Notice 1, 30 November 1958.

3. T.O. 1E-4B-1, E-4B FLIGHT MANUAL, VOLUME II, SECTION V, Change 1, 15 November 1979.

ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR	SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR
1						45					
2						46					
3						47					
4						48					
5						49					
6						50					
7						51					
8						52					
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44.1											

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL

ENVIRONMENTAL CONTROL SYSTEM
ENGINEER NOTES

0820 TOUCHDOWN — PANAMA (pm)

84% RH 74°F discharge

0825 83% RH 76°F

78°F

RACKS ARE COLD
AMBIENT HAS TO GO UP ENOUGH IN ADVANCE
THAT EQUIPMENT IS WARM WHEN MOISTURE
APPEARS

WARM RACKS ABOVE DEWPOINT
BEFORE DESCENT
DESCEND
AFTER TIME ON GROUND REDUCE TEMP
TO ALLOW MAX COOLING
WITHOUT FOG

OFF AIRCRAFT
THROUGH IMMIGRATION — PASSPORTS STAMPED
BACK TO AIRCRAFT

0930 54% RH 70°F AIR
PACK 1 OFF PACK 4 DEDICATED
PACK 2 ON TO CABIN)
1000 FOG OBSERVED ON MAIN DECK (PACKS 3 + 4 ON)
1000 PACK BAY THERMOCOUPLES INSTALLED

38°C 58°C 80-82°F UNDER
~~[illegible]~~°F 59°C (138°F) PACK BAY
100°F

250°F DISCHARGE FROM
OPN PACK HEAT EXCHANGERS

A/C REFUELED
1120 TAXI TO PARKING POSITION

~~DEPARTED A/C FOR TOWN~~

SHEET 3 OF 12 | TITLE | MODEL
RECORDER MACGREGOR | | AIRPLANE
TEST NO. | STA | THE BOEING COMPANY | DOC. NO.
DATE | | PAGE

OCCASIONAL
PERIODS OF FOGGING ON MAIN DECK IF
~~PACK~~ COMPARTMENT TEMP NOT KEPT ABOVE
70-71°F
WE ARE HOLDING ~ 74°F
AND COMFORTABLE IN BATTLESTAFF

1330 INTERMITTANT CLOUDS PASSING OVERHEAD
CONTINUING SINCE 1130

1400 SHF OT(?) SHUTDOWN
FLOW = 10.2 GPM (109°F AT SHF ON THERMOCOUPLE)
SUPPLY = 47.5°C
RETURN = 52.3 °C
18 GPM H_2O FLOW (?) (145 °F AT SHF OUT THERMO C)

INCREASING GROUND WATER FLOW
LOWERS LCS-EGW TEMPERATURES
AND SHUT OFF GOES AWAY.

1430 DURING PERIOD OF LCS/SHF TROUBLESHOOTING
FOG APPEARED UNDETECTED IN AFT LOBE
AND CAUSED LOSS OF TWO UHF/FDM
POWER SUPPLIES. POWER SUPPLIES
CAN NOT BE RESTARTED (RESTORED)

1435 35.5°C SUPPLY SHF FLOW = 10.2 GPM
39.5°C RETURN
FLOW = ~~[illegible]~~ GPM 30-35 GPM
SHF HOLDING FINE NOW.

1500 PACK 2 DISCHARGE OSCILLATING
SWAPPED PACK CONTROLLERS
PACK 3 ACM OUTLET OSCILLATING
PACK 3 INTO MANUAL MODE FULL COOL
PACK 3 CONTROLLER BAD!

SHEET 7 OF 12	TITLE		MODEL
RECORDER MACGREGOR			AIRPLANE
TEST NO.	STA	THE BOEING COMPANY	DOC. NO.
DATE 12-29-79			PAGE

FLIGHT ENGINEER NOTES

Z= +5 hours

0500

Note; Left jettison pump C/W ON and Fwd. outflow valve auto left.

0745 Fog in upper rest area zone 1 at 70 degrees ,zone at 69 degrees, heat up zone #1.

0810 Fog in rack, brought temperature to 75 degrees, #1 & #4 pack.
0830 11.99 rack overheat , put #1&#4 packs to 70 degrees, prior to this #1 pack had gone up to 80 degrees.

0840moisture on rack equipment, switched AFT. lobe control from NORMAL to CLOSED.

1100 Switch to right jettison pump on C/W, Switch to right outflow valve to AUTO.

1145 AFT. lower lobe started getting fog , raised temperature to 80 degrees from approximate 75 degrees.

0800 Local, SHIFT CHANGE NO PROBLEMS

1357z 23degrees C, DEW POINT READING

1400z LT. PYKE REQUESTED TAT & SAT readings be taken. Will comply with readings from ctr. instrument pnl.

1430z Tech control reports that #3 60hz converter out. Sgt. Dobmeyer working problem, found loose cannon unit still in operation.

1450z Msgt. Large stated TAT & SAT will not have to be taken, he said it was an oversight on Sgt. Valdez part at time of designing data sheet.

1606z Tech control readings DO NOT AGREE WITH FLT. ENGR. position
F/E: #4 =75 degrees F/E: #1 =81 degrees
T/C: #4 =80 " T/C; #1 =81 "
(PACK OUT PUT READINGS)

1605z Switch Fwd. outflow to AUTO LT. and LT. Jettison pumps on turned OFF RT. OUTFLOW and jettison pump.

1717z #4 Pack read 75 degrees F Tech control wanted it dropped 5 degrees, took it to 70 degrees F.

#1 Pack read 85 degrees F , Took it to 71 Degrees F.

1720z SHF had a power Glitch , DC Amps Kick up from +20 Amps to +50 Amps.

1411z- Took readings No problem

526z- Brought both #1 & #4 packs back to 70 degreesas tech control requested.

1540z #2 Pack overheated to 180 degreesF went to trip, turned pack OFF and reset.

1615z- Put #2 Pack back on , pack operation normal.

1814z--Lowered #1 and #4 pack to 70 Degrees F for tech control.

1915- Dew point 25, outside air temp. 30 degrees C

1959z-Noticed #2 Pack oscillating, ACM OUTLET TEMP. going from 55degrees to 80 degrees F, and bypass valve was going from 10 to 40 back and forth.

2018z-Trouble shooting #2 pack problem, switched pack controllers. Pack #3 controller is bad. switched over to #3 pack , and placed in MANUAL operation by direction of Msgt. large. Packs #1,3,4, are now in MANUAL, pack 3 bypass valve positioned full OPEN.

2038z-Overheat flickered on fuel tank#1 momentarily, twice, at 39 degrees C, Tech control reads 36.5degrees C.

2045z- Tank #1 flickered again OVERHEAT same readings as above statement.

059z-Tank #1 flickered again at same reading

2108z-Tank #1 intermittently shows a OVERHEAT, at 39degrees C.

2115z-Tech control reported intermittent OVERHEAT on #1 Tank. at 37degreesC.

2123z-Flt. engineers #1 fuel tank temperature still shows an OVERHEAT intermittently at 39degrees C.

'130z-FLT. engineers #1 fuel temp. indicates same as above statement.

2137z-SAME indication as above

2138z-OVERHEAT flashed momentarily on #1&#2 tanks; T/C #1=37Degrees C
#2=34 " C

F/E #1=39 Degrees C
#2=37 " C

2142z #1 tank is still flashing an OVERHEAT at 40 degrees C.Tech control reports temperature at 37 degrees C.

2239z-#1 tank does not flash OVERHEAT as often at 39 degrees C.
#2 tank does not flash OVERHEAT at all at this time at 37 degrees C.
2314z-Shut down #1 engine for refuel, No data taken at 2400z .

2333z-Refuel started total fuel 271,000lbs. C/W51,750 { 29th

2357z-refuel finished total fuel 327,500lbs.C/W108,750.
0000z-C/W Tank reading 39 degrees C.
#1 " " 39 " "
#2 " " 38 " "
#3 " " 35 " "
#4 " " 33 " "

026z-lowered #4 pack ACM outlet temp. from 75 degrees to 70 degrees, increased #1 pack ACM outlet temp. from 68 degrees to 70 degrees.

0020z-Stratred #1 engine and configured for self sustained operation.

0100z-Changed fwd. outflow from RT. AUTO to LT. AUTO.

0112z-AFT lower lobe reported fog at vents. Reset packs #1&#4 from 70 deg.F ACM to 75 deg.F ACM fogging stopped.

0122z-#1 Hyd. quantity gage jumped from 9 to 10 gal. and continued to jump until 0123z.

0123z- #1 tank temperature has not come on since 2314z at engine shut down.

0328z-#1 Tank OVERHEAT light blinks very dimly.

0357z-#1 tank Overheat light still blinks at 40 deg. C.

0413z- #1 TankOVERHEAT flashs tend to stay at a constant OVERHEAT indications at 40 deg, C, Tech control reads 38 deg, C.

0506z- #1 tank OVERHEAT still is trying for a constant OVERHEAT.,#2 tank flashes momentarily, Tech Control reports same.

1300z-SHIFT CHANGE; LT. COL PYKE stated we have flat tire #16.
Thermal plugreleased.

1310z- #2 pack tripped ,reset ok ACM outlet 70 deg. F.

1320z- Mr. ludwig and Sgt. duvall are looking for tire and equipt. necessary for tire change.

1340z-discovered tire thermal plug popped at 10 oclock position.

1347z- request from tech control to lower temp. from 76deg. F to 72deg. F on packs #1 and #4.

1359z- #2 fuel tank overheat light is now on STEADY.

1613z- #4 pack tripped reset OK, ACM outlet temp. 70 deg. F.

1614z_ tech control reported fog in racks, ACM outlet temp. 68 deg. F on pack #1, pack #2 65 deg. Fraised temp. to 72 deg. F on both packs.

1617z-Having difficultymaintaining 75 deg. F, on packs 1 and 4. They keep oscillating from 75 deg. F to 68 deg. F.This occured for approx. 45 minutes.

1700z- packs 1 and 4 are stabilized.

1701zpack 2 is running great with no problems since 1310z.

720z current temp. is 29deg. C and Dew point is 24

1730z- ground man says fuel is venting from LT. side overboard vent.

	#1RES.	#1	#2	#3	#4	#4RES.	C/W
FUEL READINGS :	3,275	28.0	78.8	75.9	28.0	3,200	46.0
FUEL TANK TEMP:	----	46	44	44	45	------	50 deg.

1739z- transferred fuel to C/W to stop venting

1740z- READINGS AFTER TRANSFER:

C/W	#1 RES.	#1	#2	#3	#4	#4 RES.
63.0	3.0	24,950	72.3	70,250	24,950	2,975

1749z- FUEL TANKS TEMP.

C/W	#1	#2	#3	#4
48	47	46	46	46

++

* CALCULATED APPROX. 17,000 lbs. fuel transferred to C/W tank

1853z- #4 pack tripped , Reset OK, ACM outlet 90 Deg. F

TECH CONTROL NOTES

0100z- #1 AM 4857 has very weak power out on low end- 270.0 mhz and below SN284
0120z- Land at HOWARD AFB
0140z- Equipt. powered down ro refuel
0245z- rack 11.22 has an overtemp.
0330z- ENGINES STRATED FOR TAXI , repositoning of aircraft.
0332z--water dripping from overhead air ducts in tech control
0335z- #S 2,3,4, shut down #1 engine running for power
0340z-- mission equipment on all OK, but SHF
0527z- temp. in lobe is hot to prevent fogging 11.99 shows overtemp on equipt. cooling , engineer will attempt to maintain temp. at 70 - 75 deg. C????
0800z- found slight fogging in aft. lobe ATT due to low temps. of 65deg. lt. 65 deg. Rt. on watching temp. continued to drop to 60 deg. lt. and 60 deg. Rt. before engineer could make correction.
0810z- Engineer increased temp. tp 75 deg, Lt. and 70 deg. Rt. fogging gone expect 11,99 to overheat soon, 11.99 rack needs big fan as lobe ambient air is to hot.
0839z- 11.99 rack temp overheat again we are now trying an alternate method of keeping ambient air cool while keeping condensation off off of 11.54 and 11.57 racks, aft. lobe air control valves from normal to closed and or packs #1 and #4 maintaining temp. of 75 deg.
1143 slight fogging in lobe relative humidity 94% request temp. increase of 5 deg.
1247z changed pumps from 2 to 1 LCS , changed SHF system blowers from 1 to2 changed rack cooling fans from 1 to 2 .
1400z overheat indication on 11.22 and 11.55 racks , closed switch board doors-open 11.55 valve NORMAL, temp. @1410.
1448z- 11.55 rack overheat - opened 11.55 valve
1452z-- 11.55 rack overheat ndication , NORMAL.
1555z- 11.22 overheat indication
1629z- EGW hot due to ground mistake
1631z- EGW OK
1633z- SHF overheat and back OK at 34.
1705z- 11.54 overheat indication, opened valve
1707z- 11.54 overheat OK
1708z- 11.99 overheat indication
1709 11.54 overheat indication
1714 11.54 overheat OK
1717z- adjust air temp. in aft. lobe down to 65 deg.
1734z- 11.22 overheat OK
1739z- 11.99 overheat OK, normalled 11.54 , 11.55
1741zF/E#170 deg. #4 75 deg. T/C #1 65 deg. #4 70 deg.
1744z- beam OFF klystron down LCS reading 44 deg. and 47 deg. supply and return respectively
1803 beam up supply and return 38 deg. and 42 deg.
1909z- temp. on packs #1 & #4 raised 5 deg. to 73 deg. on both packs.
2002z- 11.99 overheat
2008z- lowering packs #1 & #4 to 70 deg.

29 DEC 79

0010z- VLF rack fault suspect overheat, area warm behind rack .
154z- lost air flow
0156z- air flow back
0215z- temp. into back of 616A rack 83 deg. at front above master clock
95 deg. at 11,99 between TR 135 deg.
0235z- 11.99 rack overtemp.
0240z- all C-3811 Nightwatch presets are IN.
0538z- reduced electrical loads for refueling
0730z- power up on aircraft.
0818z- all data systems OK
1045z- overheat 11.56 and 11.22
1046z- flt. deck working proble, temp. set for 70 deg.
1059z- overheat reset fro 11.55
1106z- overheat for 11.22 went OFF
1201z- had flight deck raise the temp to 70 deg. F
1244z- changed Lcs pump from 1 to 2
1255z--11.22 overheat
1300z- had flt. deck lower temp. to 70 deg.
1524z- had flt. deck lower temp. on packs #1 & #4
1605z- had flt. deckraised temp. on pack 1 & 4, Pack #1=70 deg. Pack #4=67
1815z- 11.22 & 11.55 overheats lowering pack #1 & #4 to 70 deg.
1816z- flow thru ground cooling was 22 GPM retarding it to original
position or previous day where we experienced klystron kickoff.
1830z- dropped flow to 18 GPM
1835z- temp. rising coolant supply over 45 and climbing
1840z- klystron kick off @ 49deg. return was 53 deg. C
1859z- taking readings of inlet temp. @ LCS inlet 97deg.F, reading @ coolant
supply 37 deg. C
1900z- Beam ON
1900:30 43deg C T/C 100 deg. F 10.13
1901;15- 45 deg C 103.5F
1903;14 48 deg. C supply 52 deg C 109deg F
52 deg C return

1980	return 38 deg.	discharge 97 deg F	Beam ON
1908:30	44 "	123.1	
1909	48 "	132	
1909:30	49 "	134.2	
1910	49.5	135.7	
1910.30	50.5	136.7	
1911	51	137.2	
1911:30	51.5	138.5	
1912	52	139	
1912:30	53 return 48 supply	145	

NOTE: late entry for 1845Z UHF/FDM Tx power supplys 1,3,5, kicked Hz voltage causing gliches in CPE and AFSATCOM, aft lobe was found to be fogging. monitoring could not be accomplished as testing of ground cooling was in progress.

2002z- 11.22 overheat left 73 deg. rt. 70 deg. F/E reads 78 lt. 75 rt.
2040 after drying out the RF gear for #1,3,5, UHF/FDM Txs back up with HI voltage and power.

29 DEC 79 CONTINUED;

2115z- #1 fuel temp. overtemp light started to flashing intermittently.
2300z- engines shut down for refuel SHF beam down
2312z- packs 2 & 4 shut off
2333z- 616A rack 95 deg plus
2340z- 616A input air to rack 96deg+ replaced program clock 616A alarms are OK.

30 DEC 79

0020z- flt. deck advises power stable, transition LCS to FLT. cooler mode.
0025z-- 616A crash
0252z- #1 fuel overtemp light flashing , temp. in tank 37 deg. C
0259z- 11.22 overheat
0327z_ 616A well R & R program clock 3 demod.

Note; Late entry; 0315 trouble shooting of data systems started, data sys. #1 5X5 data system #2 down, #3 KW-7 alarm #4 KW-7 NO Rx.

0400z-data #1 4X4
0416z- #1 fuel temp. overtemp. light continues to flash and liquid cooling alarm is intermittent #1 fuel temp. reads 38 deg.
0700z- autodin modem #1 bad, constant data quality switched to #2 modem.
0835z overheat 11.22 rack
0837z- VLF coax alram
0841z- VLF coax alarm went away charge Tx line with SF6
0850z- overheat 11.99
0923z- 11,22 overheat went off
0925z- 11.22 overheat light illuminated
0926z- 11.22 overheat went off
0929z- 11.99 overheat went off
0930z- by lowering the temperature to both racks and the compartment in area 11 the overheat alarm went away on 11.99 and 11.22 both light went out a very short time after temp. adjustments were made.
1038z- fogging in area 11 equipt. rack , raised temp. awaiting results.
1122z- overheat 11.22 had flt. deck lowered the temp. 2 to 3 deg, and 2 to 3 deg more.
1200z- 11.22 overheat went out fogging noted 11.57 and tech control area.
1209z- 11.22 overheat flt. deck adjusted temp.
1211z- 11.22 overheat went out
1212z- change blower of SHF from 1 to 2.
rack cooling from fan 1 to 2
liquid cooling pumps from 2 to 1
1215z- 11.22 overheat light illuminated
1219z- 11.22 overheat light went out
1258z- 11.22 overheat
LIA. #3 constant tune
1334Z 11.55 overheat opened valve amd overheat out.
1337Z closed 11.55 valve
1346Z 11.55 alarm A1 sensor 11.99 flickering, lowering temp 5 deg both racks (1 & 4).
1409Z SHF klystron down 44 deg supply, 48 deg return

30 DEC 79 CONTINUED:

2240Z aircraft door #3 leaking water
`248Z 11.22 overheat
,ate entry; 2240Z: back to normal flt. cooler mode.
2330Z AFSAT wideband modems 1 & 2 continous fault.
2339Z AFSAT operational swapped narrow band modems and wideband #2 modem wide band #2 &,1 507 and narrow band1 #1165 modems bad. there is no 70 MHz out put of J-9.

)104Z 11.55 overheat temp. 105 deg.
05
0143Z closed VLF and SHF 2 valves
0243Z swbd. intake air alarm
0310Z 11.55 overheat out
0412Z VLF coax alarm
Late entry; 0330 all systems shut down except for SHF all operators departed

0416Z VLF coax repressurized alarm OFF
0417Z SHF PA fault
0418Z 11.22 alarm off
0422Z #4 fuel temp. overtemp. has started to flash off #4 temp. 39 deg. C
0441Z SHF system shut down
0442Z all systems down
0450Z all tech control personnel departed

31 DEC 79

1135Z TAXI, flt. cooler mode
packs 1,2,4 show ON
packs 1,2,3,4, show flow

1140Z TAKE OFF
1203Z CPE memory power supplies tripped at power on.
1231Z all overtemps cleared.
1232Z VLF coax alarm
1233Z Autodin modem#1 checks 5x5, possible heat problem

NOTE: AFSAT KG1 problem last night appears to be a perimeter problem.
1256Z AFSAT order wire R/T has key fault
1257Z SG-572 bay 2 has no pilot tone
1342 primary power to 141T, in tech control went away
1342;54 power returned
1345 primary power to 141T in tech control went away
1423 Autodin KG13 has resume problem in transmitter , reseated PCBs in KG.
1542Z #4 ARC-89 PA overheat
1544Z #4 ARC-89 PA overheat out.