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Modified A/B45Y-1 Biological Spray Tank System (Phases I, II, and III)

by
J. A. Kemp
HAYES INTERNATIONAL CORPORATION

AUGUST 1966

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**AIR FORCE ARMAMENT LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
EGLIN AIR FORCE BASE, FLORIDA**

MODIFIED A/B45Y-1 BIOLOGICAL SPRAY TANK SYSTEM
(PHASES I, II, AND III)

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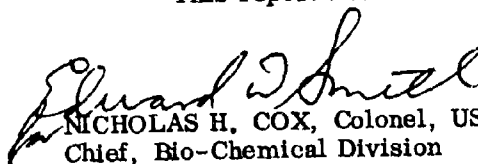
FOREWORD

Under Contract AF 08(635)-4600, Hayes International Corporation modified the existing A/B45Y-1 Biological Spray Tank to incorporate a self-contained electrical power unit capable of operating the tank heater system. This report, authored by Mr. J. A. Kemp, formally records the effort expended under the above contract including design, fabrication, and testing from July 1964 through March 1966.

The cognizant USAF project engineer for this program was Mr. Marshall Solomon representing Air Force Armament Laboratory, Research and Technology Division, Eglin Air Force Base, Florida. Mr. J. L. Harrington, Chief of the Airborne Weapons Group, supervised the program; principal engineers were Messrs. D. Holmes, J. A. Kemp, and F. A. Miller assisted by G. Burson, H. Cromwell, and C. Gaither.

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This report has been reviewed and is approved.


NICHOLAS H. COX, Colonel, USAF
Chief, Bio-Chemical Division

ABSTRACT

The existing A/B45Y-1 Biological Spray Tank was modified to incorporate a wing-driven electrical generator to power the tank heater system, thereby making the tank independent of the carrying aircraft for this service.

The generator was mounted to the nose of the tank using a new aluminum nose cone which interfaced with the existing nose cone attachment points located on the forward bulkhead. Weight and balance was adjusted by the addition of ballast weights attached to the aft bulkhead.

In addition, the tank electrical control circuitry was redesigned to ensure complete operational compatibility of the tank with the existing aircraft control wiring and the variety of umbilical connector types and locations at the numerous pylon stations on the various designated aircraft (F-4C, F-105, F-100).

As modified, the tank was subjected to environmental testing and incurred damage. An analysis of the test data indicated that the generator and its attachments were being subjected to excessive loads due to the flexing of the tank plastic centerbody.

It was concluded that the existing tank structure, which could not be readily modified, did not lend itself to the mounting of additional weight at its extremities.

Consequently, it was decided to limit the modification of the remaining existing tanks, to control circuit and aircraft mating changes only. The Class I drawings were revised to reflect all the changes made during the development of the tank modification, and show the tank structure strengthened to allow for the mounting of a wind-driven generator on future tanks. Wiring was included to give a choice of supplying heater power from either the wind-driven generator or the carrying aircraft.

These modifications were supplemented with the design of a test set to aid in checking out the electrical systems of the tank and the control circuits of the various carrying aircraft at the numerous pylon stations.

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1.0 INTRODUCTION

The purpose of this report is to provide a summary of the activity resulting from work performed on Contract AF 08(635)-4600 with the Air Force Armament Laboratory, Research and Technology Division, Eglin Air Force Base, Florida. Information contained herein pertains to activity during Phase I, II, and III of the contract including design, fabrication, and development testing. The scope of the program called for the modification of the A/B45Y-1 Biological Spray Tank as originally developed by Fairchild Stratos under Contract DA-18-064-AMC-7(A). This consisted primarily of modifying the existing spray tank to incorporate a self-contained electrical power unit capable of operating the tank heater system thereby making the tank independent of the carrying aircraft for this electrical power. The incorporation of the power unit into the tank had to be made with minimum change to the overall tank configuration, total weight, and the original location of the center of gravity. The unit had to have a five year shelf storage life and be capable of operation throughout the entire mission profile of the designated carrier aircraft; F-4C, F-105, and F-100. This modification was supplemented with a review and redesign of the tank electrical control circuit to ensure complete operational compatibility of the tank with the existing aircraft control wiring and the variety of umbilical connector sizes and locations incorporated at the numerous pylon stations on the different aircraft. As modified, the tank retained as many of the existing functional characteristics and components as feasible.

The second part of the program was the design and development of a suitable test set to aid in checking out all the electrical systems of the tank and the control circuits of the various carrying aircraft at the numerous pylon stations prior to operational use of the tank.

The information as presented in Section 2.0 represents a description of the development of the final modified tank design and a summary of the problems encountered, and solutions rendered. This is followed with a description of the development of the test set.

2.0 TECHNICAL DATA

Background

The A/B45Y-1 Biological Spray Tank is an expendable type store which is capable of being attached to and ejected from the F100, F105, and F4C aircraft. In aerodynamic shape, size, and weight, the A/B45Y-1 tank resembles other stores presently carried and ejected from these aircraft. The tank is basically a laminated fiberglass shell in three sections, enclosing a flexible bladder liquid reservoir, a pressurization system, and a liquid control and spray system. Tank operation is electrically controlled from a remote panel. Upon application of the appropriate electrical signals from the panel, heaters may be turned on, pressurization is accomplished, and liquid dissemination initiated or stopped. The heaters prevent freezing of the liquid. The pressurization system introduces air into the cavity surrounding the liquid reservoir, and tends to collapse the bladder. The liquid system controls escape of liquid under pressure from the bladder to the dissemination nozzles. Liquid flow is sensed by a transmitter which returns an electrical signal to the control head and causes a flow indicator light to illuminate. Suspension lugs are provided for attaching the unit to the aircraft. Four fins stabilize the tank aerodynamically and support the spray nozzles. An external electrical receptacle links the tank to the control head and to the aircraft electrical heating equipment. Refer to Figure 1.

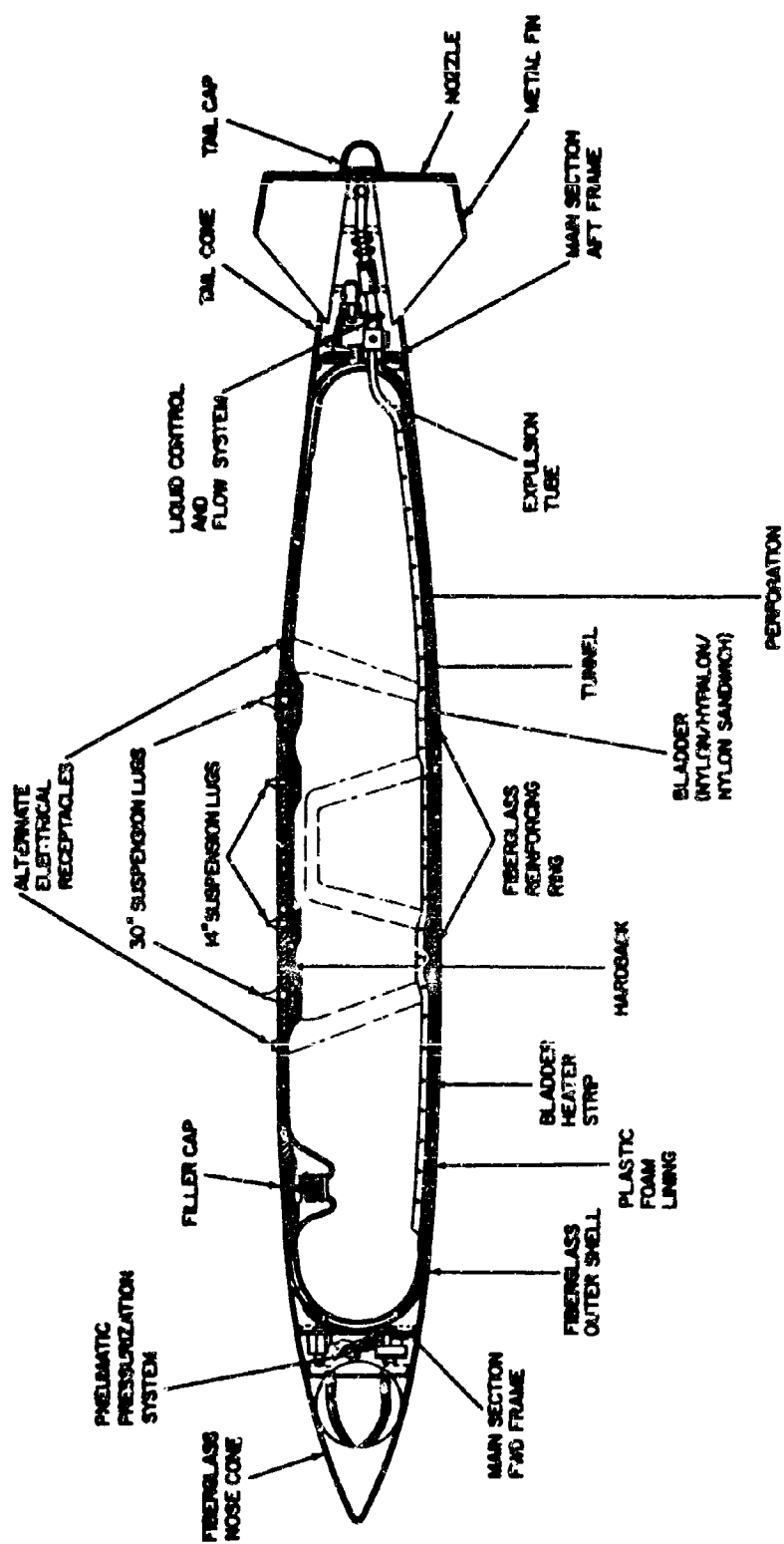


Figure 1 CUTAWAY VIEW, ORIGINAL TANK

At the onset of the program an analysis was made of the original A/B45Y-1 Biological Spray Tank to determine the necessary engineering design changes required for compliance with the customer's request. This analysis of the tank was supplemented with a review of the designated carrying aircraft, F100, F105, and F4C, in order to ascertain the individual aircraft to tank interface details and the existing control circuits available in the aircraft for operating the tank.

The major areas investigated were:

The Tank Control System.

The Tank Heater System.

The Tank Aircraft Mating.

The redesign required in each of these areas is recorded separately to show how each was developed, then all are combined to describe the development of the overall tank modification finally adopted.

2.1 The Tank Control System

2.1.1 Analysis of the Tank Electrical Control Circuit

The electrical control circuit for the original A/B45Y-1 Biological Spray Tank was divided into two distinct and separate halves, located as follows:

That portion installed in the tank.

That portion installed in the carrying aircraft.

The circuit installed in the tank (see Figure 2) was designed to be compatible with the circuit of a universal control panel (see Figure 3) which was intended for installation in the carrier aircraft. Unfortunately, plans to retrofit aircraft with this universal control panel were never carried out resulting in the control circuit in the tank being completely incompatible with the existing wiring available at all the pylon stations for the designated aircraft.

The universal control panel was designed to provide the tank heater power, arming signal and give two types of dissemination control. These were:

Push on, Release off at the Pickle Button

Switch on and Switch off on the control panel

The control panel also included a number of indicator lights including a pilot display dissemination flow indication, operated by the flow indicator located in the tank discharge line. Consequently, the requirement for the redesign of the spray tank electrical control system to make operation possible through the existing aircraft wiring and switches without modification to the aircraft was mandatory.

2.1.2 Analysis of the Aircraft Electrical Control Circuits

A review of the Technical Orders for the subject aircraft was carried out in order to ascertain details of the existing aircraft wiring and switching available at the external store locations for operating the spray tank. Schematic diagrams of these circuits are given in the following figures:

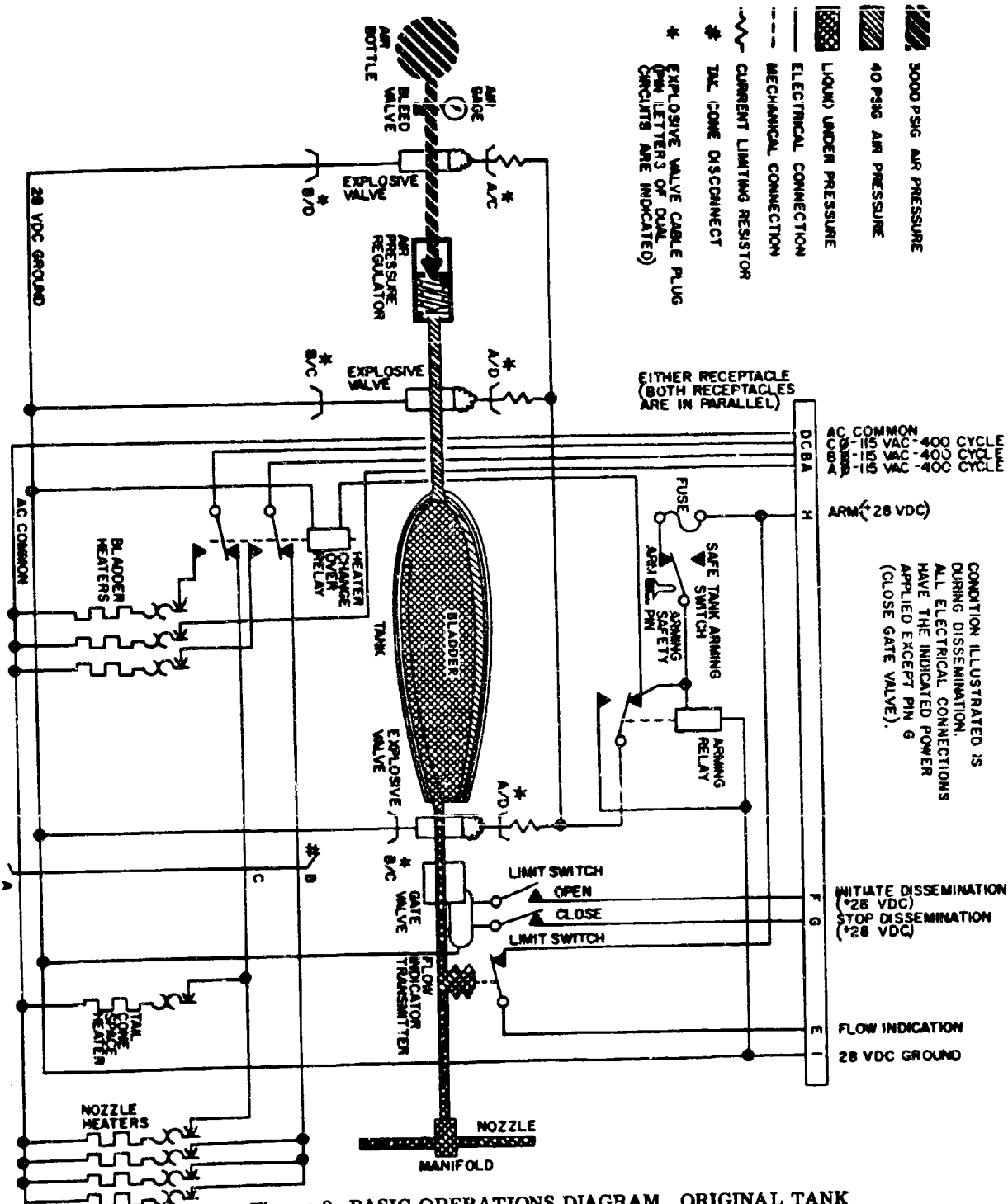


Figure 2 BASIC OPERATIONS DIAGRAM, ORIGINAL TANK

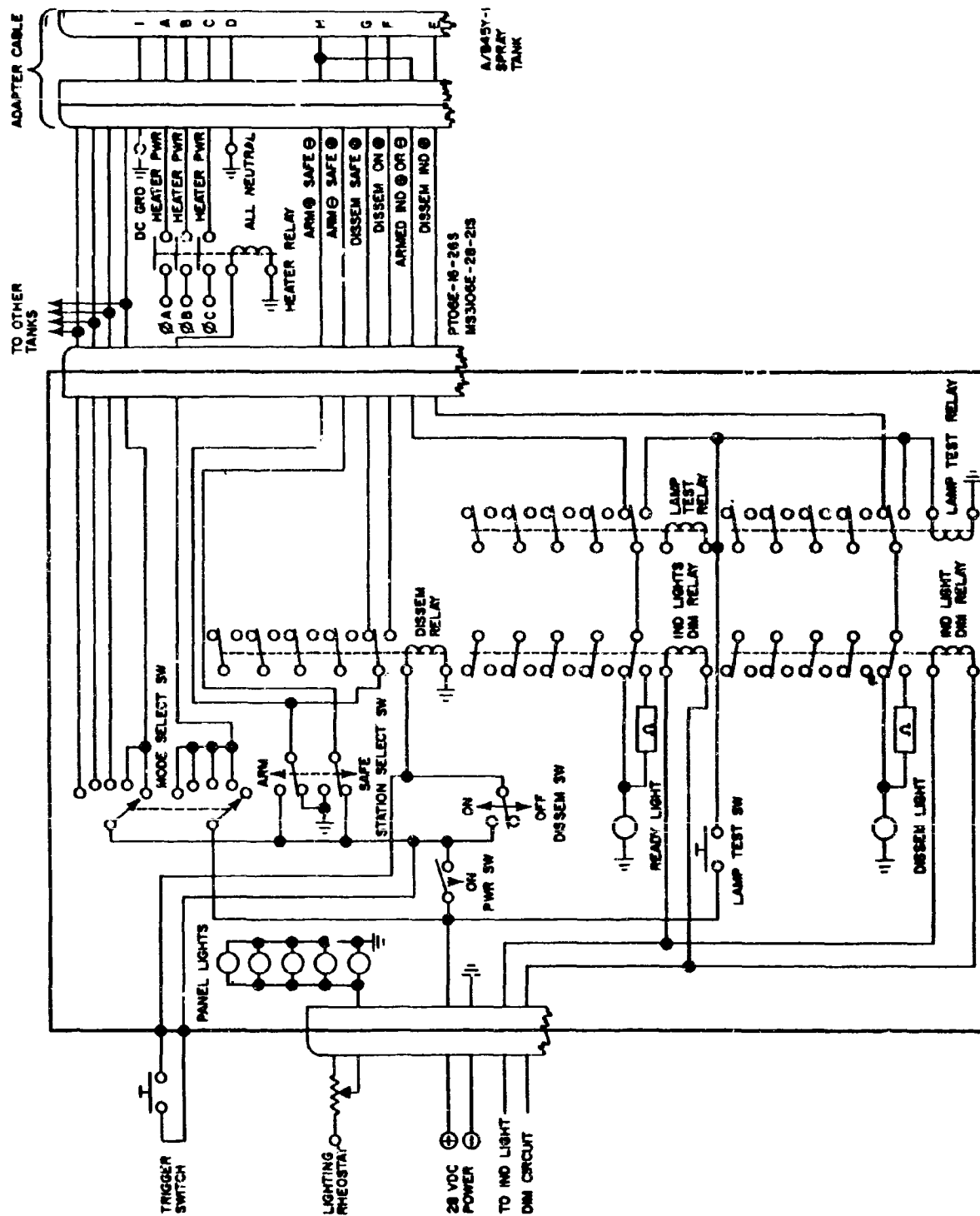


Figure 3 UNIVERSAL CONTROL PANEL WIRING SCHEMATIC

F4C aircraft, see Figure 4

F105 aircraft, see Figure 5

F100 aircraft, see Figure 6

In order to operate the spray tank from all these aircraft, it is necessary that the common portion of the control circuit located within the tank be compatible with each individual aircraft circuit.

A comparison of the circuits for the F4C, F105, and F100 aircraft shows that the following signals are common to all aircraft:

- | | |
|--------------------|--------|
| 1. Nose arm signal | 28 VDC |
| 2. Tail arm signal | 28 VDC |
| 3. Firing signal | 28 VDC |
| 4. Ground | 28 VDC |

Other common features of these circuits are:

The nose and tail arming circuits to each external store location are wired in parallel giving blanket arming to all stations.

The firing signal to each external store location can be selected, either individually, or collectively in a variety of combinations. Uncommon features of these circuits are:

The F4C is the only aircraft fitted with CBU lights, wired to the external store locations which can be used to indicate to the pilot some feature of the store carried at that location. For this aircraft, this light can be used to give an indication of tank dissemination by using this circuit in conjunction with the flow indicator circuit in the tank. Single firing signals on this aircraft are automatically stepped alternately from the left wing to the right wing then repeated.

The F100 and F105 aircraft are equipped with bomb racks which allow for direct jettisoning of the tank from the pylon. Some early versions of the F4C are not equipped in this manner so in order to jettison the tank from these aircraft, the pylon has to be jettisoned. Later versions of the F4C will be equipped with the MAU-12/A bomb rack which will provide a capability for direct jettisoning of the tank.

Further investigation of the aircraft wiring brought to light the fact that while all the wiring was available at the pylon location in the wing of the aircraft, the arming wiring was not carried down through the pylon in some instances and was therefore not available for use with the tank. This was the situation for the Type I and Type III pylons used at all stations on the F100 aircraft and the outboard pylon stations on the F105 aircraft.

In reply to request for the addition of this wiring to these pylons, Tactical Air Command subsequently indicated a favorable response for this modification to all TAC F100 Type III pylons and TAC F105 multi-weapon pylon; (reference ATCB, Mr. Solomon/882-2457, letter to Hayes from Air Force Armament Laboratory). It was decided not to include this change on the F100 Type I pylons as it was intimated that the tank would never be carried at this location on the aircraft.

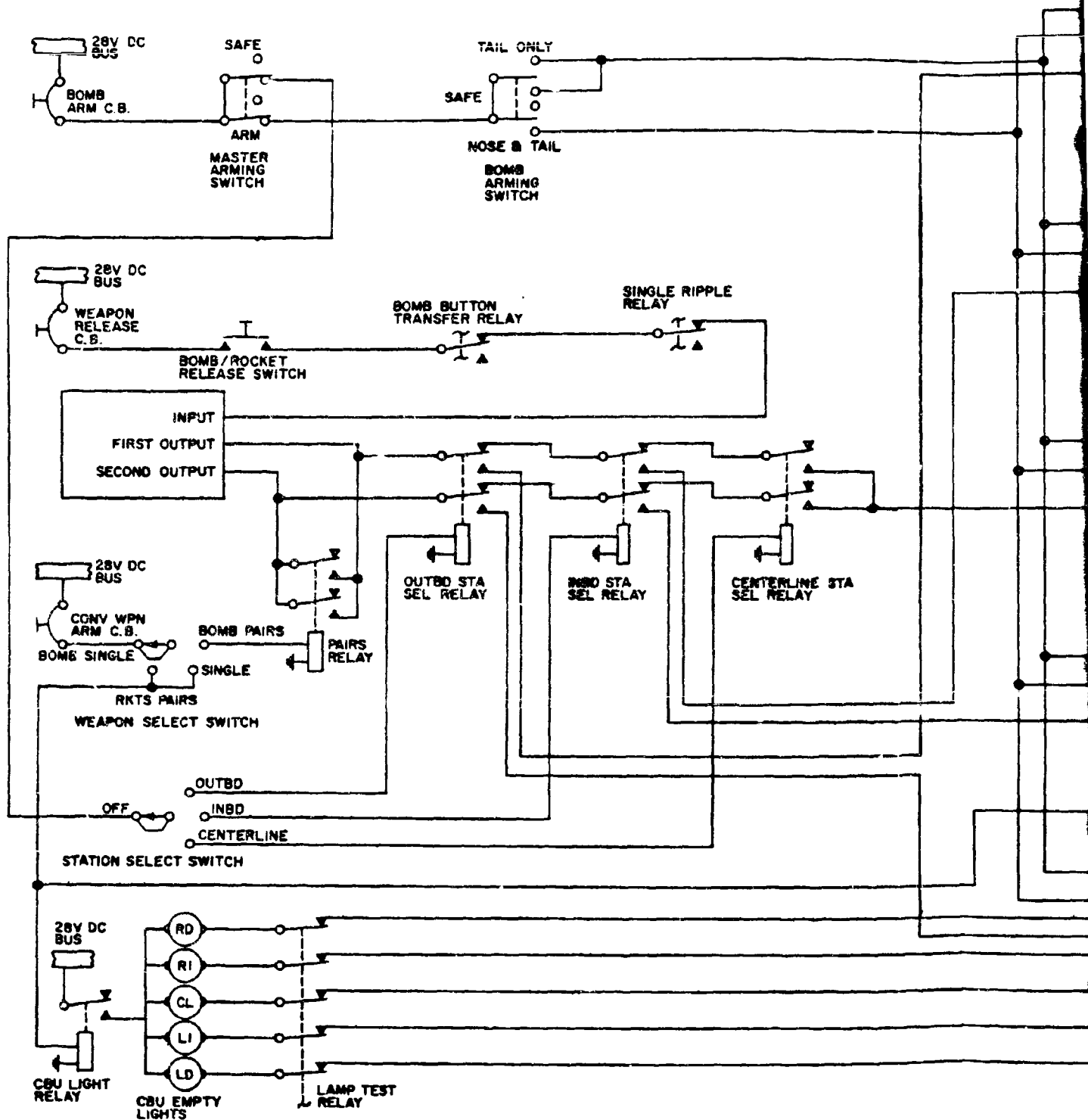
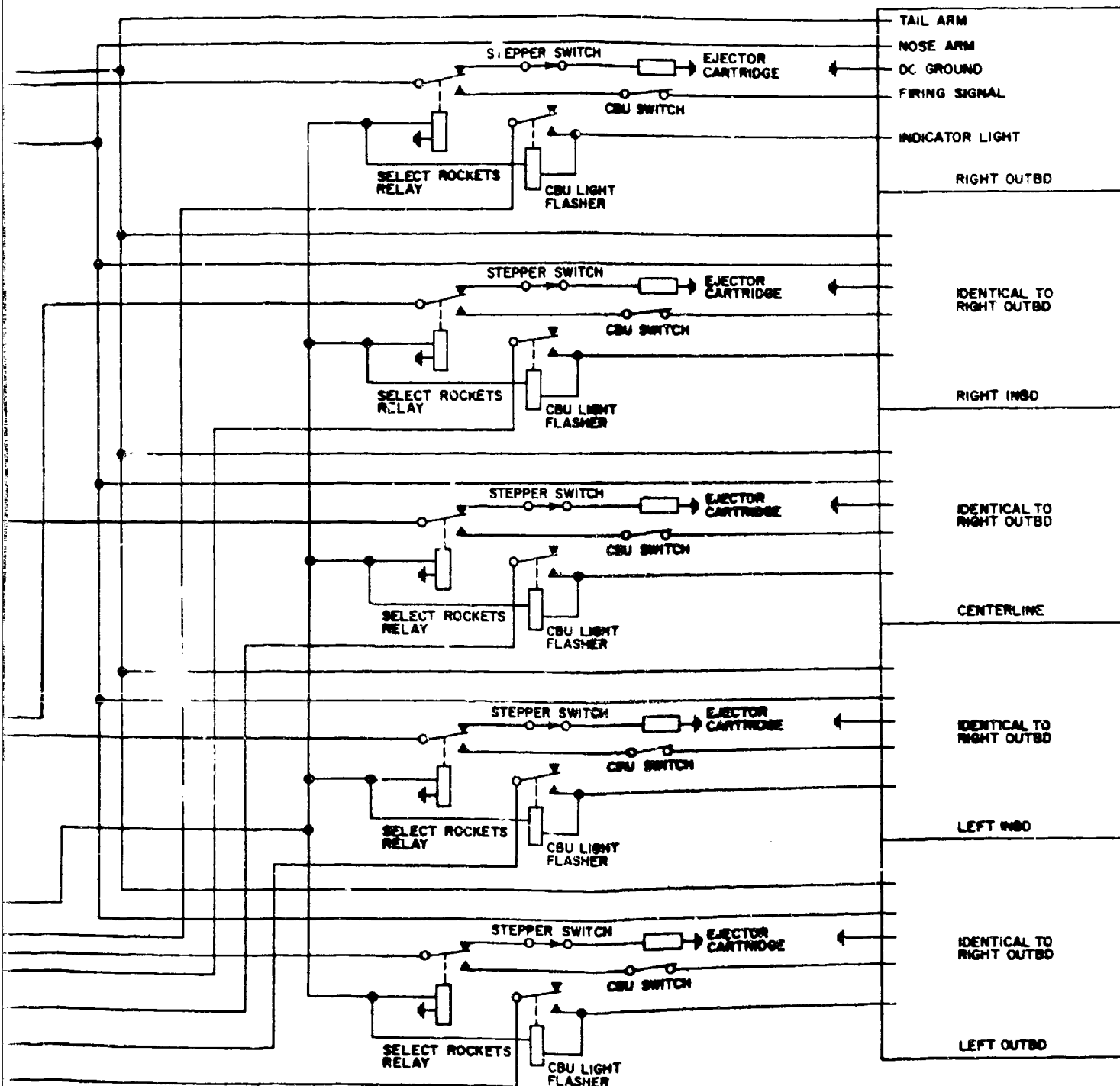


Figure 4. ELECTRICAL CONTROL CIRCUIT, F4C AIRCRAFT



b

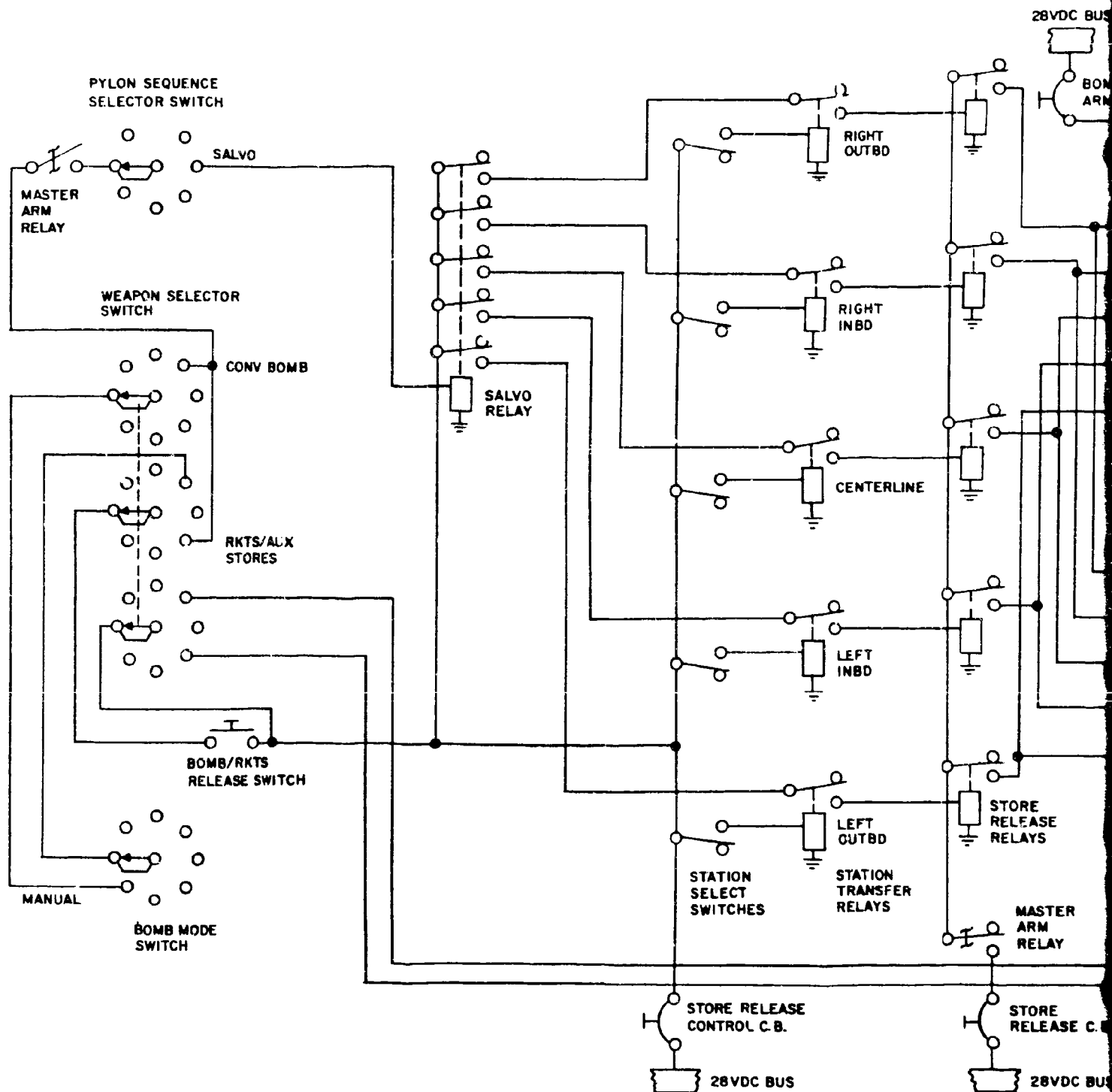
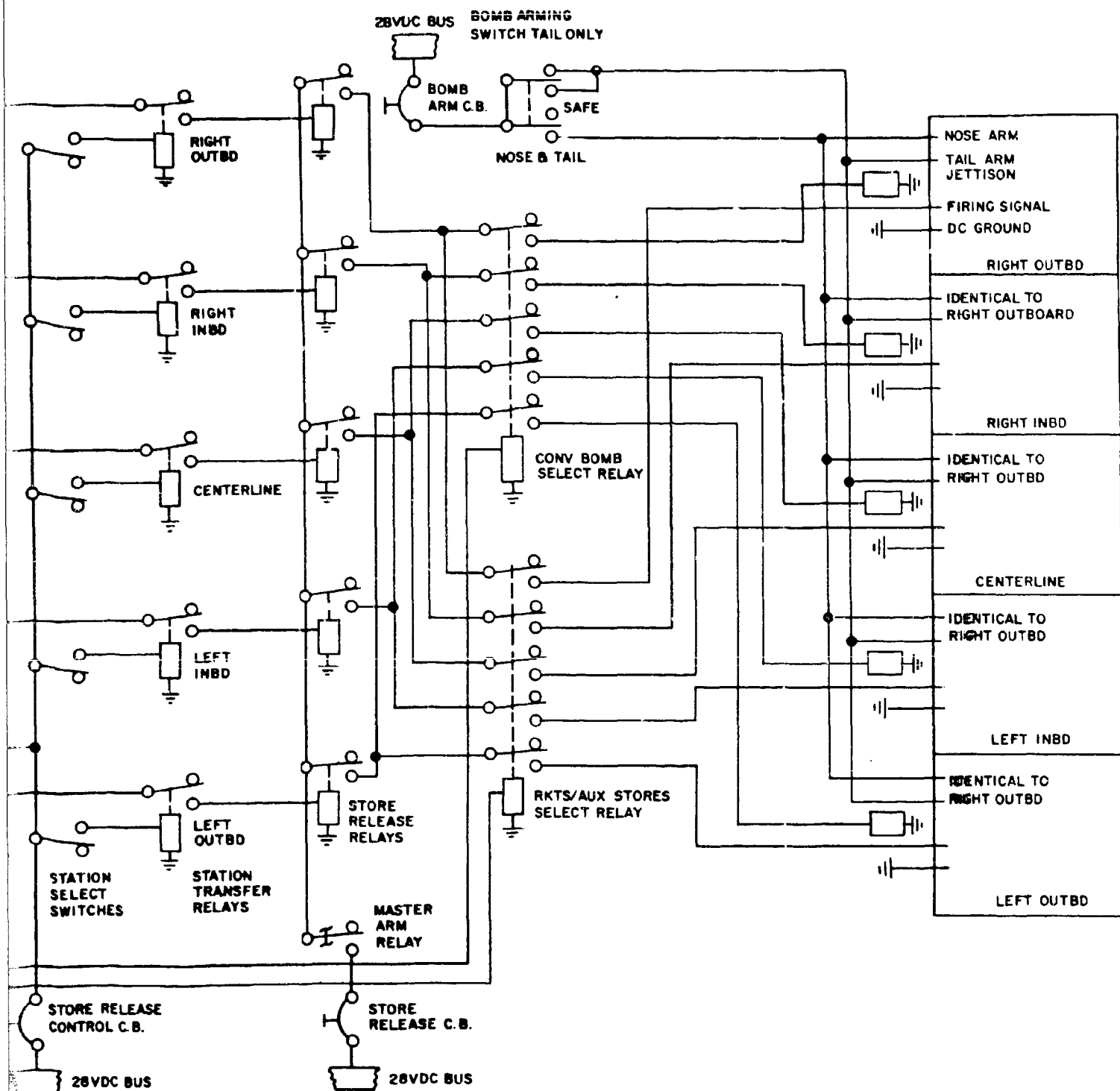


Figure 5 ELECTRICAL CONTROL CIRCUIT, F105 AIRCRAFT

A



F105 AIRCRAFT

B

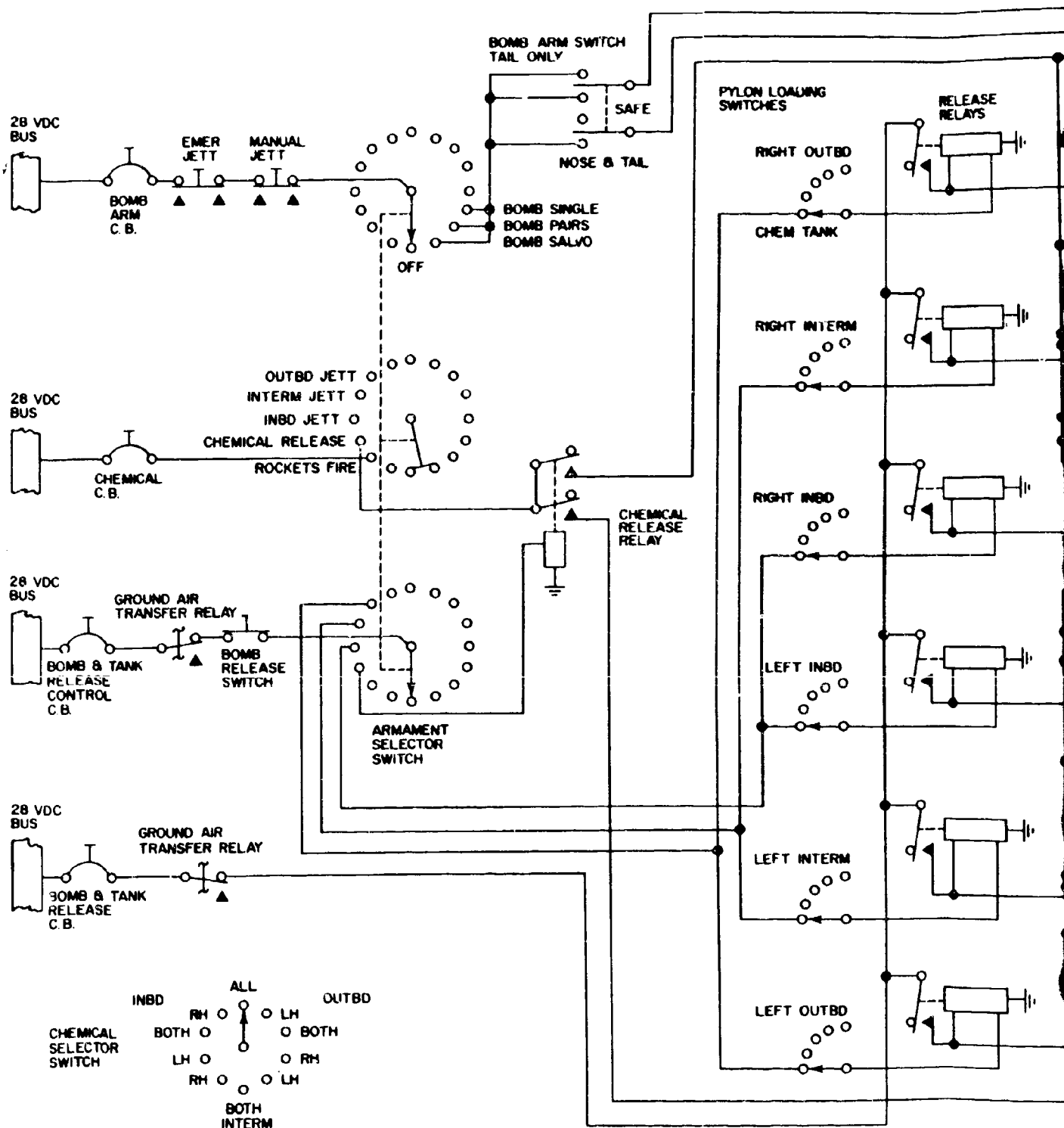
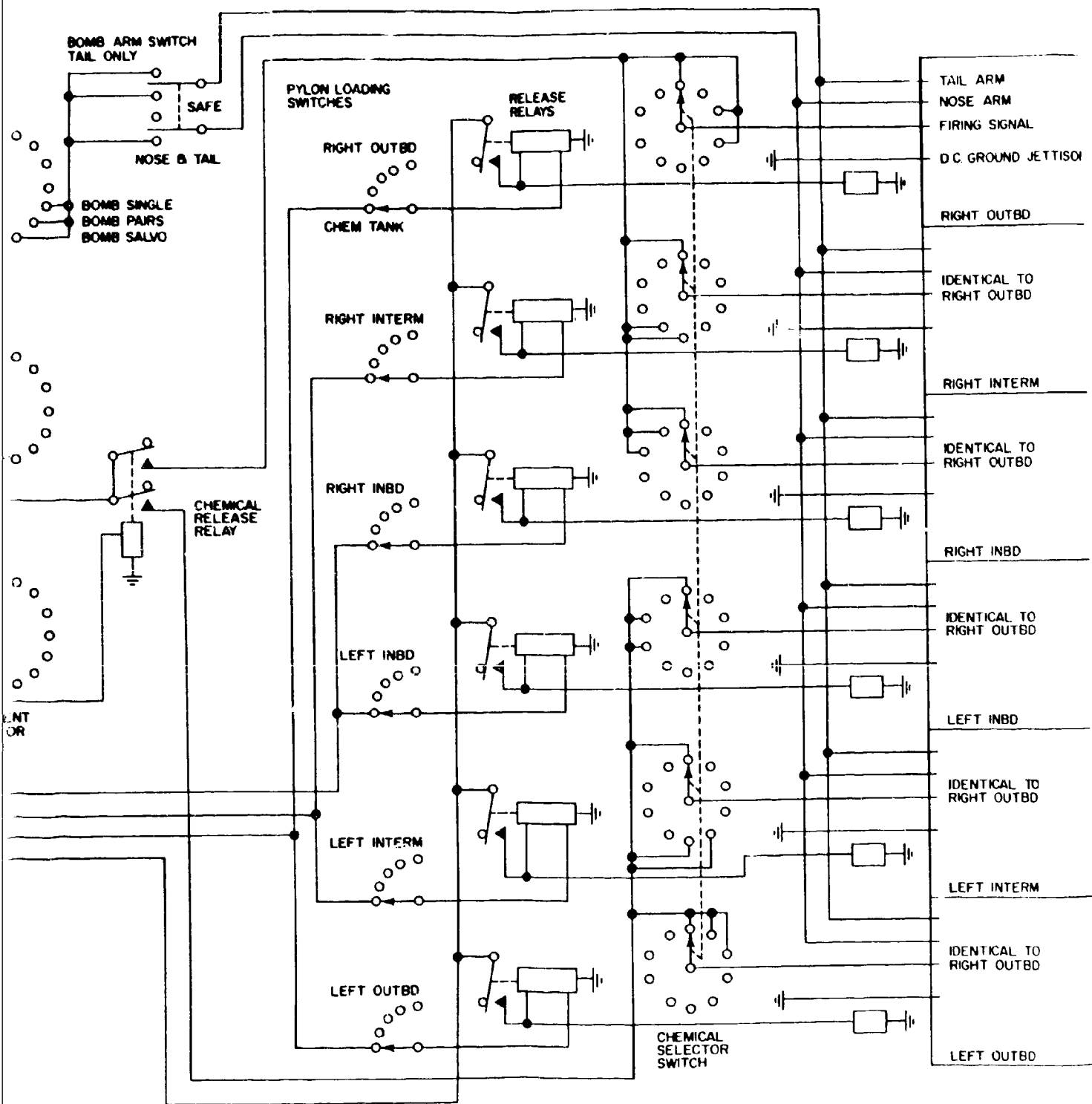


Figure 6 ELECTRICAL CONTROL CIRCUIT, F100 AIRCRAFT



TRICAL CONTROL CIRCUIT, F100 AIRCRAFT

B

Prior to the approval of this modification to the F100 and F105 aircraft to include these wiring changes in their pylons, the design of the electrical control system for the spray tank had to proceed based upon the existing wiring then available. This wiring for these store locations comprised a single signal wire terminated at the chemical binding post operated from the pickle button.

Section 2.1.3 gives a detailed description of the circuit originally designed to cater to this situation and subsequently discarded after the approval of the wiring addition in the aircraft pylons in favor of the control circuit finally adopted.

2.1.3 Development of the Tank Control Circuit

The original approach to the redesign of a new control circuit for the spray tank was based on the following criteria:

1. Only one signal wire was available for operating the tank.
2. The pickle button should be used to start and stop dissemination.
3. It was undesirable for the pilot to have to hold down the pickle button for any length of time (more than several seconds) dictating a preferred requirement for a "push on" - "push off" dissemination control operation.

In order to fully operate the spray tank with the one signal wire available, the wire had to carry five services:

1. The arming signal
2. The dissemination on signal
3. The dissemination off signal
4. 28 VDC power to operate the gate valve motor
5. The dissemination indicator light circuit

A review was made to see which services could be eliminated. It was felt that 28 VDC power to operate the gate valve could, if necessary, be obtained from the generator on board the tank, the requirement being for 50 watts intermittently. Dispense with the indicator light requirement as not all the aircraft had indicator lights that could be used. This reduced the number of services to three, all being controlled from the pickle button:

1. Arming
2. Dissemination on
3. Dissemination off

It was also requested that a second circuit be prepared utilizing the proposed feed through wiring that had been recommended for installation in the Type I and Type III pylons on the F100 aircraft and the outboard pylon of the F105 aircraft should this be approved.

The control sequence for this circuit would be:

1. Arm with the nose and tail arming switch
2. Start and stop dissemination with the pickle button.

2.1.3.1 Initial Control Circuit

Initially, two circuits were designed utilizing the same components (see Figures 7 and 8), thereby allowing the control circuit to be readily converted from one configuration to the other by changing one wire. (The arming wire connected to the gate valve motor limit switch is transferred to the appropriate pin on the electrical control receptacle). This was done so that if the tanks were modified and delivered before receipt of approval for the additional pylon wiring, they could be readily changed in the field.

These two circuits used a stepping switch operated by the pickle button which was set up to alternately open and close the gate valve. During the preflight checkout, the switch is homed either to the "OPEN" or "CLOSED" gate valve position by the test set depending upon which control circuit is used while the gate valve is operated to check functioning and then left in the closed position.

Both circuits utilize 28 VDC power from the aircraft to operate the gate valve rather than using on-board power from the air-driven generator. This was done as the pilot can isolate this 28 VDC from the spray tank until required whereas if it were taken from the on-board generator, 28 VDC would be available from take off and might result in possible inadvertent arming or control operation. Being that the gate valve operating time is of approximately one second duration, the pilot has to keep the pickle button depressed for at least this length of time by making a positive actuation of the pickle button of say, two seconds duration.

Single Wire Circuit - In the single wire circuit, the gate valve and arming circuits are coupled together and interlocked (see Figure 7). The stepping switch is homed to the "OPEN" gate valve position at checkout and the gate valve is closed. This is achieved by the test set as the stepping switch and gate valve are not connected during checkout.

In operation, the pilot switches on the master arm switch and sets the necessary station selector switches. This makes 28 VDC power available at the pickle button. The first pulse from the pickle button steps the stepping switch to the "CLOSED" gate valve position. This puts power on the valve and if the valve is not closed for any reason, it is closed by this power. Activation of the "CLOSED" position limit switch then steers 28 VDC power to the arming circuit and arms the spray tank. This interlock ensures that the gate valve has to be closed before arming can take place.

The second pulse from the pickle button steps the stepping switch to the "OPEN" gate valve position. This opens the gate valve and initiates dissemination.

The next pulse from the pickle button steps the stepping switch to the "CLOSED" gate valve position. This closes the gate valve and stops dissemination. Successive pulses repeat the on-off dissemination control.

Multiwire Circuit - In the multiwire circuit, the gate valve and arming circuits are separated (see Figure 8). The stepping switch is homed to the "CLOSED" gate valve position at checkout and the gate valve is closed. This is achieved by the test set. Operation of the bomb arming switch to the nose and tail position arms the spray tank. The first pulse on the pickle button steps the stepping switch to the "OPEN" gate valve position. This opens the gate valve and initiates dissemination. The second pulse from the pickle button steps the stepping switch to the "CLOSED" gate valve position. This closes the gate valve and stops dissemination. Successive pulses repeat this on-off dissemination control.

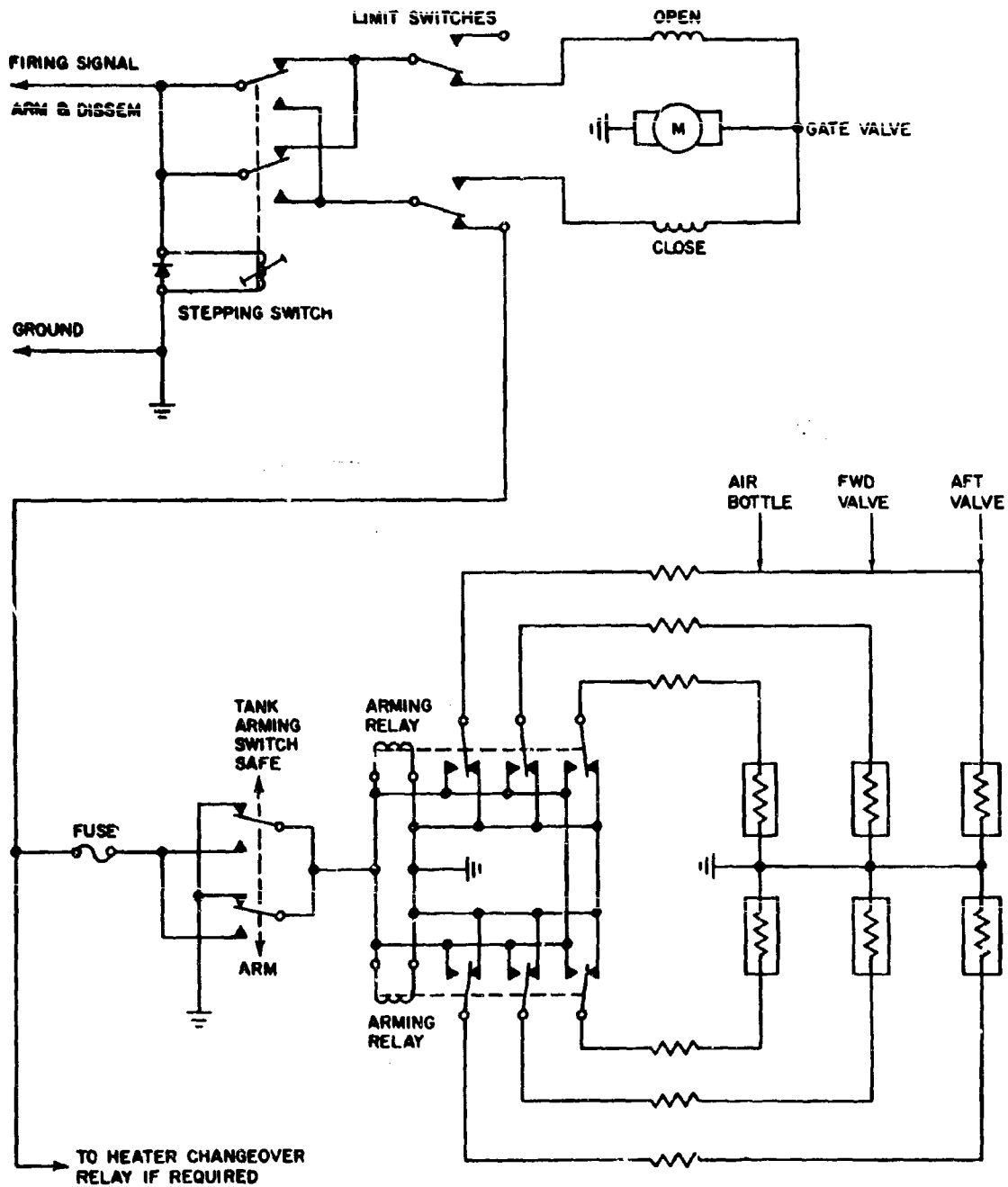


Figure 7 TANK CONTROL CIRCUIT - SINGLE WIRE

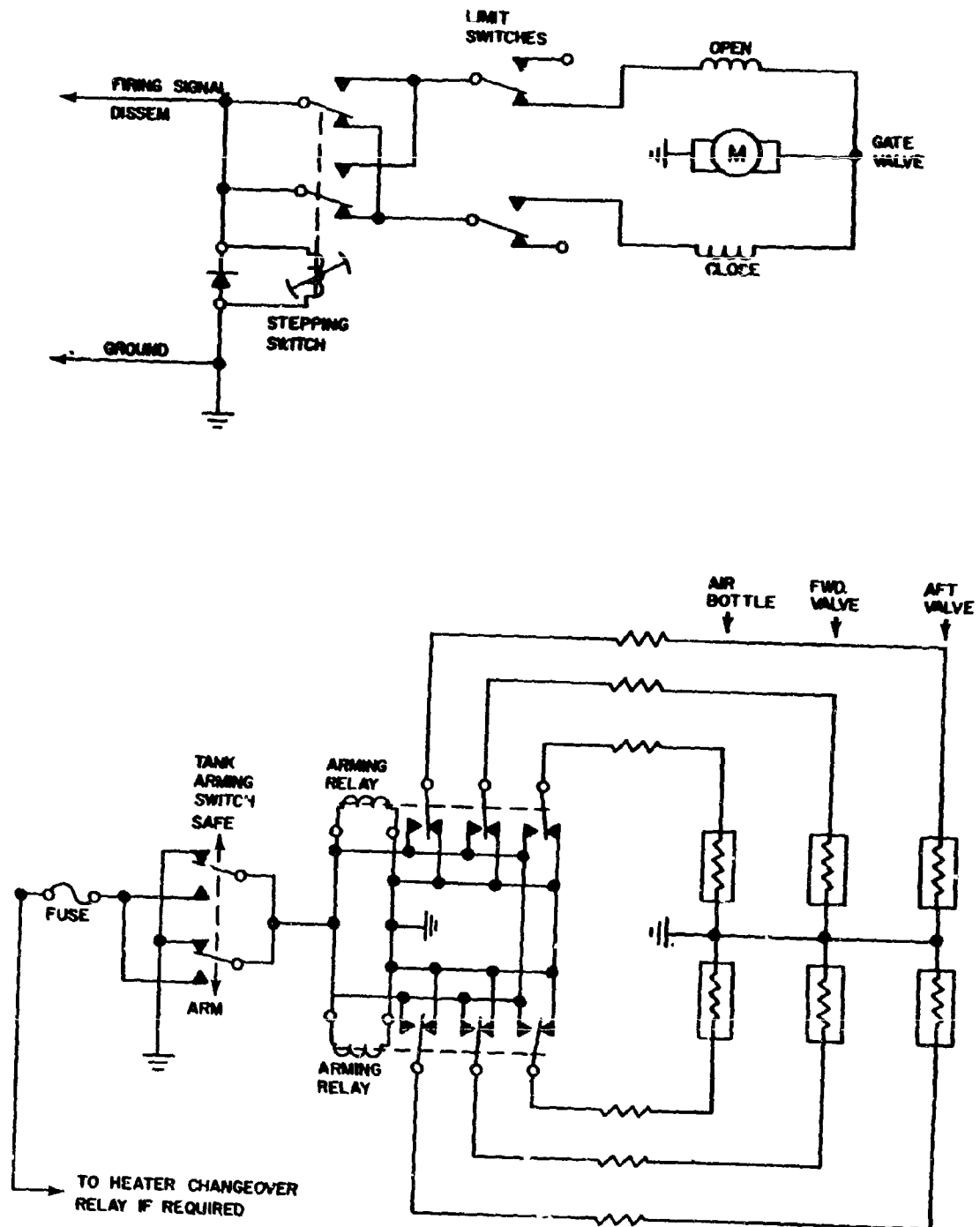


Figure 8 TANK CONTROL CIRCUIT - MULTIWIRE

Approval for the additional wiring in the F100 and F105 pylons was received shortly after these two circuits had been evolved. Initially, the obvious choice was to use the multiwire circuit (see Figure 8), however, as the stepping switch had originally been selected because sequential operation for arming and push on - push off control had been dictated by the single wire circuit, it was decided to review the control system. Problem areas associated with the stepping switch and sequential operation which prompted this review were:

1. The pilot has no indication of tank dissemination (no indicator light), therefore endeavoring to remember the status of the stepping switch will certainly give him some mental gymnastics, using the push on, push off control sequence.
2. The problem becomes even more complex if the pilot has also to switch back and forth between tanks carried at different stations, push reset buttons as can be required on the F4C, and try to keep a mental record of how much time each tank has sprayed or how much spray time is left, or even which tank is spraying.
3. On top of this, the pilot has also to fly the aircraft at low level at night over unfamiliar territory at high speed.
4. Accidental operation of the pickle button could lead to accidental discharge without the pilot knowing it and getting the sequence of operations out of phase.

Because of these problems, it was decided to change the control circuit requirement to give push on, release off dissemination control by the pickle button to ensure that the pilot would have positive indication of dissemination status regardless of the lack of indicator lights as is the case for the F100 and F105 aircraft. Consequently, the circuit was redesigned to incorporate this feature as shown in Figure 9. This was readily achieved by substituting a relay for the stepping switch. Later when it was found possible to eliminate the heater changeover relay from the heater circuit, this existing relay already located on the tank control module was utilized for the control circuit.

It was also decided to provide the necessary wiring for the indicator light circuit as CBU lights were available on the F4C aircraft and would probably be installed on later service aircraft like the F111A and possibly retrofitted on the F100 and F105.

2.1.3.2 Final Control Circuit

The final control circuit (see Figure 9) uses a relay to steer power to the "OPEN" or "CLOSED" windings of the gate valve motor. The normally open contacts of the relay are connected to the "CLOSED" side of the gate valve motor. Power to drive the gate valve motor is taken from the nose-tail arming circuit which is also used to arm the tank. The gate valve relay coil is connected to the pickle button. Depression of the pickle button energizes the relay coil closing the relay contacts which steers arming power to open the gate valve motor. Release of the pickle button de-energizes the relay coil which steers power to close the gate valve. This gives push on, release off dissemination control.

The nose-tail arming switch is energized through a circuit breaker connected in series with this switch on the F100 and F105 aircraft and on the F4C aircraft, the circuit is also directed through the master arming switch located in series between the circuit breaker and arming switch. This gives a minimum of two stage isolation on all aircraft.

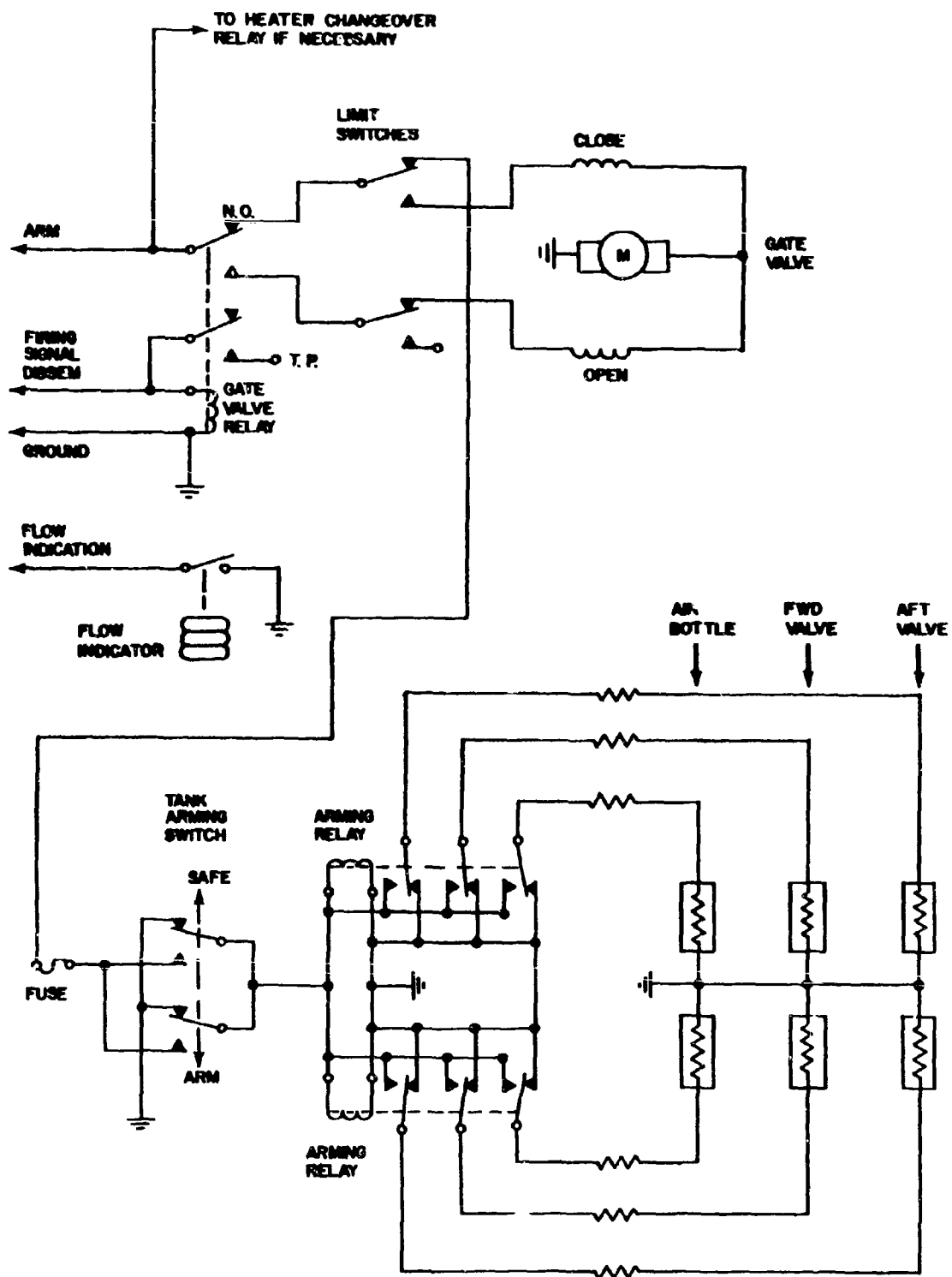


Figure 9 TANK CONTROL CIRCUIT - FINAL CONFIGURATION

The pickle button is connected in series with, and energized through, a circuit breaker and the master arming relay on all three aircraft resulting in a three stage isolation of the pickle button.

The pickle button circuit is used to operate the gate valve relay to steer power to operate the gate valve motor. It is separate from the arming circuit which also provides power to operate the gate valve motor. This ensures that the gate valve cannot be opened unless all five switching operations have been completed.

Energizing the arming circuit provides power which positively closes the gate valve if for some reason it is in any position but closed. Operation of the closed position limit switch then directs power to the tank arming circuit. This ensures that the tank cannot be armed without the gate valve being closed.

2.1.4 Individual Aircraft Operating Procedures

Individual aircraft operating procedures for functioning the A/B45Y-1 Biological Spray Tank are given in Appendix I.

2.1.5 Indicator Light Circuit

The dissemination flow indication circuit to operate the available CBU lights in the F4C aircraft was readily provided by using the existing flow indicator unit to complete the light circuit by wiring it to ground.

A "gone" signal indication can be incorporated by including a jumper between the two appropriate pins in the tank umbilical connector that mates with the aircraft. This requirement was proposed for the F111A aircraft only, and was not originally included in the program. As information is presently unavailable relating to the pylon electrical connectors for this aircraft, no umbilical adapter kits have been provided at this time.

2.2 The Tank Heater System

2.2.1 Analysis of the Original Tank Heating System and the Electrical Power Requirements.

The original tank heating system is made up from:

1. Three (3) bladder heaters
2. Four (4) nozzle heaters
3. One (1) tail cone heater

All heaters operate at 115 volts AC.

Bladder Heaters - Three heater strips 1-1/2 inches wide by 80 inches long are embedded lengthwise in the foam liner of the bladder container along the bottom to the tank. Each heater is capable of dissipating 120 watts and all are controlled by thermostats to maintain the fluid agent temperature between +2°C and +10°C.

Nozzle Heaters - Four spray-on type nozzle heaters, one for each nozzle, which are thermostatically controlled and maintain the nozzle temperature between +2°C and +10°C. Each heater is capable of dissipating a maximum of 75 watts.

Tail Cone Heater - A heater strip one inch wide and six feet long is wrapped spirally inside the tail cone and is thermostatically controlled to maintain a temperature between +4°C and +7°C. The heater dissipates a maximum of 150 watts.

The original tank heater control circuit was wired so that power was only supplied to the three bladder heaters when the tank was in storage and on the aircraft prior to arming.

After the tank was armed, power to two of the bladder heaters was removed and supplied to the nozzle heaters and the tail cone heater, while the remaining bladder heater continued to function.

The maximum power requirements for these two heater configurations was,
Prior to arming:

3 bladder heaters @120 watts each = 360 watts

After arming:

1 bladder heater @120 watts = 120

4 nozzle heaters @75 watts each = 300

1 tail cone heater @150 watts = 150

Total 570 watts

The customer requested investigation of the feasibility of having all the heaters on, all the time the tank was airborne. The power requirement would then be:

3 bladder heaters @120 watts each = 360

4 nozzle heaters @75 watts each = 300

1 tail cone heater @150 watts = 150

Total 810 watts

With this latter configuration it was still desirable to maintain the capability of being able to supply external power to the three bladder heaters only, when the tank was in storage.

2.2.2 Development of the Tank Heater Circuit

The eight existing heaters installed within the tank were wired so that power was only supplied to the three bladder heaters when the tank was in storage or on the aircraft prior to arming. After arming, power to two of the bladder heaters was removed and supplied to the nozzle heaters and tail cone heater and the remaining bladder heater. The circuit was arranged to operate from external three phase power supplied by either the carrying aircraft or a ground source through the umbilical connector (see Figure 2).

The modification to the tank called for the installation of a self-contained power unit to supply this power for the heaters while in flight. The customer also requested investigation of the feasibility of functioning all heaters during the entire flight and additionally have the capability of being able to supply external power to the three bladder heaters while the tank was in storage.

Initially two heater circuits were designed with the final selection of circuit being dependent upon the power available from the self-contained power unit, (see Section 2.2.3).

The first circuit (see Figure 10) incorporated the original heater change-over relay to switch on the tail cone and nozzle heaters at the time the tank is armed as in the original tank heater circuit. This circuit required 360 watts of power prior to arming and 570 watts of power after arming.

The second circuit (see Figure 11) eliminated the heater change-over relay placing all heaters on all the time requiring a total of 810 watts of power.

Both circuits are connected directly to the on-board, 115 VAC three-phase power. For external power, a separate receptacle was located in the tail cone of the tank. The reason for using a second receptacle for this power rather than combining it on the umbilical connector to the aircraft was to allow for the connection of an external power source for heater operation even though the spray tank was mated to the aircraft.

An internal to external power change-over relay was incorporated in the circuit for two reasons. This relay, which is operated by external power when it is connected, isolates the wind driven generator from the heater circuit and ensures that external power is only applied to the three bladder heaters.

With the subsequent modification of the wind driven generator to supply 115 VAC single phase power the initial test results indicated that this configuration would provide the necessary 810 watts. The second heater circuit was adopted because of this and the three phase input connections from the generator were coupled together, (see Figure 12).

2.2.3 Development of the Self-Contained Power Unit

The self-contained power unit originally proposed for installation of the A/B45Y-1 spray tank, was the Hayes International Corporation air-driven generator, Model HIC-90A (see Figure 13), having the following characteristics:

Nomenclature: Air-driven generator, Model HIC-90A, Part Number
500-00689

Blade Diameter: 6.5 inches

Number of Blades: 9

Overall Length: 17.94 inches

Weight: 18 pounds

RPM: 3,000 - 10,000

Frequency: 300 - 1,000 CPS

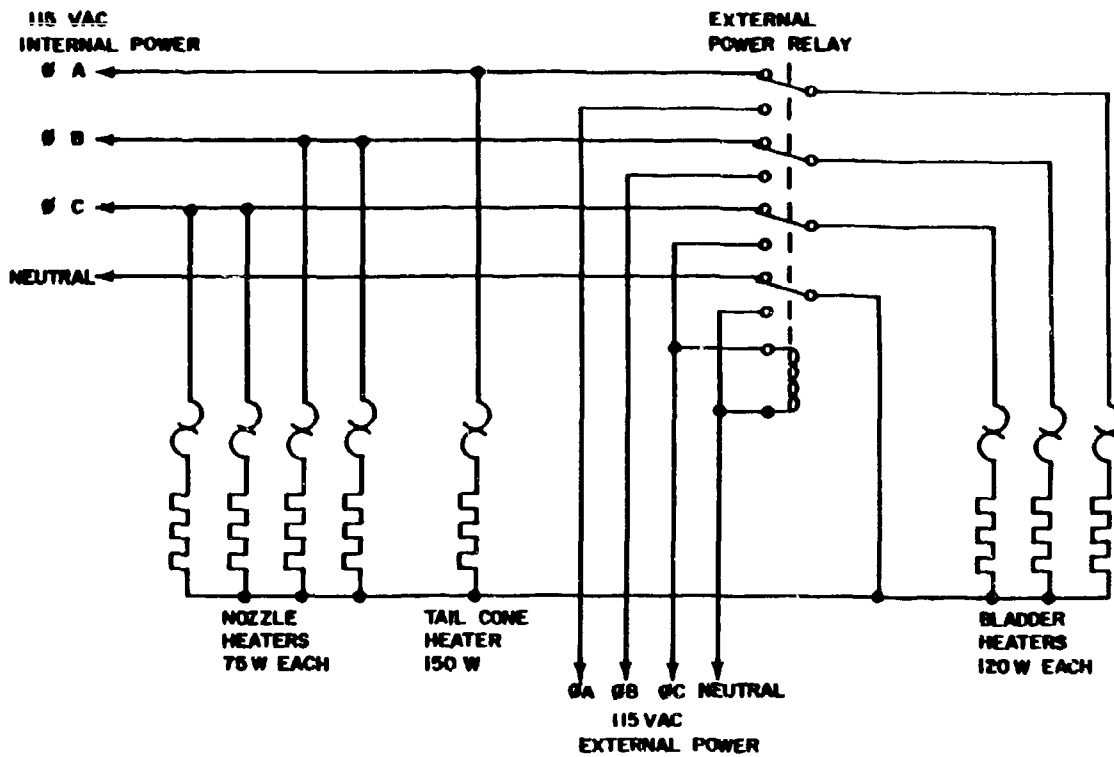


Figure 10 HEATER CIRCUIT WITH CHANGEOVER AT ARMING - THREE PHASE

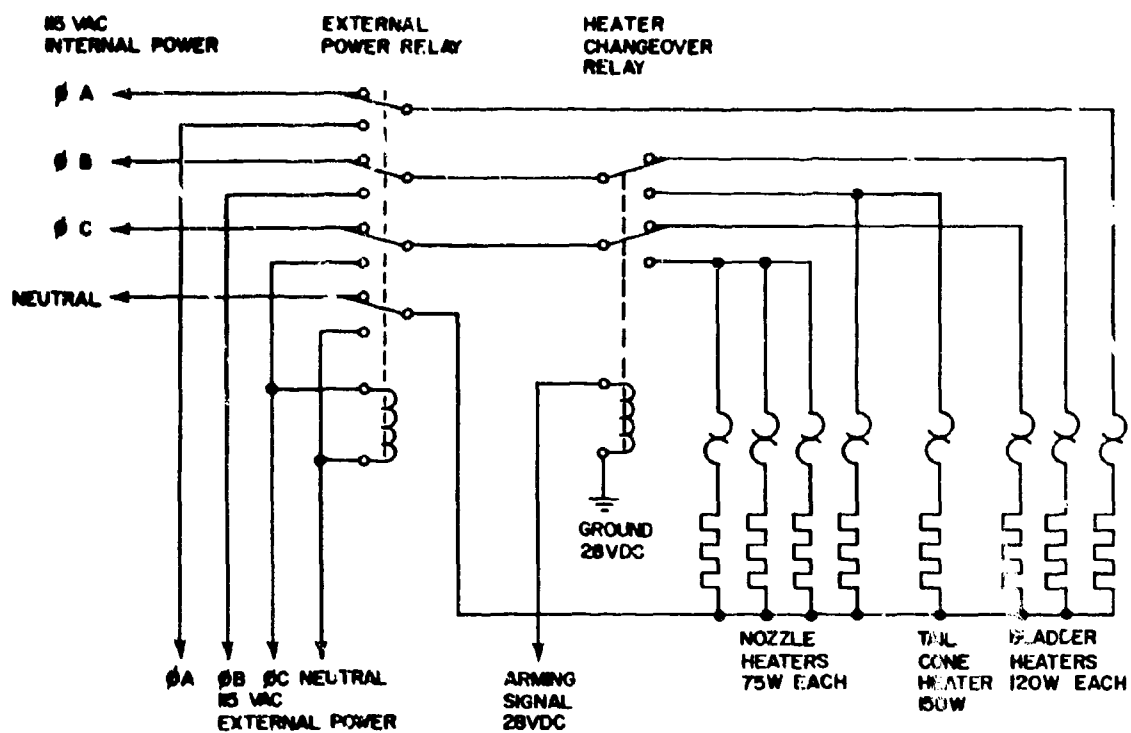


Figure 11 HEATER CIRCUIT WITH ALL HEATERS ON - THREE PHASE

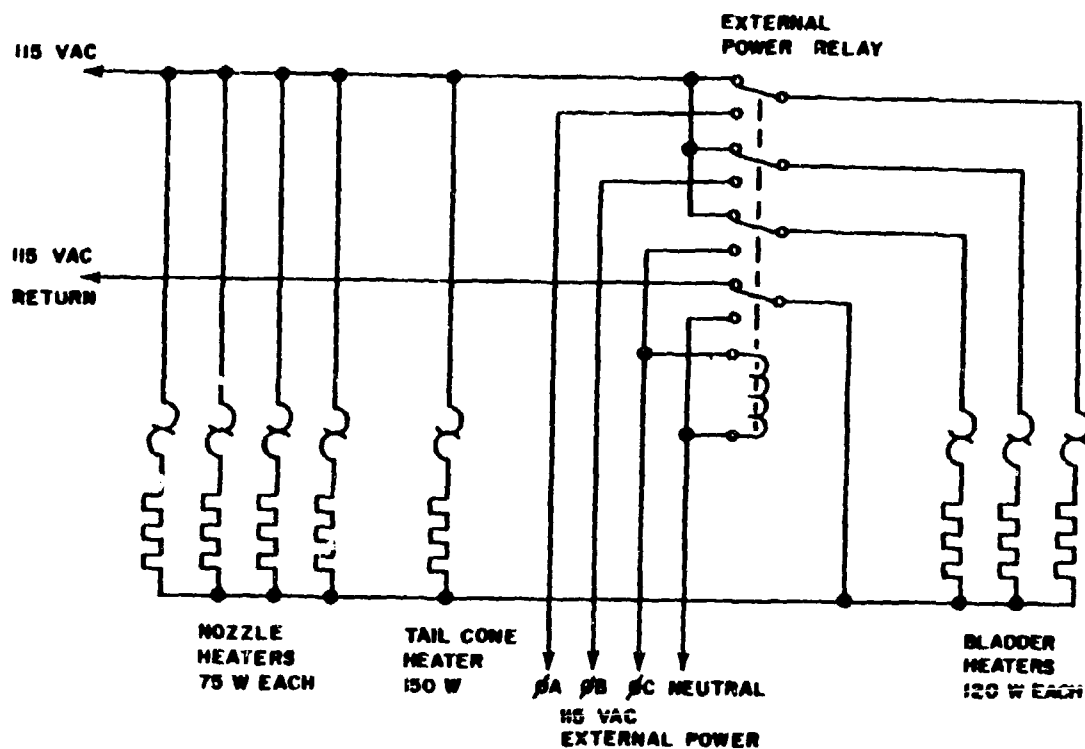


Figure 12 HEATER CIRCUIT WITH ALL HEATERS ON - SINGLE PHASE

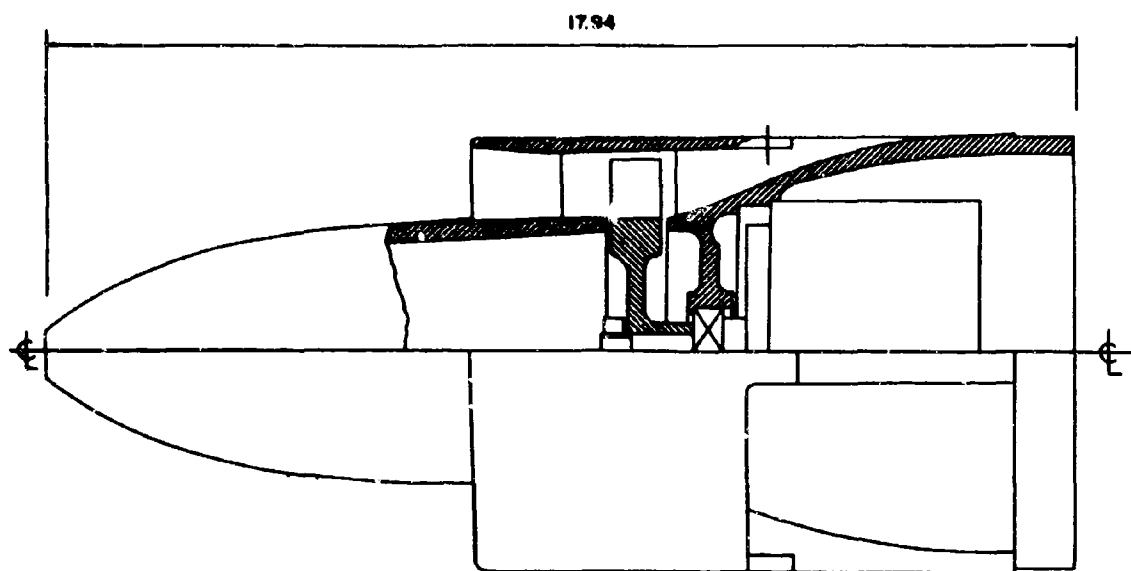


Figure 13 WIND DRIVEN GENERATOR - MODEL HIC-90A

Minimum Airspeed: 250 MPH
Maximum Airspeed: See Figure 14
Voltage: 24 VAC
Power Output: 900 watts

This unit was assembled from a two piece aluminum housing containing the turbine and the generator coupled together by an integral shaft. Rotational drive was provided by a shrouded multi-blade fixed pitch turbine wheel 6.5 inches in diameter. The speed range of the unit was 3000 - 10,000 RPM giving a frequency of 300 - 1,000 CPS. The generator was three phase wye connected having a power output of 900 watts at 24 VAC. The unit had undergone various environmental and calibration tests and had been successfully flown in the TA-9 target. The voltage regulator (see Figure 15), which is an integral part of the unit is basically an electronic switching device. It senses the output voltage from the alternator and supplies the necessary field current for maintaining this voltage. When the output voltage from the alternator rises to a predetermined value, the voltage which appears across the Zener diode is the critical Zener voltage and the Zener diode conducts. This permits current to flow to the base of the first transistor and causes the transistor to turn on and reverse bias a second transistor which turns off the current supplied to the field. When the system voltage drops below the predetermined value, the Zener diode stops conducting, the first transistor turns off, and the second transistor turns on. When this second transistor is turned on, field current is again supplied to the alternator. The operation of this second transistor is effectively like a switch, turning the alternator field current on and off as the electrical output voltage varies due to varying load. This action occurs so rapidly that it cannot be detected in the output. A relay operated by the output voltage is also included in the circuit which cuts out the operation of the regulator until the output voltage has built up to a predetermined value.

In order to meet the heater voltage requirements, it was proposed to use three step up transformers to convert the 24 VAC output from the generator to 115 VAC (see Figure 15). These transformers were to be located in the tail cone of the tank where their weight would help offset that of the added power unit installed in the nose.

At the onset of the program, a review was made of the generator design to see if it were possible to affect a weight reduction that would subsequently detract from the overall weight penalty imposed by the tank modification. The review led to the substitution of magnesium for aluminum as the material for the generator housing and resulted in a unit weight reduction of four pounds.

This weight reduction applicable at the nose of the tank was supplemented by an equivalent reduction in the weight of ballast required in the tail to maintain the original tank center of gravity location resulting in an overall weight saving of eight pounds.

Initially a breadboard of the self-contained power unit and heaters was assembled in order to bench test the overall power system. A resistor bank with appropriate switching, was used to simulate the various load combinations of the thermostatically controlled heaters. Power to rotate the generator was provided by a three horsepower electric motor through a vee belt drive and a variety of pulley combinations. The object of this bench test was to determine the power output and the efficiency of the generator transformer combination, and aid in the final selection of the heater circuit (see Figures 10 and 11), the requirements being 570 watts and 810 watts, respectively.

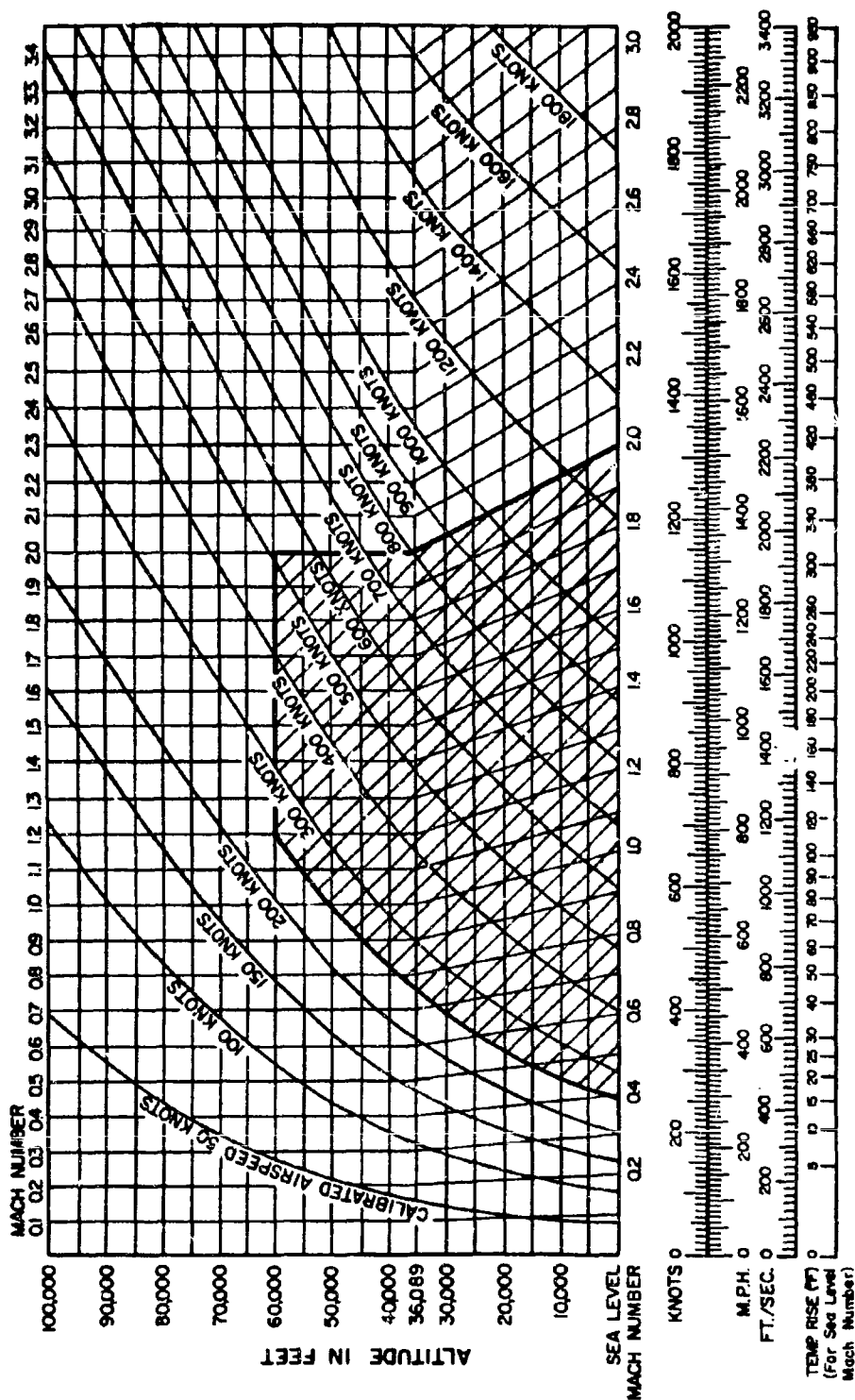


Figure 14 PERFORMANCE ENVELOPE - HAYES WIND DRIVEN GENERATOR
MODEL HIC-90A

The bench test was supplemented by a captive flight test program, the object being to determine the performance and power rating of the turbine, alternator combination. In all, a total of approximately five hours captive flight testing was carried out. The flight test unit was coupled to a resistor bank equipped with a programmer to step the applied load through the range of required design loads. An on-board tape recorder and telemetry transmitter provided information on the alternator speed. A knowledge of the airspeed and altitude together with alternator speed and calibration curves provided all the necessary information for determining the power unit capabilities.

The programmer operated through one complete load cycle each eight minutes, which dictated the duration of the test run at each altitude and speed combination. A total of eight altitude speed runs were accomplished on each flight mission as shown in Table 1.

<u>RUN</u>	<u>ALTITUDE</u> <u>(ft)</u>	<u>SPEED</u>	<u>MACH</u> <u>NO.</u>	<u>DURATION</u>
1	3,000	200 KIAS	0.3	8 Minutes
2	3,000	340 KIAS	0.52	8 Minutes
3	3,000	450 KIAS	0.7	8 Minutes
4	20,000	200 KIAS	0.45	8 Minutes
5	20,000	300 KIAS	0.67	8 Minutes
6	20,000	420 KIAS	0.9	8 Minutes
7	36,000	200 KIAS	0.6	8 Minutes
8	36,000	300 KIAS	0.9	8 Minutes

TABLE I CAPTIVE FLIGHT TEST CRITERIA

The major results from these two test programs indicated the following:

1. The turbine alternator combination was capable of providing at least 900 watts of power.

2. Because the turbine alternator speed varies, since the unit does not incorporate a constant speed unit, it readily became apparent that the power loss in the transformer conversion would be as high as 15% due to the swinging frequency. The physical size of the transformers would also dictate extensive modification of the spray tank tail cone in order to package them in this location.

3. As the heaters are individually thermostatically controlled, the total load would vary randomly and this could be applied assymmetrically between phases creating a phase unbalance condition. The design of the regulator (see Figure 15) was such that the sensed output voltage was the average of the rectified outputs from the three individual phases. Consequently, a no load condition on one or more phases would produce a larger sensed voltage resulting in a reduced field current being supplied by the regulator to the field exciter winding resulting in a reduction of the output voltage and power delivered by the loaded phase or phases. As the turbine was capable of providing at least 900 watts of power, which exceeded the maximum demand of 810 watts required by the preferred all-heater-on-all-the-time condition, it was decided to eliminate the transformers because of their possible 85% efficiency and to rewind the alternator to provide a 115 VAC single phase output. Single phase was chosen to eliminate the three phase unbalance problem. Consequently, the self-contained power unit circuitry was redesigned as shown in Figure 16.

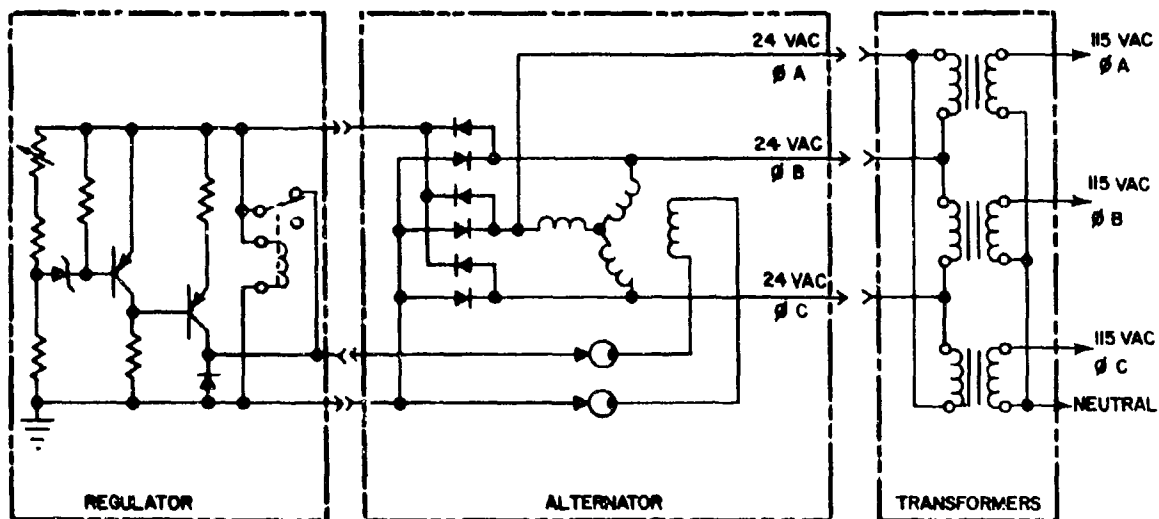


Figure 15 115 VAC THREE PHASE POWER SUPPLY

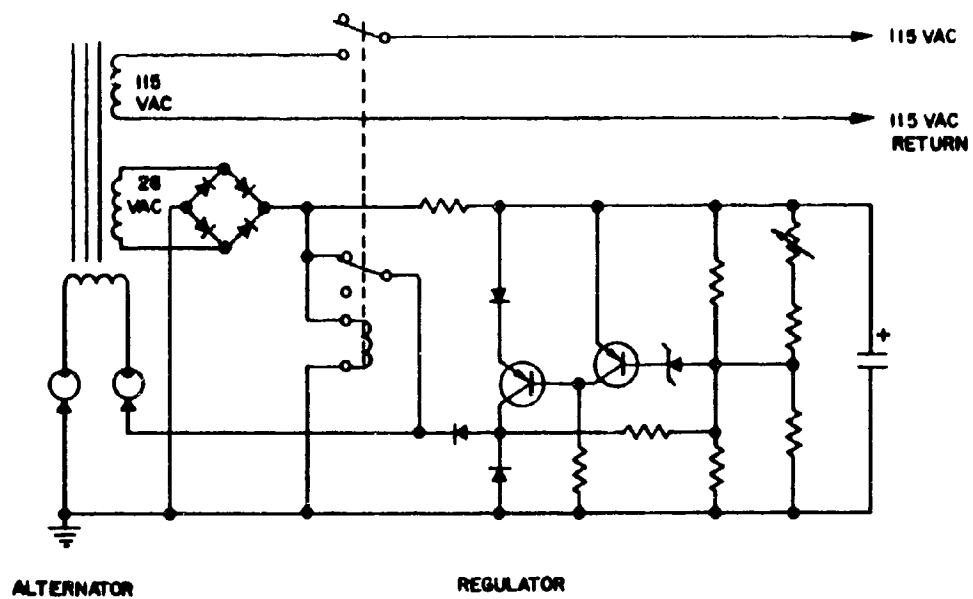


Figure 16 115 VAC SINGLE PHASE POWER SUPPLY

It was also decided to increase the number of blades on the turbine wheel to eighteen (18) in order to improve the characteristics of the turbine at low airspeeds.

A unit of this configuration was assembled and subjected to bench testing. An output of 1100 watts was obtained at 8800 RPM. As a result of these tests, it was decided to utilize the second set of contacts on the regulator relay to isolate the 115 VAC output load until the field current had built up in order to improve the starting up characteristics.

This configuration of the power supply was initially adopted and produced to meet the hardware requirements of Phase II, altogether a total of six functional and two dummy units were built. Three of the functional units were destined for further testing. One of these units was forwarded to WYLE Laboratories, Huntsville, Alabama, for environmental testing and two units were forwarded to the Arnold Engineering Development Center, Tullahoma, Tennessee, for wind tunnel testing.

2.2.3.1 Environmental Testing

The environmental tests carried out on the unit forwarded to WYLE Laboratories were:

1. Vibration test per procedure 4.2 of MIL-T-5442
2. Shock test per procedure 4.3 of MIL-T-5442
3. Temperature shock test per procedure 1 of MIL-E-5272
4. Performance and functional test subsequent to each of the above tests

The testing took place during the period 21 October through 24 December 1964 and was completed successfully.

Detail data relating to these tests is contained in WYLE Laboratories Report, Job #40323, (Reference #1.)

2.2.3.2 Wind Tunnel Testing

For this test program, the unit was assembled without the regulator installed as this was located outside the tunnel during the test program in order to facilitate the recording of various data. These units were also equipped with a spray tank nozzle cone in order to correctly simulate the air flow through and around the turbine.

The curves presented in Figures 17, 18, and 19, present a summary of the significant results obtained during the wind tunnel testing. Data were obtained at simulated flight conditions within a MACH number range of 0.4 to 1.29 at altitudes ranging from sea level to 40,000 feet. The tests were conducted during the period January 13 through February 5 1965 in propulsion engine test cell (T-1) of the rocket test facility.

The initial test of the program was made at pressure altitudes from 10,000 feet to 40,000 feet and MACH numbers from 0.4 to 1.0. The alternator output was found to be much lower than the desired 900 watts, hence modifications consisting of a new alternator field exciter winding, addition of an output to field voltage feedback circuit and a longer turbine inlet shroud were designed and incorporated by Hayes personnel to improve system performance. Comparative data showing system performance with each

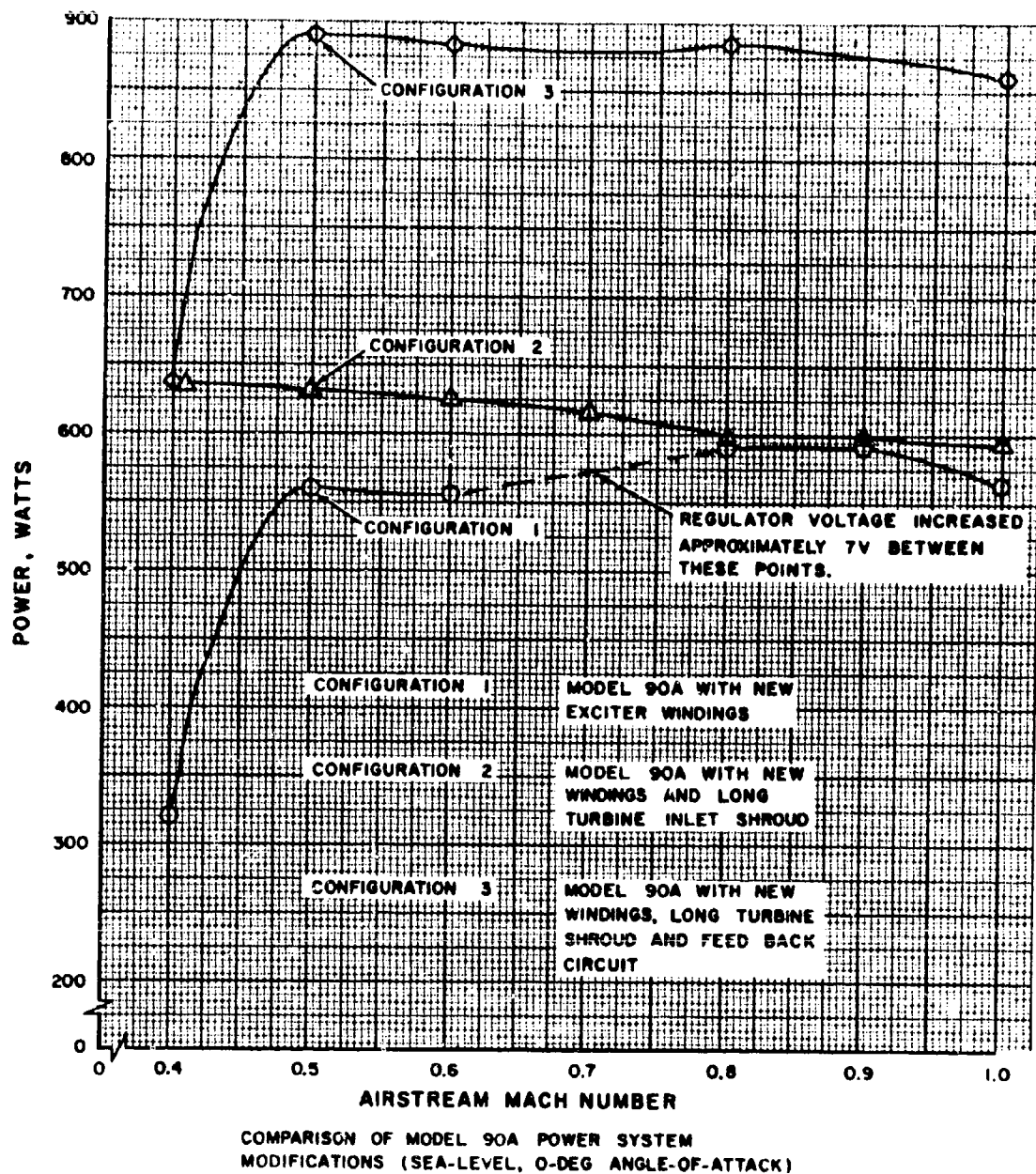


Figure 17 COMPARISON OF MODEL 90A POWER SYSTEM

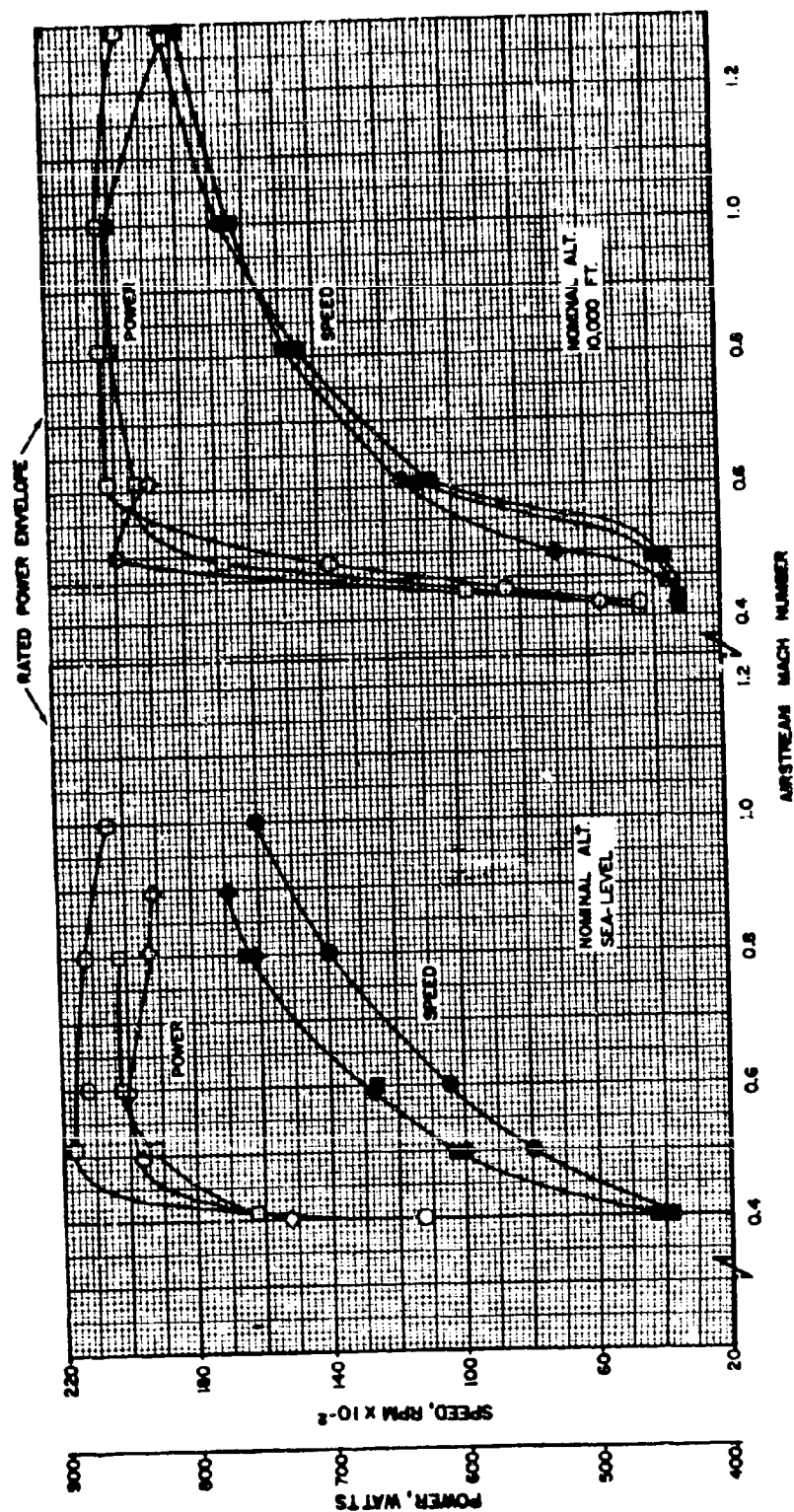
SYMBOL

ANGLE-OF-ATTACK

○ DEGREES

□ 4 DEGREES

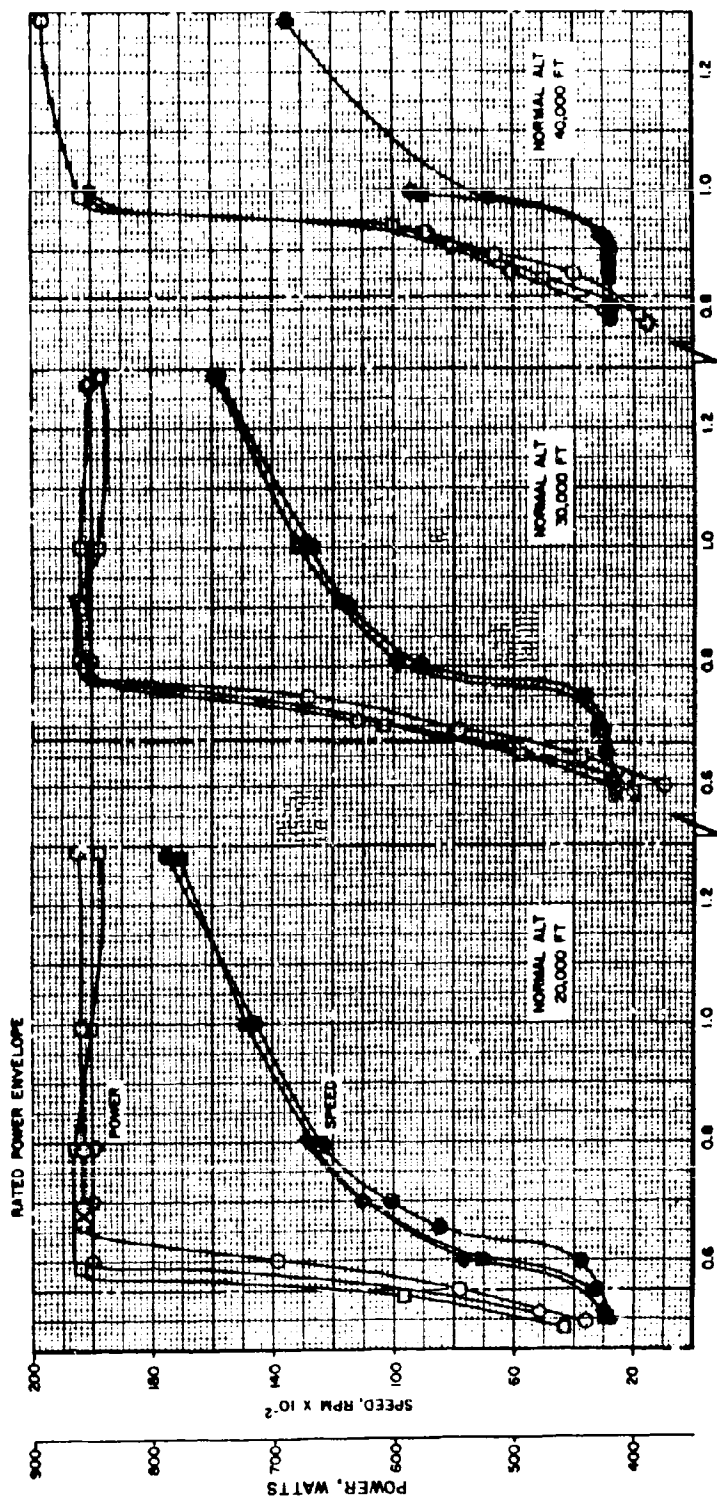
◇ 8 DEGREES



FULL-LOAD PERFORMANCE OF THE CONFIG. 3, MODEL 90A POWER SYSTEM

Figure 18 FULL LOAD PERFORMANCE OF CONFIGURATION 3, MODEL 90A POWER SYSTEM

SYMBOL ANGLE OF ATTACK
 ○ 0 DEGREES
 □ 4 DEGREES
 ◇ 8 DEGREES



AIRSTREAM MACH NUMBER

Figure 19 FULL LOAD PERFORMANCE OF CONFIGURATION 3, MODEL 90A POWER SYSTEM -
 CONTINUED

modification at sea level conditions, 0 degrees angle of attack are shown in Figure 17. The modifications improved performance significantly and the remainder of the test program was conducted with the configuration 3 power unit (new exciter field winding, addition of feedback and longer turbine shroud).

The data obtained with the configuration 3 system at 0, 4, and 8 degree angle of attack at four pressure altitudes are shown in Figures 18 and 19. Performance data consisting of alternator output power and speed are shown for each test condition. Except for sea level 0 degree angle of attack, all data were obtained with the alternator loaded with nine 125 ohm resistors plus one 100 watt bulb. When the sea level 0 degree angle of attack data were obtained, a faulty voltmeter imposed an approximate 45 watt additional load on the alternator. This probably accounted for the high power output although the additional 45 watts should not drop the alternator speed as much as indicated. The fact that these data were obtained with a slightly different turbine wheel than the remainder of the data were obtained with, could also contribute to the speed difference.

System performance relative to the test rated output power envelope shown on each curve is marginal in the low MACH number regions at all altitudes. It was not attempted to obtain the rated power of 900 watts at the high MACH number by using additional loads although adequate speed was available. However, it should be pointed out that the maximum rated requirement for the alternator application is 810 watts while 900 watts was established purely as a test requirement feature.

The data presented in Figures 18 and 19 were obtained with an alternator no-load output voltage maintained by the voltage regulator at a nominal value of 114 VRMS. In most cases the voltage drop between the alternator no-load level and maximum power was approximately 7 volts. The maximum alternator no-load speed of 19,020 RPM was recorded at MACH number 1.29, 10,000 feet altitude, 0 degree angle of attack.

Structural integrity of the power system was adequate except for one test during which turbine blade failure occurred. This part had accrued a total running time of 47 hours and a post test metallurgical analysis indicated that the failure was caused by metal fatigue.

The test results shown in Figures 18 and 19 are based on partial analysis of the test data contained in the Arnold Engineering Development Center Test Report Project Number RA 0512, (Reference #2.)

Final analysis of this data is contained in Arnold Engineering Development Center Document No. AEDC-TR-65-112, "A Performance Evaluation of the A/B45Y-1 Biological Spray Tank Electrical Power System at Simulated Flight Conditions", (Reference #3.)

The alternator configuration showing the extended shroud added during the wind tunnel test program and the revised regulator circuits are shown in Figures 20 and 21.

This configuration and circuit was adopted for inclusion on the remaining Phase II hardware, existing units being retrofitted to incorporate the changes.

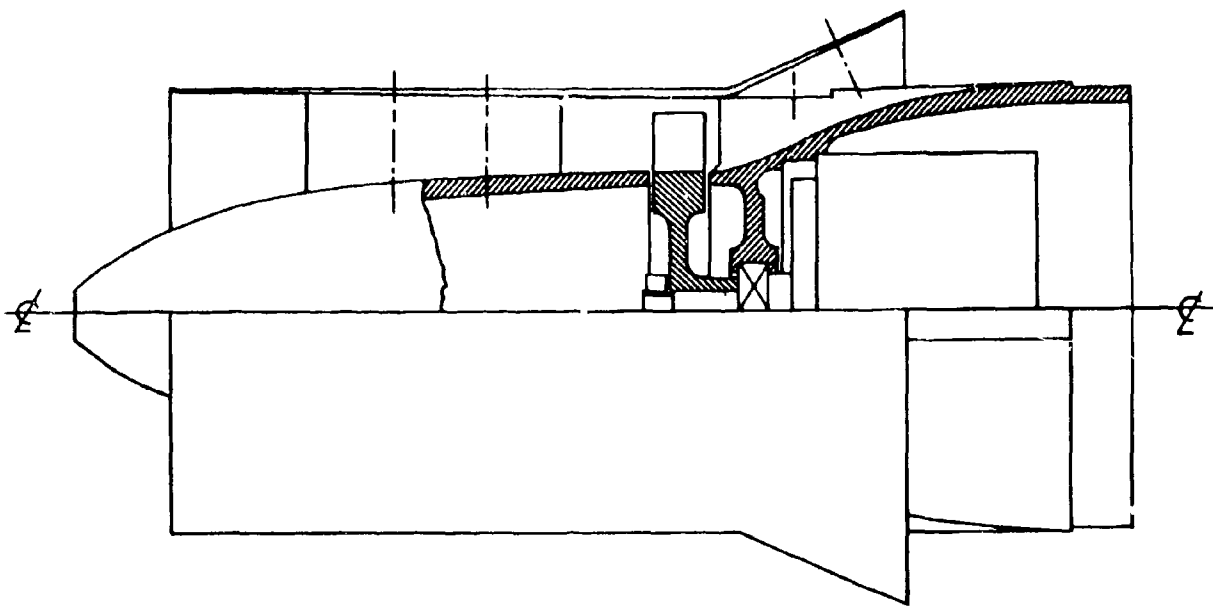


Figure 20 SHROUD EXTENSION - WIND DRIVEN GENERATOR,
MODEL HIC-90A

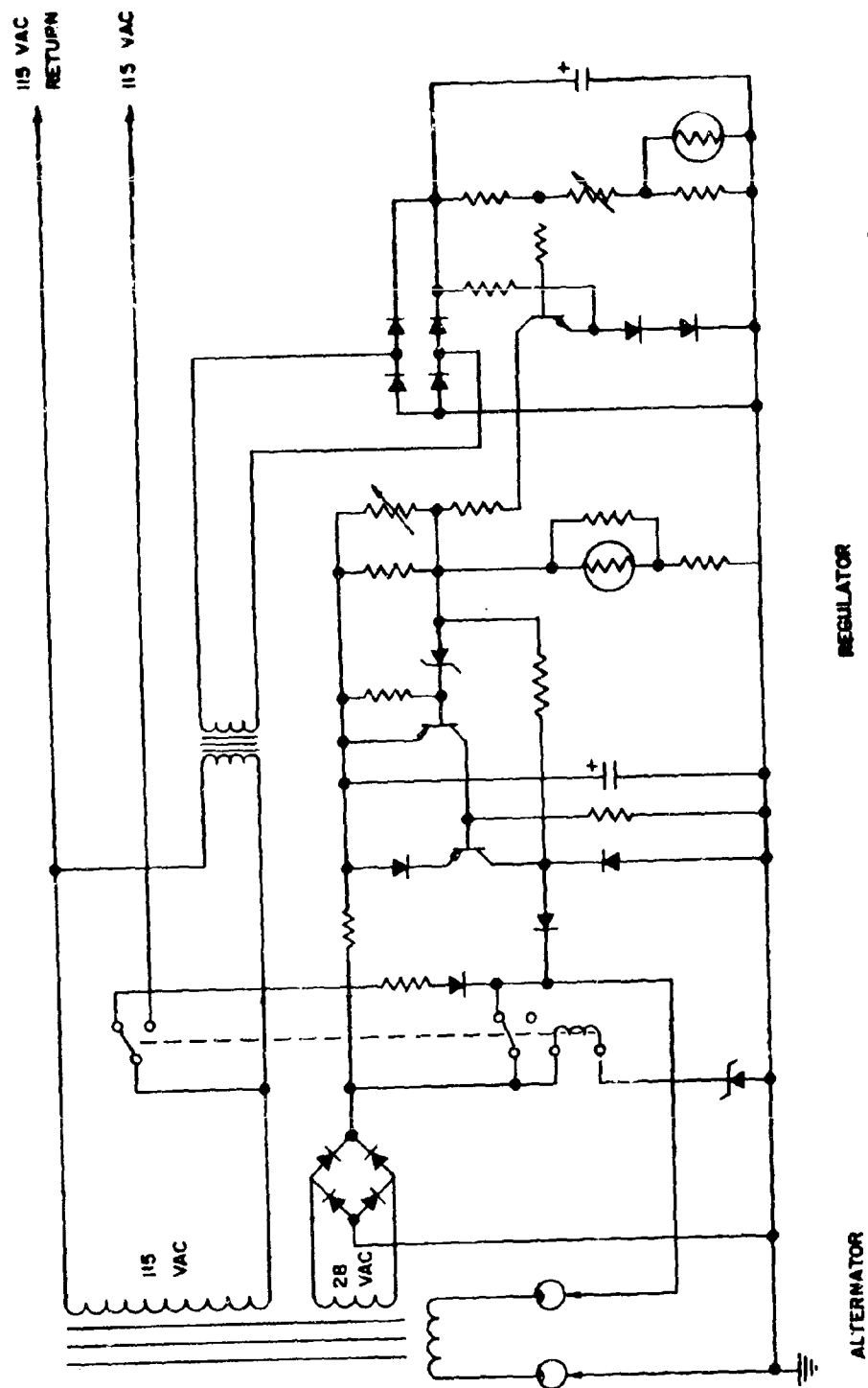


Figure 21 115 VAC SINGLE PHASE POWER SUPPLY, CONFIGURATION 3

2.3 Analysis of the Tank Aircraft Mating

In order to mechanically mate the original spray tank to the carrying aircraft, the tank was furnished with 30 inch suspension lugs at Stations 57 and 87, and 14 inch suspension lugs at Stations 65 and 79.

For electrical mating, two identical connectors, Part Number MS3102R-24-7P wired in parallel were provided forward and aft of the suspension lugs at Stations 52 and 92.75.

A review of the pylons, racks, and electrical connectors installed in the subject aircraft, F4C, F105, and F100, revealed that the existing suspension lugs were adequate for mechanical mating. However, in all instances the electrical connector was located aft of the aft 30 inch suspension lug and only the F105 aircraft was equipped with a connector that would physically mate with the connector installed on the tank. This connector was located in the pylon at a distance of 6.25 inches aft of the aft 30 inch suspension lug corresponding with Station 93.25 on the tank, giving a one-half inch misalignment.

Consequently the tank as it existed was incapable of being mated electrically to any of the proposed carrying aircraft, thereby dictating a redesign of the tank electrical mating system.

2.3.1 Individual Aircraft Installation

F4C Aircraft - The tank attaches to the outboard pylon only, as mechanical interference with the undercarriage prevents carriage at the inboard station on this aircraft. There is no ejection capability from this pylon. Electrical connection is made through an adapter plate assembly to the multiple weapons and GAM-83 A&B disconnect, P1, on the outboard pylon, (access door 211).

F105 Aircraft - The tank attaches to the 14 inch ejector rack in the outboard universal bomb pylon and the 14" or 30" ejector rack in the inboard multiple weapons pylon. Electrical connection is made through an adapter plate assembly to the auxiliary stores electrical plug (aft), P357, in the outboard pylon. Electrical connection to the inboard pylon is made through an adapter plate assembly to the universal stores disconnect, P678 (P1).

F100 Aircraft - The tank attaches to the 14-inch ejector rack in the type IIIA pylon at outboard and/or intermediate wing stations. Electrical connection is made through an adapter plate assembly to the LAU-3/A quick disconnect plug (P737).

2.3.2 Development of the Tank Aircraft Electrical Mating

From the review of the subject aircraft, it was determined that the tank would have to be furnished with some method of electrical interface that would provide a variety of different connectors located at various positions in relation to the suspension lugs.

The necessary connector requirements are tabulated in Tables II and III. The individual locations are spelled out both as the required distance aft of the aft 30 inch suspension lug and the corresponding station number on the original tank together with the connector part number required on the tank, and the connector pin function allocation. As all connectors are located aft of the suspension lugs, the requirement for the forward connector was eliminated.

<u>AIRCRAFT TYPE</u>	<u>TANK CONNECTOR PART NO.</u>	<u>DISTANCE AFT OF AFT 30 INCH LUG</u>	<u>CORRESPONDING TANK STATION NO.</u>
F4C	Deutsch, 5606-1912P	6.75	93.75
F105	MS3102A-24-7P	6.25	93.25
F100	MS3102A-14-5P	6.375	93.375

TABLE II CONNECTOR LOCATION

<u>AIRCRAFT TYPE</u>	<u>TAIL ARM</u>	<u>DISSEMINATION CIRCUIT</u>	<u>GROUND</u>	<u>INDICATOR LIGHT</u>
F4C	3	8	7	1
F105	N	A	E	
F100	B	D	E	

TABLE III CONNECTOR PIN FUNCTION ALLOCATION

In order to provide the required interchangeable connector capability, it was decided to terminate the wiring in the tank at a single common connector and furnish individual adapter cables that would mate with this common connector and provide the desired pylon interface connector.

For mechanically locating the interface connector, a well was cut in the tank by elongating the existing hole in the wiring tunnel and a boss bonded to the outer skin to provide a flat mounting surface with eight tapped mounting holes (see Figure 22). For each aircraft type, an adapter plate was designed that would mount to this surface with provision to assemble the appropriate interface connector at the correct station location (see Figure 23). The adapter plate and adapter cable are furnished as an integral assembly and suitably identified. For shipping, the tank is fitted with a cover plate on the boss, which is removed and replaced by the appropriate electrical interface adapter assembly prior to installing the tank on the aircraft.

This design readily lends itself to producing other adapter plate and cable assemblies in order to mate the tank to aircraft other than those originally specified.

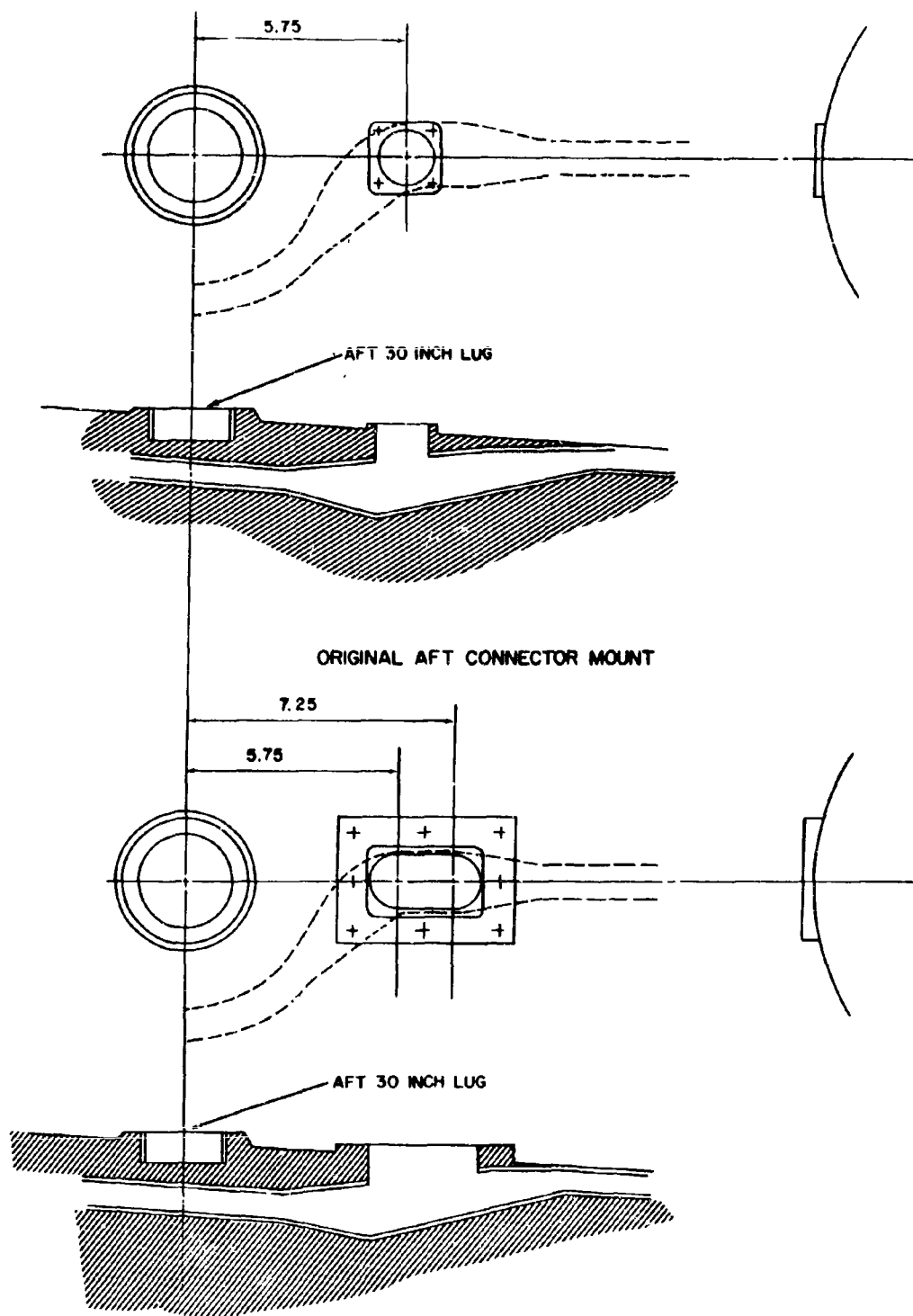


Figure 22 MODIFIED AFT CONNECTOR MOUNT

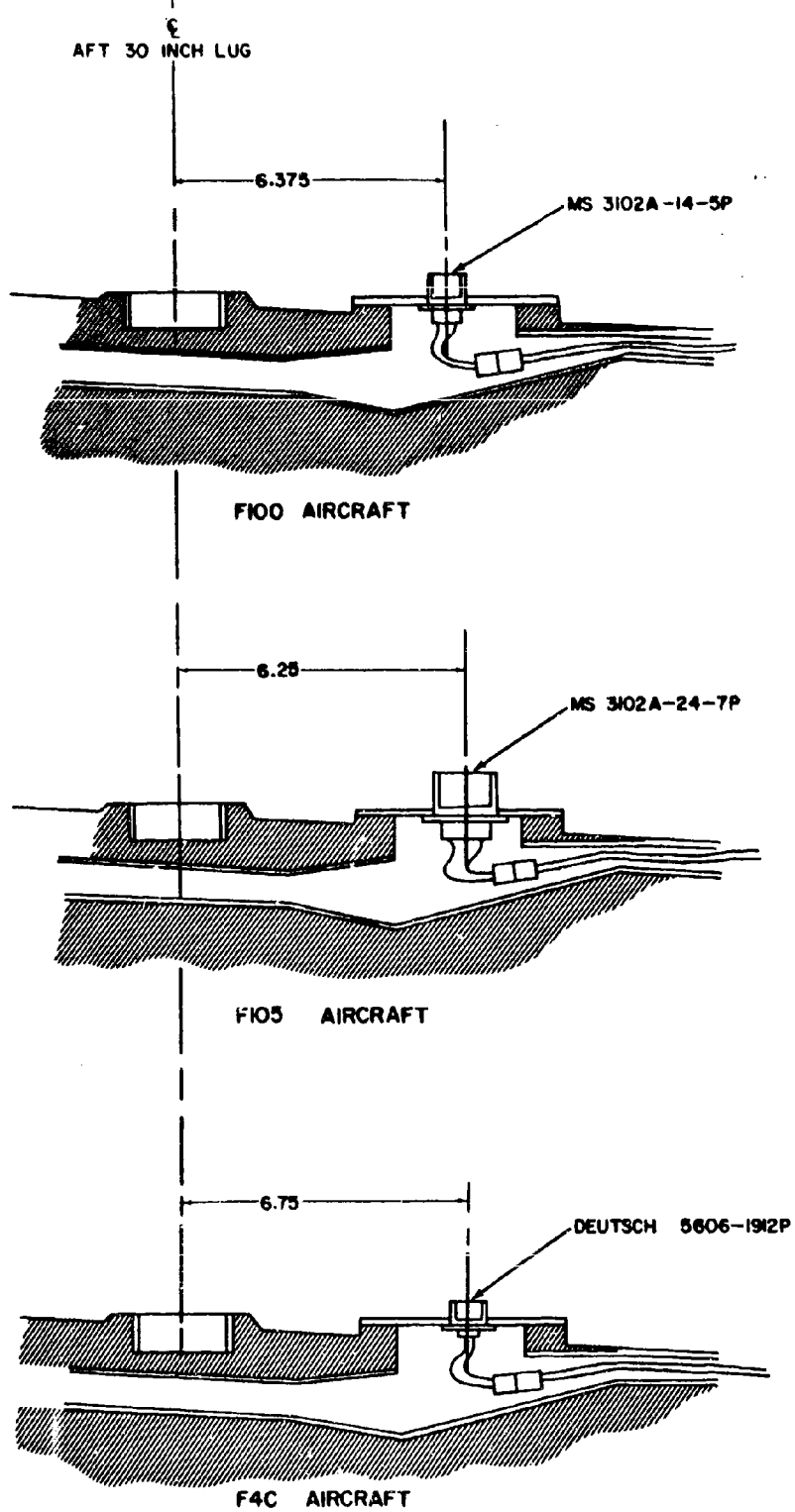


Figure 23 TANK AIRCRAFT ELECTRICAL MATING

2.4 Development of the Tank Modification and Test Set

2.4.1 Phase II Requirements

Originally the requirements of Phase II called for the following hardware to be modified or fabricated:

1. Two (2) modified tanks, functionally operational Serial numbers 14 and 15.
2. Two (2) modified tanks, nonfunctional Serial numbers 13 and 17.

The modification of the nonfunctional tanks to be identical to the functional tanks with the exception of the new wiring.

3. Four (4) test sets
4. Two (2) spare generator and nose cone assemblies

All this hardware was scheduled for delivery to Eglin Air Force Base.

Prior to the commencement of Phase II, the hardware requirements were changed to include one extra tank and the delivery instructions revised as follows:

1. Three (3) modified tanks functionally operational made up of:
 - a. One (1) modified old tank Serial No. 15 for delivery to Picatinny Arsenal for environmental tests.
 - b. Two (2) modified new tanks for delivery to Eglin for flight tests, Serial numbers 23 and 27.
2. Two (2) modified old tanks, Serial numbers 13 and 17, nonfunctional for airborne jettison tests for delivery to Eglin.
3. Four (4) test sets for delivery to Eglin.
4. Two (2) spare generator and nose cone assemblies to be initially delivered to Arnold Engineering Development Center, Tullahoma, for wind tunnel testing then forwarded to Eglin.

Later in June 1965, an additional functionally operational modified tank Serial number 22 was transferred to Phase II from Phase III for delivery to Eglin Air Force Base.

2.4.2 Development of the Tank Modification

The overall tank modification was made up from a combination of those areas whose detail analysis and development have been described in the undermentioned sections.

1. Tank control circuit: Section 2.1.3
2. Tank heater circuit: Section 2.2.2
3. Self contained power supply: Section 2.2.3
4. Tank aircraft mating: Section 2.3.2

The first overall design configuration of the modification tank was assembled to cater to the single wire control system and to utilize the originally proposed 115 VAC three phase self-contained power supply. Choice of heater circuit was left open pending preliminary testing of the generator and transformers to determine the power output from this combination. The configuration utilized the following circuits:

1. Control Circuit: Figure 7
2. Heater Circuit: Figure 10 or Figure 11
3. Power Supply: Figure 15

In order to mount the wind driven generator at the forward end of the tank, a new nose cone made from an aluminum spinning was designed. A preliminary stress analysis of this new nose cone is included in Appendix II. The three (3) transformers, external power relay, and the stepping switch were mounted on a new bracket attached to the rear frame of the tank center body. Ballast to maintain weight and balance was provided in the tail of the tank by filling the tail cone cap with "Cerrobase" alloy and locating additional weight on the tail pipe.

With the approval of the additional wiring added to the various pylons on the designated aircraft, the overall design configuration was changed to incorporate the control circuit that had been prepared for this wiring change which provided separate arming and dissemination control. It was also decided at this time to retain the original heater circuit, which used the heater changeover relay. This configuration, the first submitted for approval, was assembled from the following circuits:

1. Control Circuit: Figure 9
2. Heater Circuit: Figure 10
3. Power Supply: Figure 15

With the approval of this second configuration, procurement of components was initiated. This enabled preliminary testing of the generator transformer combination to be carried out. The problems brought to light by this testing associated with phase unbalance due to random loading and the high power loss in the transformers due to varying frequency are described in Section 2.2.3. This dictated the abandonment of the three phase power supply in favor of a 115 VAC single phase supply and the elimination of the three transformers. Preliminary testing of the single phase power supply indicated that the power output was adequate to meet the requirements of an all-heater-on-all-the-time condition so the heater circuit was changed accordingly. During this period, the umbilical connector arrangement was also revised.

Consequently, a third configuration was prepared incorporating these changes and submitted for approval. This configuration, the one adopted for the modification of the spray tanks under Phase II utilized the following circuits and tank aircraft mating.

1. Control Circuit: Figure 9
2. Heater Circuit: Figure 12
3. Power Supply: Figure 16
4. Tank Aircraft Mating: Figures 22 and 23

In order to offset the weight of the transformers which had been eliminated, ballast weights were substituted at the same location at Station 128. The existing heater changeover relay located in the control module which had been made redundant was now used in the gate valve control circuit. All the spray tanks initially supplied under Phase II were modified to this configuration.

During November 1964, the following hardware under Item 2a of the contract was completed and delivered:

1. One (1) functional modified tank, Serial number 15, was completed and shipped to Picatinny Arsenal on 16 November 1964.
2. Two (2) nonfunctional modified tanks, Serial numbers 13 and 17 were completed and shipped to Eglin Air Force Base on 20 November 1964.
3. Two (2) generator and nose cone assemblies were completed and shipped to the Arnold Engineering Development Center, Tullahoma, 20 November 1964.

During December 1964, the following hardware was delivered:

1. Two (2) functional modified tanks, Serial numbers 23 and 27, were shipped to Eglin on 19 December 1964.
2. Two (2) test sets, Serial numbers 001, and 002, were completed and shipped to Eglin on 19 December 1964.

Two test sets, Serial numbers 003 and 004, were retained at Hayes for eventual check-out of hardware built under Phase III.

The shipping of this hardware completed the following items of the contract:

- Item 1 - Phase I, Design
- Item 2 - Phase II (a), Modification of Test Items
- Item 4 - Test Sets
- Item 6 - Dummy Tanks
- Item 7 - Spares (shipped to Tullahoma)
- Item 12 - Test Plan

During July 1965, the following additional hardware was delivered:

1. One (1) functional modified tank, serial no. 22, was completed and shipped to Eglin Air Force Base 28 July 1965.

With the delivery of the initial hardware, testing was commenced and completed as follows:

1. Environmental testing conducted at WYLE Laboratories, Huntsville, on the wind driven generator was completed on 24 December 1964, (see Reference 1).
2. Environmental testing conducted at Picatinny Arsenal, Dover, New Jersey, on a modified functional tank, serial number 15, was commenced during December 1964 and completed during January 1965, (see Reference 4).
3. Wind tunnel testing, conducted at the Arnold Engineering Test Center, Tullahoma, on the wind driven generator was started in December 1964 and continued from 13 January 1965 through 5 February 1965, (see References 2 and 3).

As a result of the wind tunnel tests carried out on the generator at the Arnold Engineering Test Center at Tullahoma and the environmental tests carried out on a complete tank at Picatinny Arsenal, a number of changes were deemed necessary to resolve various problems which arose.

These changes were subsequently incorporated into the four (4) remaining tanks - two (2) functional, serial numbers 23 and 27, and two (2) nonfunctional, serial numbers 13 and 17 - by a retrofit program prior to proceeding with the remainder of the test program under Phase II.

The problems arising from the wind tunnel testing and the remedial changes both mechanical and electrical relating to the generator and regulator are detailed in Section 2.2.3. Basically these were the addition of the shroud extension shown in Figure 20 and the electrical circuit changes shown in Figure 21. The final overall electrical schematic for these modified spray tanks is shown in Figure 24.

During the environmental test program carried out at Picatinny Arsenal, tank serial number 15 incurred damage. The tests carried out were vibration testing per MIL-E-5272C, Procedure XII, in the vertical, lateral, and longitudinal axes.

A detail report of this test program is contained in the Tactical Warhead Laboratory, Nuclear Engineering Directorate, Picatinny Arsenal, Dover, New Jersey, document: A/B45Y-1 Biological Spray Tank (Modified), Part Number 100-06528, Test Number 87-64, (Reference 4).

Vertical and lateral testing was completed successfully.

After twenty-eight minutes of the final thirty-minute resonance run in the longitudinal axis at 60 CPS, one suspension hook on the bomb rack attaching the tank to the test fixture failed. The test was terminated.

Subsequent inspection of the tank revealed the following damage confined to the nose section and the tail section.

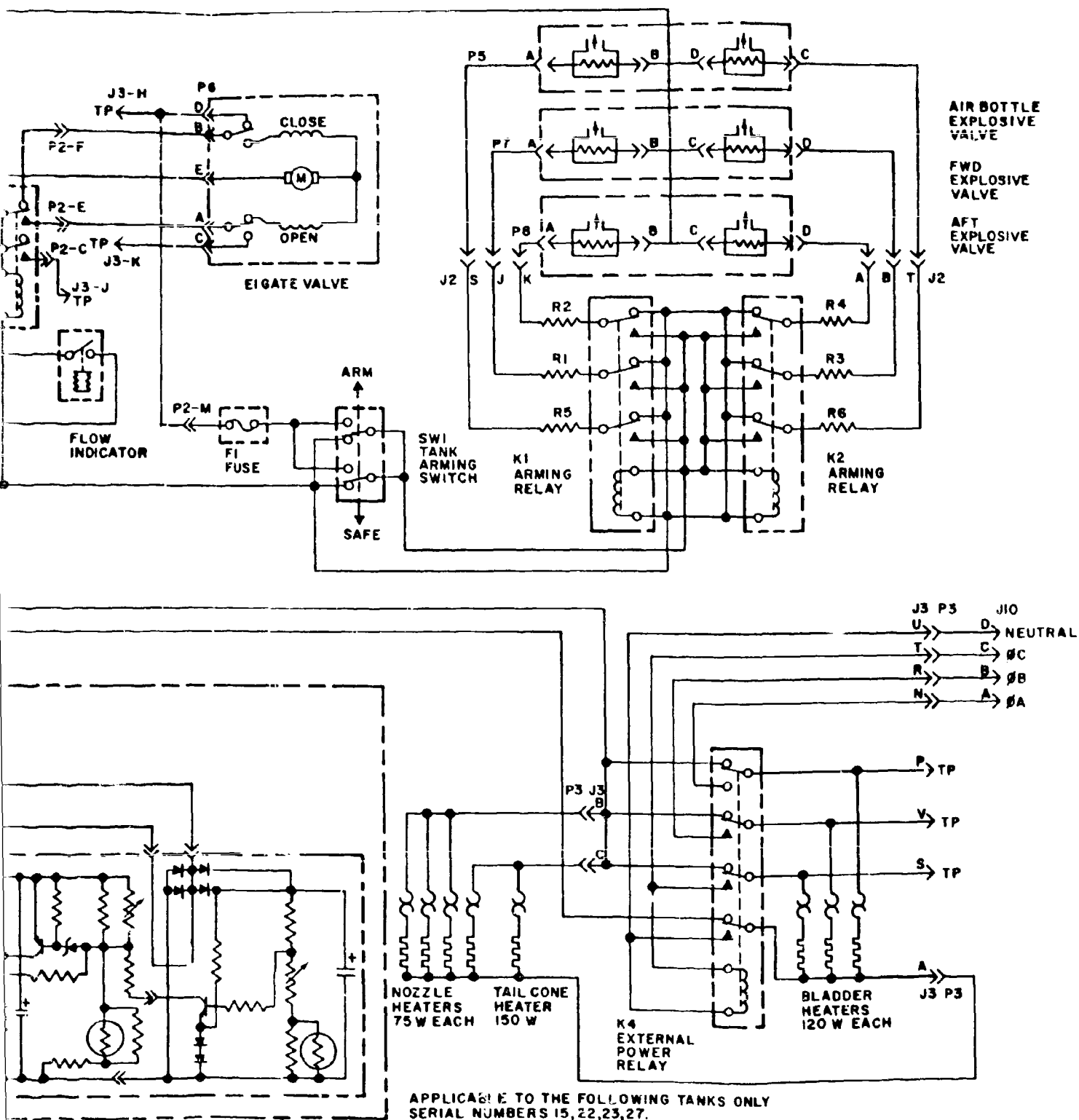
Nose Section:

1. Three upper attachment screws attaching the wind driven generator to the nose cone had sheared.
2. The bolt at one end of one of the air bottle retaining straps was sheared off.
3. Two of the four channel sections attaching the air bottle mounting ring to the nose cone mounting ring were broken.
4. The high pressure air line between the air bottle and the explosive valve was broken.

Tail Section:

1. The liquid line between the gate valve and the flow indicator was fractured at the pipe-to-flange weld at the flow indicator end.
2. The upper and lower ballast weight brackets at Station 128 were fractured on the left hand side. One was fractured at the bend, the other at the mounting hole.





The following changes were made to remedy these failures:

Nose Section:

1. The gap between the air bottle mounting bracket and the new nose cone was filled by the addition of a 1/16 thick metal splice ring, part number 100-06545, backed with a strip of 1/16 thick 3M Scotch-Mount Foam Tape, part number Y-9063A.

Tail Section:

1. The ballast weight was removed from the delivery pipe.
2. The upper and lower brackets used to mount the ballast weights were redesigned to be stiffer to increase their spring rate and raise their resonant frequency.
3. The shear plate previously designed as part of the ballast attachment, but omitted from the test unit was installed.

Upon completion of the retrofit to incorporate these changes, modified functional tank, serial number 23, was shipped to Picatinny Arsenal in order to repeat the environmental test program. For this testing, which was carried out during June 1965, the test program was revised insofar as vibration testing was carried out in the lateral, longitudinal, and vertical axes in accordance with MIL-STD-810A, as opposed to MIL-E-5272, Procedure XII, used previously. Lateral axis testing was completed successfully. During longitudinal axis testing, four screws on the generator nose cone interface sheared, and internal examination of the generator at the completion of this test revealed fracture of the transformer mounts. It was also necessary to retighten screws securing the generator shroud at intervals during the test.

Testing in the vertical axis was halted after 18 minutes when the tail cap sheared loose at its mounting points. During this period, the generator mounting hardware loosened. Prior to resuming the vertical axis test, the tank was modified with the installation of additional hardware at the generator nose cone interface, redesign of the transformer mount, and substitution of a lightweight tail cap. During the cycling test, three screws at the nose cone centerbody sheared and were replaced. During the resonance test at 45 CPS, the generator shroud attachment hardware loosened, the shroud breaking loose after 21 minutes. Additionally, two screws sheared at the generator nose cone interface.

Inspection of the tank at completion of the test revealed that the air bottle had broken loose due to failure of a retaining strap screw and the tail pipe had fractured forward of the flow indicator flange.

A detail report of this test program is contained in the Tactical Warhead Laboratory Nuclear Engineering Directorate, Picatinny Arsenal, Dover, New Jersey: document: A/B45Y-1 Biological Spray Tank (Modified), Part Number 100-06528, Test Number 43-55, (Reference 5).

At the completion of this latter environmental test program, all the changes made during the test together with elimination of the generator shroud to spacer mounting hardware by using welded construction were incorporated into the remaining existing modified tanks.

Because of the inability of the modified A/B45Y-1 Biological Spray Tank to withstand the vibrational stresses imposed upon it during these two consecutive environmental test programs, an analysis was made of all the environmental testing carried out during the development history of the tank to see if any particular phenomena or failure pattern were present.

A detailed report of this analysis is contained in Appendix V.

In essence, a review and analysis was made of all the test reports pertaining to environmental testing of the A/B45Y-1 Biological Spray Tank. It was concluded that the tank had been overdriven in all test programs as test input vibratory acceleration levels for resonance dwell were not attenuated in accordance with the appropriate test specifications MIL-E-5272 and MIL-STD-810A to which the tanks were tested where a test specimen weighs in excess of 50 pounds. Large magnification factors were evident in the bomb rack to store suspension system and through the plastic center body structure of the tank. It was felt that these two factors significantly contributed to the failure of the test specimen tank during testing. The effect of these latter factors was further amplified by the failure of attachment hardware locking mechanisms which allowed the nose and tail assemblies to whip.

The recommendation of the report was for the tank to be retested in accordance with MIL-STD-810A with full attenuation values applied to input levels, additional locking devices incorporated to prevent the loosening of attachment hardware, and local hardpad plates provided at the tank to bomb rack sway brace interfaces.

Modified A/B45Y-1 Biological Spray Tank serial number 22 was prepared for testing per these recommendations. Self-locking screws, part number NAS 1164, were substituted for the nose cone and tail cone attachment hardware, and local sway brace hardpads of 1/8" thick sheet aluminum were affixed to the tank centerbody.

The tank was shipped to Picatinny Arsenal for testing which was carried out 6 December through 10 December 1965.

A weight and balance analysis of this final modified design equipped with a wind driven generator is included in Appendix III.

A list of Class II drawings detailing the tank modification is given in Appendix IV.

The test program called for vibration testing per MIL-STD-810A method 514.1, Curve B, per Time Table 514-11 in the longitudinal and vertical axis. As the tank had successfully completed testing in the lateral axis on a previous occasion, it was decided not to repeat this axis due to the work load at the test facility.

The tank successfully completed three hours of vibration testing in the longitudinal axis made up of two hours of cycling and one hour of resonance dwell.

Vibration testing in the vertical axis was terminated after two hours made up of one and a half hours of cycling and one-half hour of resonance dwell as the test item incurred damage as follows:

Three (3) nose cone to center body attach screws sheared.

Three (3) generator to nose cone attach screws sheared.

Two (2) generator shroud attach hardware sheared.

After the tank was repaired, it was decided to recommence the vertical axis testing from the beginning.

After 22 minutes of cycling, noises were heard in the tail. The tail cone was removed, and it was found that the tail pipe had come loose forward of the flow indicator. The screws were replaced and the tail cone reassembled. Two existing captive nuts on top were sheared at this interface.

Testing was continued for a total of two and a half hours cycling and one-half hour at resonance dwell. (This gave a grand total of vertical axis testing of four hours cycling and one hour at resonance.)

Ten minutes before completion of the test noises emanating from the nose indicated that the air bottle might be loose. Upon completion of testing, the nose cone and tail cone were removed. Inspection showed that the air bottle attachment screws had sheared and the tail pipe welded flange joint forward of the flow indicator was fractured.

As a result of failures incurred by the tank during this latest test, a review of the overall modification program was made in February 1966 to determine if the original concept of adding a wind driven generator to the nose of the existing tank structure was indeed feasible. The second objective of the review was to decide the future action in regard to the remaining tanks scheduled for modification under Phase III of the program and the modification data to be incorporated into the updating of the existing Class I drawings.

The following decisions were arrived at and future action decided upon at this review:

1. Decisions

- a. It was decided that the existing tank structure did not lend itself to the attachment of a wind driven generator at the forward extremity due to the flexibility of the basic tank structure which resulted in high magnification factors imposing excessive loads on the generator and nose cone attachment, 46 g being recorded for an input of 5 g during the latest test.

- b. The existing tank structure could not readily be modified to alleviate this problem.

- c. It could not be definitely determined if the excessive deflection of the tank structure had been the prime reason for the failure of other components like the air bottle attachment or the tail pipe assembly. These items had experienced trouble in all environmental testing of modified tanks equipped with generators, but appeared to have survived testing of the original tank configuration.

2. Modification of remaining existing tanks

The remaining existing tanks originally scheduled for modification under Phase III should incorporate the following changes.

- a. The revised arming and control circuit wiring.
 - b. The heater circuit to be revised with provision for 115 VAC, 3 phase, 400 CPS aircraft power at the tank to aircraft electrical connector.
 - c. Eliminate the wind driven generator.
 - d. Eliminate the electrical hook up for the wind driven generator.

- e. Provide the external power connector.
- f. Provide the redesigned tank to aircraft electrical connector arrangement with associated adapter plate assemblies.
- g. Eliminate the forward tank to aircraft electrical connector.

3. Updating of Class I Drawings

The updating of Class I drawings for the modified A/B45Y-1 Biological Spray Tank and the TUU-251/E Test Set should:

a. Tank Drawings

1. Eliminate the wind driven generator but provide means for installing one at some future date.
2. Provide an improved method of securing the nose cone by increasing the quantity and size of the attachment hardware.
3. Reflect the possibility of providing better accessibility to the forward explosive valves.
4. Provide electrical hook up for the wind driven generator.
5. Provide wiring at the tank to aircraft electrical connector for 115 VAC, 3 phase, 400 CPS aircraft power to supply the heater circuit.
6. Remove the forward existing tank to aircraft electrical connector.
7. Retain the redesigned tank to aircraft electrical connector arrangement with appropriate adapter plate assemblies but lower the overall height 1/8 inch.
8. Provide metal hardpad inserts at points where the bomb rack sway braces interface with the tank body.
9. Provide an improved method of securing the tail cone similar to the nose cone.
10. Investigate and if necessary incorporate, the need to strengthen both the forward and aft bulkheads.
11. Remove the Flow Indicator and make the tail pipe a one-piece assembly.
12. Retain the external power connector.
13. Show the bolts securing the air bottle retaining straps increased in size with increased strap thickness as necessary.
14. Provide a rubber pad beneath the nozzle mounting bracket at the upper end of the tail fin.
15. Revise the nameplate drawing per supplied sample.

b. Test Set

1. Provide the test set with the capability to check out 115 VAC, 3 phase, 400 CPS power at the aircraft pylon connector.

The Class I drawings for both the tank and the test set were updated during March 1966. The Handbook of Instructions for Operation and Maintenance of the A/B45Y-1 Biological Spray Tank was also updated at this time to reflect the tank configuration changes included in the Class I drawings.

2.4.3 Final Design Configuration for the Modified Tank

In order to meet the desired requirements agreed upon at the February 1966 review for inclusion in the updated Class I drawings, the following mechanical and electrical changes were made to the tank configuration:

1. Mechanical Changes

a. Nose Cone Attachment - the attachment hardware was changed from six (6) 1/4 - 28 UNF screws to twelve (12) 5/16 - 24 UNF self-locking screws (NAS 1165). The mating captive nuts were also changed in like quantity and size and a heavier duty unit called out, (NAS 1031).

b. Tail Cone Attachment - the attachment hardware was changed from sixteen (16) 1/4 - 28 UNF screws to sixteen (16) 5/16 - 24 UNF self-locking screws (NAS 1165). The mating captive nuts were changed to a like size heavier duty unit (NAS 1031).

c. Explosive Valve Access - minor configuration changes were made to the forward longerons to give improved access to the forward explosive valves.

d. Tail Pipe - the flow indicator was removed and the tail pipe made as a single welded assembly, with increased tube wall thickness.

e. The boss located on the top of the tank associated with the aircraft to tank electrical connector was reduced in height.

f. Local hardpads of aluminum sheet were added to the top of the tank adjacent to the suspension lugs.

g. Air Bottle Attachment - the attachment hardware was changed from 1/4 - 28 UNF to 5/16 - 24 UNF and the strap thickness increased.

h. A rubber pad was installed beneath the nozzle mounting bracket at the upper end of the tail fin.

2. Electrical Changes

a. Heater Circuit - the heater circuit was changed to accept 115 VAC, 3 phase, 400 CPS aircraft power (see Figure 25). In order to isolate this circuit, a relay K5 was added. Relays K4 and K5 were incorporated into a new electrical power module located on the right hand side of the aft bulkhead.

The overall electrical schematic for the final design configuration of the modified spray tank is given in Figure 26.

The basic nominal characteristics of this tank configuration are unchanged from those of the original tank which are given in Figure 27.

2.4.4 Design Configuration for the Remaining Six Modified Tanks Reworked Under Phase III

In order to meet the desired requirements agreed upon at the February 1966 review in regard to the remaining tanks scheduled for modification under Phase III, the following mechanical and electrical changes were made to the existing tank configuration.

1. Mechanical Changes

a. The nose cone attachment hardware was changed to 1/4 - 28 UNF self-locking screws (NAS 1164).

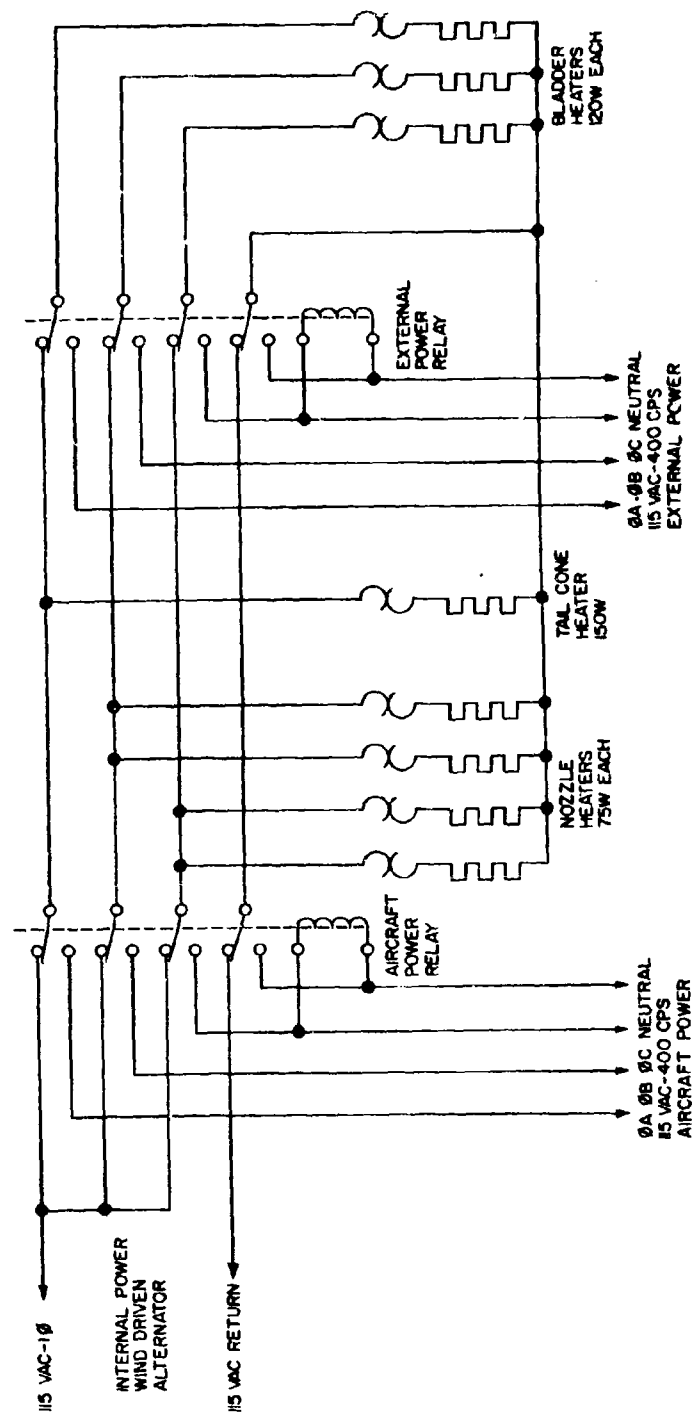


Figure 25 HEATER CIRCUIT, ALL HEATERS ON - INTERNAL POWER
AIRCRAFT POWER, EXTERNAL POWER

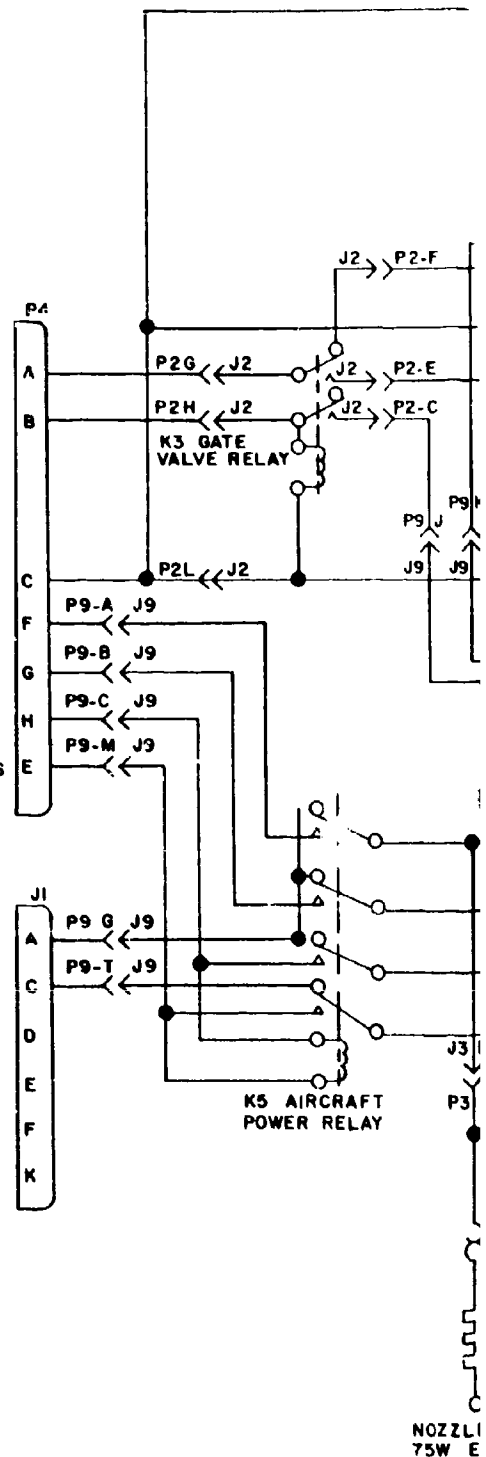
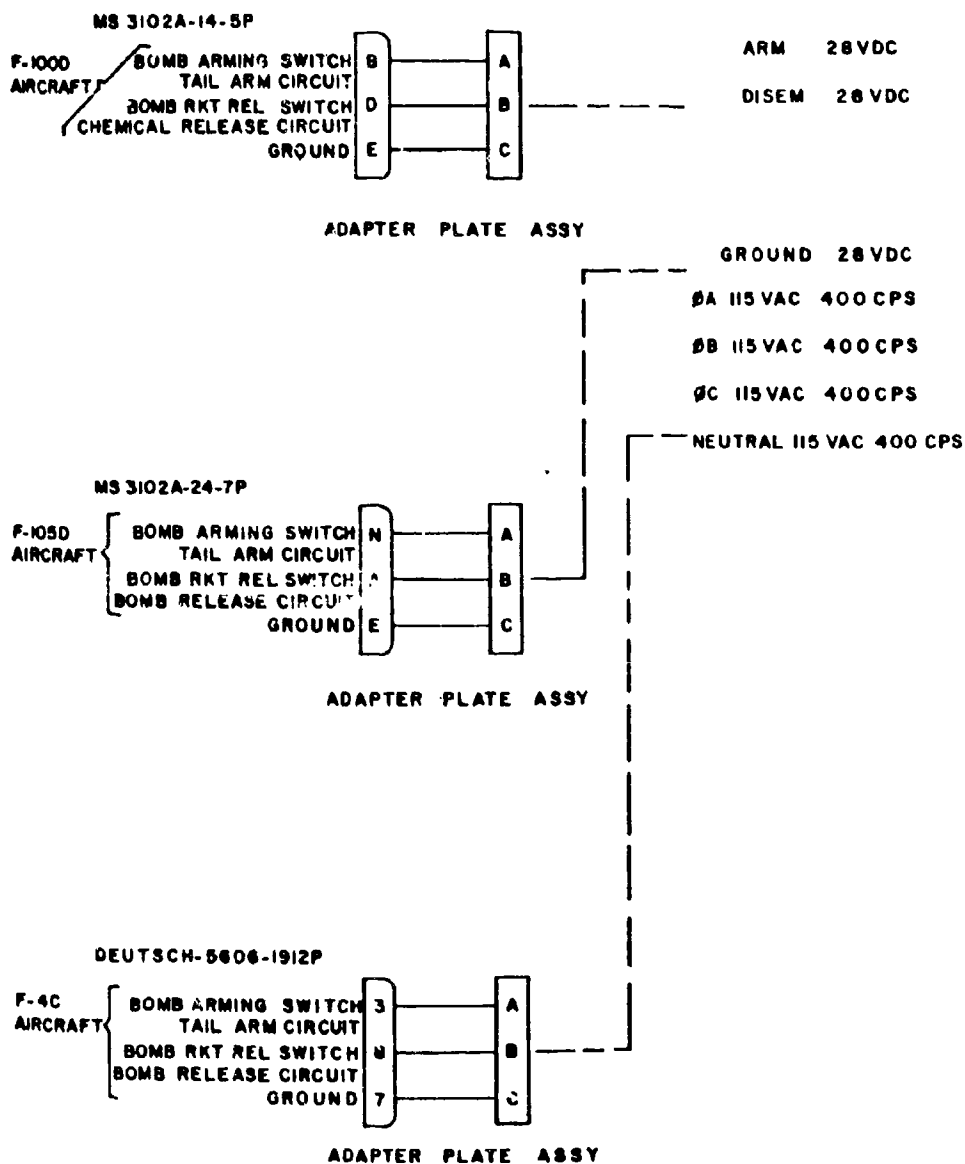
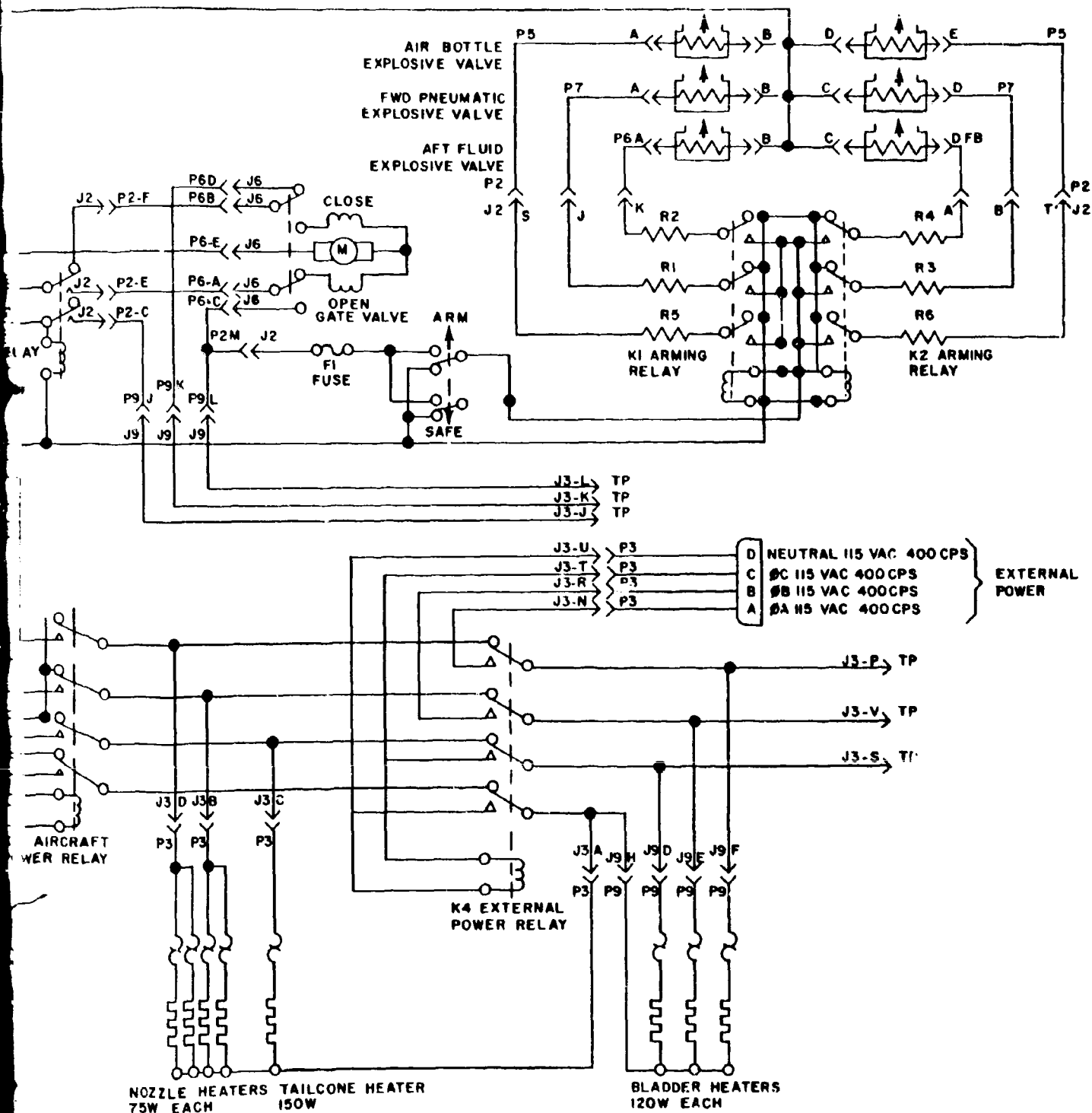


Figure 26 SCHEMATIC A/B45Y-1 SPRAY TANK FINAL CONFIGURATION

A



B

BASIC NOMINAL STATISTICS

SHAPE: Douglas Store
 Length Overall: 149.69 inches (from sta 0 at projected apex of nose cone)
 Diameter (maximum): 17.0 inches
 Fineness Ratio: 3.805
 Constant Section: 24.5 inches

EXTERNAL SURFACE:
 Tank (except fins): 41.44 square feet
 Fins (projected) 9.136 square feet

WEIGHTS:
 Nose Cone: 5.5 pounds
 Tail Cone: 23.7 pounds
 Main Section: 201.3 pounds

Tank Empty Total: 230.5 pounds
 Agent: 529.0 pounds

Tank Full Total: 759.5 pounds

VOLUMES AND CENTROIDS:
 Gross: 66.2 U. S. Gallons Sta 71.7
 Agent: 63.5 U. S. Gallons Sta 70.2
 Expansion Space: 4% of gross volume ---
 Tank Empty: - Sta 75.3

NOTE

Maximum moment change (20° nose up to 20° nose down attitude) is 11,500 in-lbs (incurred when 32.5 U. S. gallons of liquid remains in tank).

SYSTEMS:
 Pressurization (reservoir): 375 cubic inches 3,000 psig
 Pressurization (active): --- 40 psig
 Liquid Discharge Rate: 20 U. S. gal/minute 166 lb/minute

TEMPERATURE LIMITS:
 Ambient: -54°C to +71°C
 Liquid: + 2°C to agent limit
 Heater Operation: -54°C to +10°C

Figure 27 BASIC NOMINAL STATISTICS

b. The tail cone attachment hardware was changed to self-locking screws (NAS 1164).

c. The external power connector was added to the underside of the tail cone.

d. The redesigned tank to aircraft electrical connector arrangement with associated adapter plates was added to replace the aft electrical connector.

e. The forward electrical connector was eliminated.

f. A new bracket was made to replace the tail cone disconnect plug bracket with provision for mounting the external power relay K4.

g. A rubber pad was installed beneath the nozzle mounting bracket at the upper end of the tail fin.

2. Electrical Changes

a. Heater Circuit - the heater circuit was revised to eliminate the wind driven generator hookup and accept 115 VAC, 3 phase, 400 CPS aircraft power (see figure 28).

The overall electrical schematic for the six tanks modified under Phase III is given in Figure 29.

The basic nominal characteristics of this tank configuration are unchanged from those of the original tank which are given in Figure 27.

2.4.5 Development of the TTU-251/E Test Set

At the completion of the first overall design configuration for the modified tank, a preliminary circuit was prepared for the test set. This circuit was assembled around a twenty-four position rotary selector switch, a number of indicator lamps, a press-to-test switch, and five cable assemblies; one for the forward end of the tank, one for the aft end of the tank, one for the tank umbilical connector, one for the external power supply and one for the aircraft. In operation, the test set is connected to the appropriate locations and the rotary switch progressively rotated, and at each position, the press-to-test switch is operated and the pertinent go-no-go information provided by an indicator lamp. The unit also incorporates its own self-checking circuit.

The TTU-251/E test set is basically a continuity tester used to check out the electrical wiring in the tank, however, the unit will also check the wind driven electrical generator, gate valve operation, and all relays. Provision is also included for checking the operation of the appropriate aircraft control circuits at the pylon electrical disconnect which mates with the tank umbilical connector.

The circuit is packaged in a standard military approved combination case which measures twelve (12) inches wide by eighteen (18) inches long by nine (9) inches high and weighs twenty-four (24) pounds. The various adapter cables and a handbook are also stored within the case. The test set is not self contained in the true sense of the word, insofar as it does not contain its own 28 VDC power which is required for operation. Consequently, provision is included for connecting the unit to an external power source like the standard MD3 auxiliary power unit which is available at most Air Force facilities.

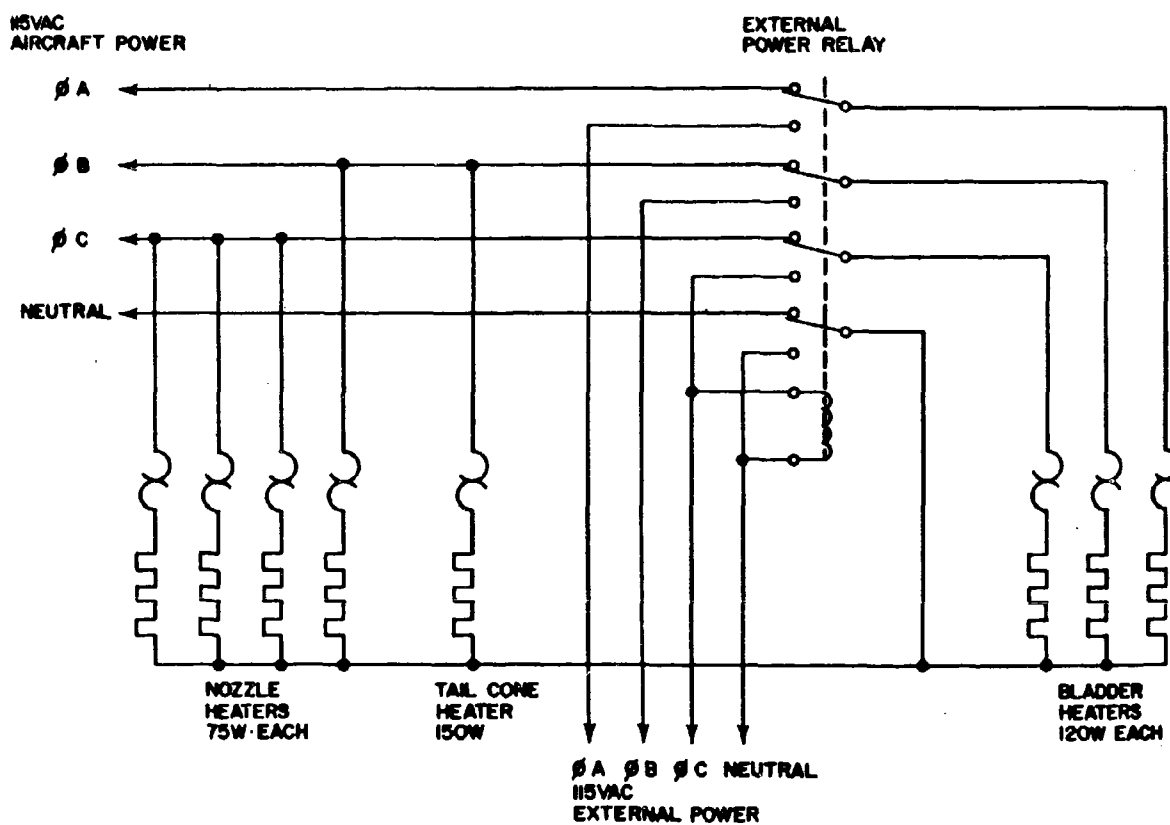
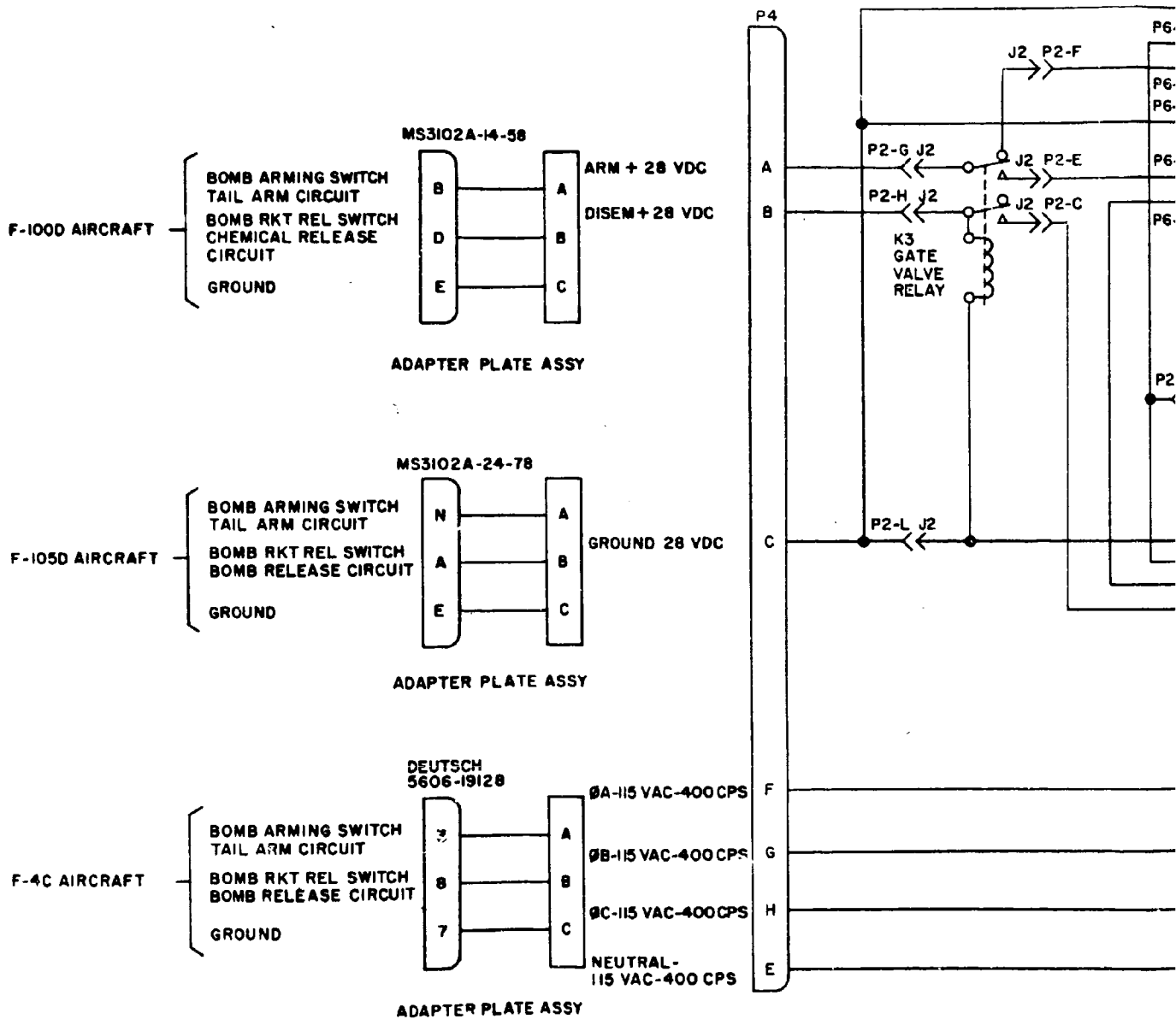


Figure 28 HEATER CIRCUIT, ALL HEATERS ON -
AIRCRAFT POWER, INTERNAL POWER

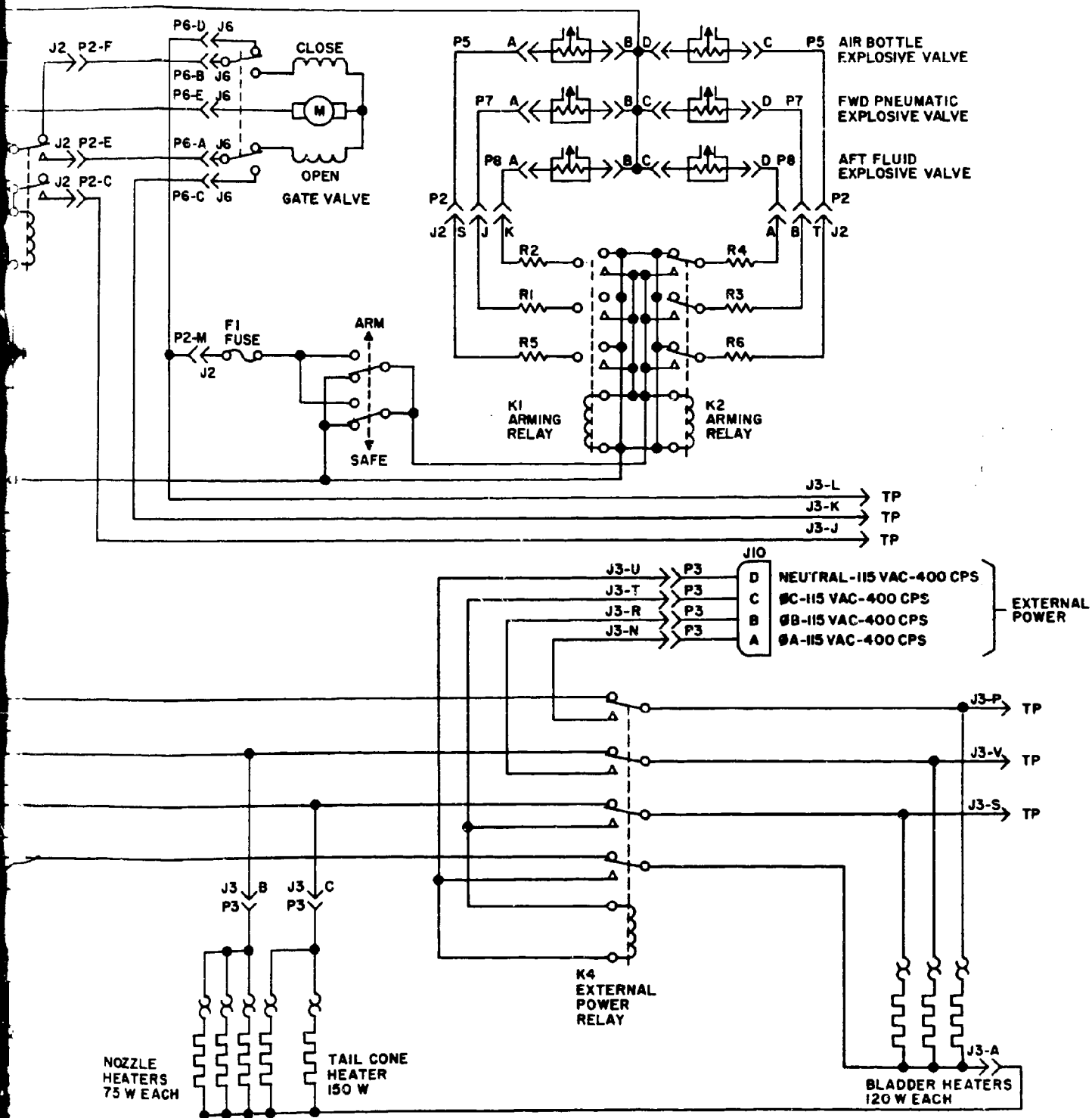


APPLICABLE TO THE FOLLOWING TANKS ONLY:
SERIAL NUMBERS

Figure 29 SCHEMATIC A/B45Y-1 SPRAY TANK MODIFIED UNDER PHASE III

NOZZLE
HEATERS
75 W EACH

A



B

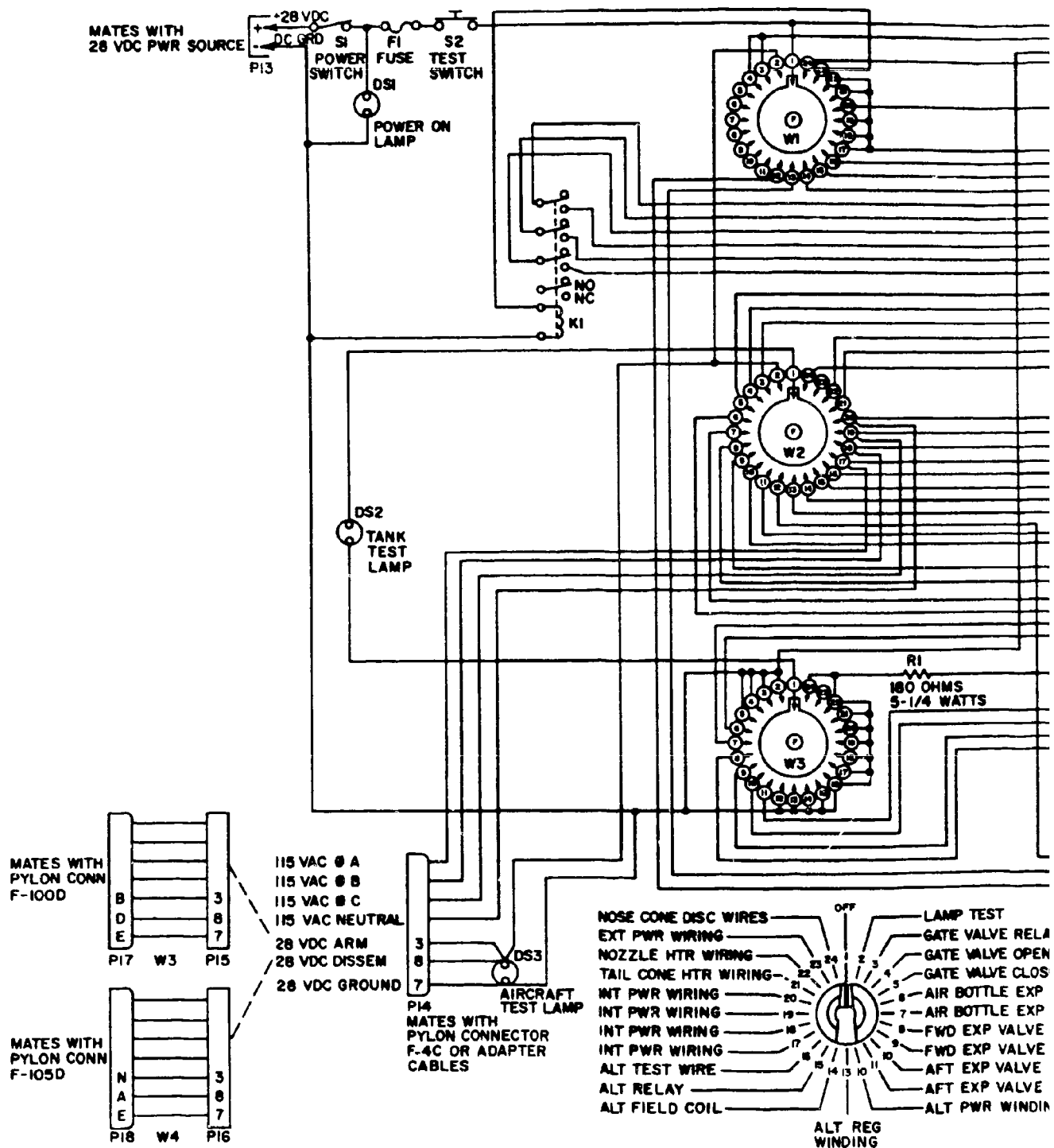
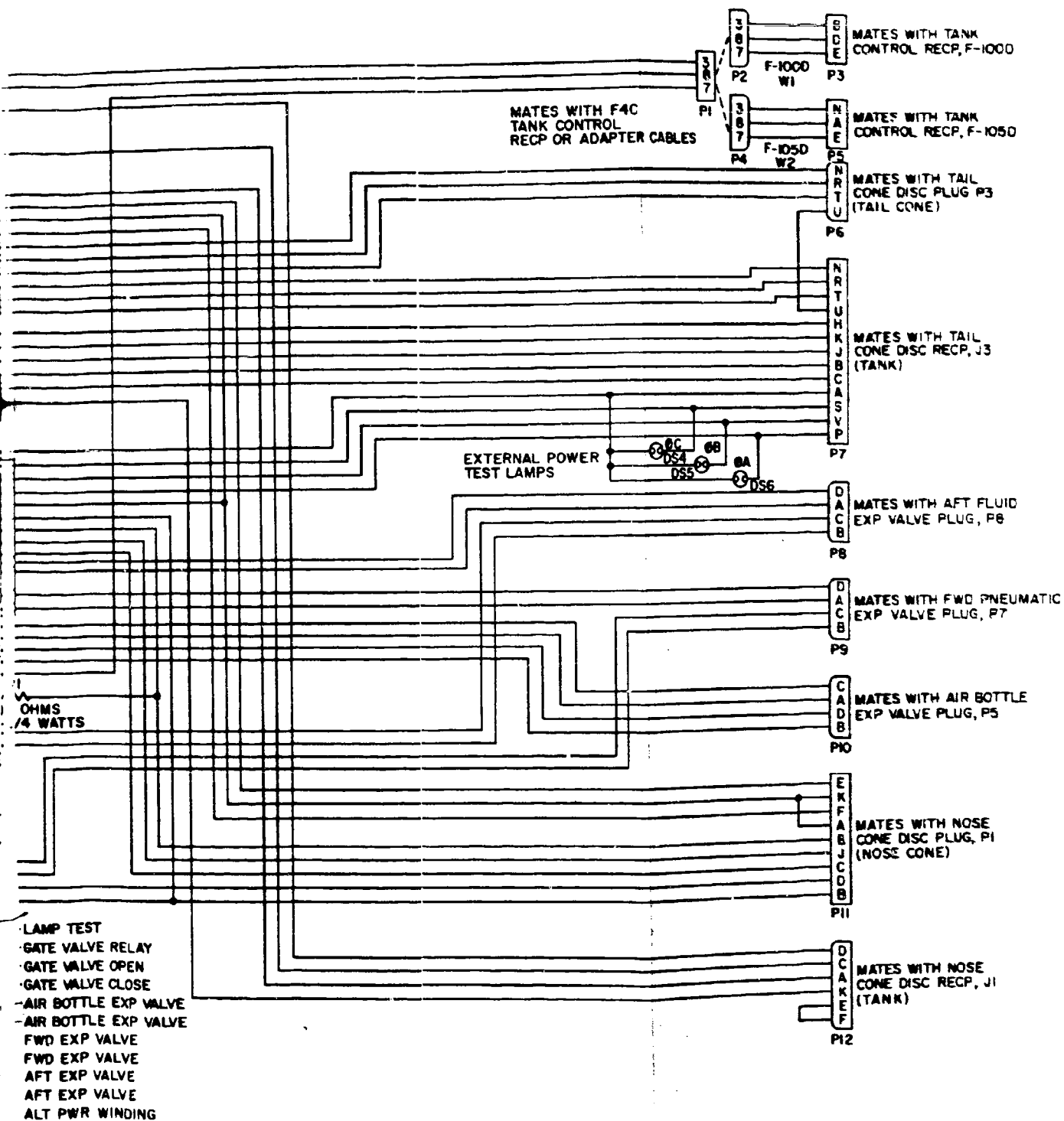


Figure 30 SCHEMATIC TTU-251/E TEST SET



B

The combination case which is divided into two halves uses the lower half to house the test equipment and the upper half to store the auxiliary equipment. The test equipment is assembled to a single panel located centrally in the lower half which mounts the controls and indicator lights. From this assembly, the various integral cable assemblies emanate which couple to the tank, aircraft and external power source. These cable assemblies are normally stored to either side of the panel in the lower half of the case and are designed to suit the F4C aircraft for mating to the aircraft and tank. Adapter cables are provided for conversion to mate with the F100 and F105 aircraft. This was done because it was felt that the F4C being the last of these aircraft to enter service with the USAF would probably be the last aircraft to be phased out and would therefore enjoy longest utilization. Other adapter cables can be readily made up when necessary to suit other aircraft types should it be decided to operate the tank on aircraft types other than those originally planned for. These adapter cables form part of the auxiliary equipment stored with the handbook in the upper half of the test set.

As the design of the modified tank configuration developed and changes were incorporated, so the design of the test set was progressively revised in order to remain compatible with the tank. Most of these revisions were confined to the test set circuit and were readily introduced as wiring changes and new test mode nomenclature. A relay was the only additional component added during development and this was incorporated to ensure positive isolation between the 28 VDC and 115 VAC, 400 CPS power. The final circuit adapted for the test set is given in Figure 30.

A list of Class II drawings detailing the test set design is given in Appendix D.

REFERENCES

1. WYLE Laboratories Report, Job Number 40323, Environmental Tests - Airborne Generator, Part Number HIC-90A.
2. Arnold Engineering Development Center Test Report, Project Number RA 0512.
3. Arnold Engineering Development Center, Document Number AEDC-TR-65-112, A Performance Evaluation of The A/B45Y-1 Biological Spray Tank Electrical Power System at Simulated Flight Conditions.
4. Tactical Warheads Laboratory, Nuclear Engineering Directorate, Picatinny Arsenal, Dover, New Jersey, A/B45Y-1 Biological Spray Tank (Modified), Part Number 100-06528, Test Number 87-64.
5. Tactical Warheads Laboratory, Nuclear Engineering Directorate, Picatinny Arsenal, Dover, New Jersey, A/B45Y-1 Biological Spray Tank (Modified), Part Number 100-06528, Test Number 43-65.

APPENDIX I

INDIVIDUAL AIRCRAFT OPERATING PROCEDURES
FOR THE
MODIFIED A/B45Y-1 BIOLOGICAL SPRAY TANK

1.0 F4C AIRCRAFT

Operating Procedures - The tank is armed from the cockpit of the F4C aircraft through the bomb arming circuit. Dissemination on/off function is accomplished through the rocket firing circuit by use of the BOMB ROCKET RELEASE switch. The tank is jettisoned using the bomb release circuit.

Tank operation is accomplished in the following switching sequence.

Preflight

1. MASTER ARMING switch - SAFE
2. STATION SELECT switch - OFF
3. Tank SAFETY PIN - REMOVE (just prior to flight)

Pream

1. BOMB ARMING circuit breaker - IN
2. WEAPON RELEASE circuit breaker - IN
3. CONV WPN ARM circuit breaker - IN
4. BOMB & ROCKET RELEASE circuit breaker - IN

Arm

1. MASTER ARMING switch - ARM
2. BOMB ARMING switch - NOSE & TAIL

NOTE: The above step arms all tanks carried.

Chemical Release

1. WEAPON SELECT switch - applicable position:
RKTS SINGLE or RKTS PAIRS
2. STATION SELECT switch - applicable position:
OUTBD
3. RESET switch - RESET
4. Start: BOMB ROCKET RELEASE switch - DEPRESS (Dissemination will continue as long as the switch is depressed or until switch is released or tank is empty).
5. Stop: BOMB ROCKET RELEASE switch - RELEASE

NOTE: The WEAPON SELECT switch is indexed to RKTS PAIRS to supply a release signal to both outboard stations simultaneously. If only one tank is carried, it must be carried on a left outboard station. Also, if it is desired to operate only one tank (left side) the WEAPONS SELECT switch must be indexed to RKTS SINGLE and the RESET switch must be indexed to RESET before the BOMB ROCKET RELEASE switch is depressed again to restart dissemination. To disseminate from RH wing station after the corresponding LH tank has been emptied, the WEAPON SELECT switch should be indexed to RKTS PAIRS.

Switch and Circuit Breaker Location Table

<u>NOMENCLATURE</u>	<u>LOCATION</u>
Bomb Arming Circuit Breaker	No. 1 Circuit Breaker Panel
Bomb Arming Switch	Panel Assembly - Pedestal
Bomb and Rocket Release Circuit Breaker	No. 1 Circuit Breaker Panel
Bomb Rocket Release Switch	Control Stick, both cockpits
Conventional Weapons Arm Circuit Breaker	No. 1 Circuit Breaker Panel
Master Arming Switch	Panel Assembly - Pedestal
Reset Switch	Panel Assembly - Pedestal
Station Select Switch	Panel Assembly - Pedestal
Tank Safety Pin	Tank Tail Cone, LH side
Weapon Release Circuit Breaker	No. 1 Circuit Breaker Panel
Weapon Select Switch	Panel Assembly - Pedestal

2.0 F105D Aircraft (F-105D-25 and Later, and Model 610 and 707)

Operating Procedures - The tank is armed from the cockpit of the F-105D Aircraft through the bomb arming circuit. Dissemination on/off function is obtained from the rocket firing circuit by use of the STORE RELEASE switch. The tank is jet-tisoned using the bomb release circuit.

Tank operation is accomplished through the following switching sequence.

Preflight

1. BOMB ARMING NOSE circuit breaker - OUT
2. BOMB ARMING TAIL circuit breaker - OUT
3. MASTER ARMAMENT switch - OFF
4. ALL STATION SELECT switches - OUT
5. Tank SAFETY PIN - REMOVE (just prior to flight)

Prearm

1. STORE REL CONT circuit breaker - IN
2. STORE REL LH circuit breaker - IN
3. STORE REL RH circuit breaker - IN
4. MASTER ARMAMENT circuit breaker - IN

Arm

1. BOMB ARMING NOSE circuit breaker - IN
2. BOMB ARMING TAIL circuit breaker - IN

3. BOMB ARMING switch - NOSE AND TAIL

NOTE: The above step arms all tank carried

Chemical Release

1. MASTER ARMAMENT switch - WEAPONS
2. WEAPONS SELECTOR switch - RKTS/AUX STORES
3. PYLON SEQUENCE SELECT switch - SALVO
4. Applicable STATION SELECT switch or switches:
(R1, L1, RO, LO) - IN
5. Start: STORE RELEASE switch - DEPRESS (Dissemination will continue as long as switch is depressed or until switch is released or tank is empty).
6. Stop: STORE RELEASE switch - RELEASE

Tank Release

1. WEAPONS SELECTOR switch - CONV BOMBS
2. BOMB MODE SELECT switch - MANUAL
3. Applicable STATION SELECT switch or switches:
(R1, L1, RO, LO) - IN
4. STORE RELEASE switch - DEPRESS

CAUTION

Reduce aircraft speed per standing orders or T.O. before tank release.

Switch and Circuit Breaker Location Table

<u>NOMENCLATURE</u>	<u>LOCATION</u>
Bomb Arming Nose Circuit Breaker	Armament Circuit Breaker Panel
Bomb Arming Tail Circuit Breaker	Armament Circuit Breaker Panel
Bomb Arming Switch	Main Instrument Panel
Bomb Mode Select Switch	Main Instrument Panel
Master Armament Switch	Main Instrument Panel
Master Armament Circuit Breaker	Main Instrument Panel
Pylon Sequence Select Switch	Main Instrument Panel
Store Release Control Circuit Breaker	Armament Circuit Breaker Panel
Store Release LH Circuit Breaker	Armament Circuit Breaker Panel
Store Release RH Circuit Breaker	Armament Circuit Breaker Panel
Store Release Switch	Control Stick Grip
Station Select Switch	Main Instrument Panel

NOMENCLATURE

Tank Safety Pin
Weapons Select Switch

LOCATION

Tank Tail Cone, LH side
Main Instrument Panel

3.0 F100 Aircraft

Operating Procedures - The tank is armed from the cockpit of the F100 Aircraft through the bomb arming circuit and jettisoned through the chemical tank release circuit. The dissemination on/off function is obtained with the chemical release circuit by use of the BOMB ROCKET RELEASE switch.

Tank operation is accomplished through the following switching sequence:

Preflight

1. Applicable PYLON LOADING switches - CHEM TANK

CAUTION

PYLON LOADING switches should not be changed from stated position once the electrical system has been energized, since to do so may eject the stores from the pylon.

2. BOMB ARMING circuit breaker - OUT
3. CHEMICAL circuit breaker - OUT
4. Tank SAFETY PIN - REMOVE (just prior to flight)

Prearm

1. BOMB & TANK RELEASE circuit breaker - IN
2. BOMB & TANK REL CONT circuit breaker - IN

Arm

1. CHEMICAL circuit breaker - IN
2. BOMB ARMING circuit breaker - IN
3. BOMB ARMING switch - NOSE & TAIL

NOTE: The above step arms all tanks carried.

Chemical Release

1. ARMAMENT SELECTOR switch - CHEMICAL (RELEASE)
2. CHEMICAL SELECTOR switch - applicable position: OUTBD, (LH, BOTH, RH): INTERM (LH, BOTH, RH). Use ALL position for simultaneous dissemination from all stations.
3. Start: BOMB ROCKET RELEASE switch - DEPRESS (Dissemination will continue as long as switch is depressed or until switch is released or tank is empty).
4. Stop: BOMB ROCKET RELEASE switch - RELEASE

Tank Release

1. ARMAMENT SELECTOR switch - applicable position: CHEMICAL (OUTBD JETT, INTERM JETT).

2. BOMB ROCKET RELEASE switch - DEPRESS

CAUTION

Reduce aircraft speed per standing orders or T.O. before tank release.

Switch and Circuit Breaker Location Table

NOMENCLATURE

LOCATION

Armament Selector Switch

Armament Selector Switch Panel LH Console

Bomb Arming Circuit Breaker

LH Vertical CB Panel

Bomb Arming Switch

Armament Selector Switch Panel

Bomb Rocket Release Switch

Control Stick

Bomb & Tank Release Circuit Breaker

LH Fuselage Station, 200 CB Panel

Bomb & Tank Release Control Circuit Breaker

LH Fuselage Station, 200 CB Panel

Chemical Circuit Breaker

LH Vertical CB Panel

Chemical Selector Switch

Arm Control Panel

Pylon Loading Switches

Pylon Loading Switch Panel, LH Console

Tank Safety Pin Switch

Tank Tail Cone, LH side

APPENDIX II

SPRAY TANK NOSE CONE ANALYSIS

PREPARED BY
CSM 175 Sep 64

CHECKED BY
DATE

REVISED BY
DATE



PAGE 65

REPORT

SPRAY TANK NOSE CONE ANALYSIS

MODEL M-490

4-84

INTRODUCTION

THIS PRELIMINARY STRESS ANALYSIS IS PREPARED TO PROVE THE STRUCTURAL ADEQUACY OF THE ADAPTER SHELL ON THE M-490 "B" SPRAY TANKS.

THE ADAPTER SHELL IS SPUN FROM 6061 ALUMINUM ALLOY, THEN HEAT TREATED AND AGED TO OBTAIN A T6 CONDITION. THERE ARE LOCALIZED INCREASES IN CROSS-SECTIONAL AREA AT BOTH THE GENERATOR ATTACHMENT POINT AND THE CENTER SECTION ATTACHMENTS.

INERTIA AND AIRLOADS ARE SHOWN IN THIS ANALYSIS, AND REFERENCES ARE GIVEN AS REQUIRED.

THE ANALYSIS CONTAINS SHELL STRESSES, PRIMARY AND SECONDARY, AND ATTACHMENT LOADS. THE METHODS USED ARE CONSIDERED TO BE SOMEWHAT CONSERVATIVE, AND ARE REFERENCED IF UNCOMMON.

PREPARED BY <i>LSM</i>	DATE <i>17 Sept 64</i>
CHECKED BY	DATE
REVISED BY	DATE

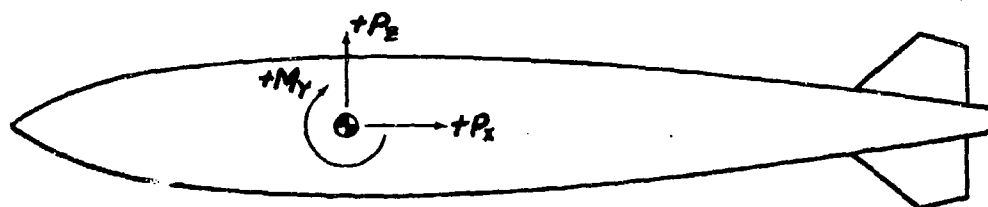


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MODEL M-490

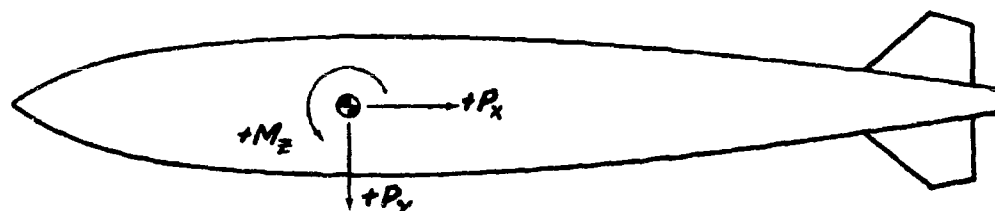
SPRAY TANK NOSE CONE ANALYSIS

SIGN CONVENTION

THE SIGN CONVENTION USED IN THIS STRESS ANALYSIS IS THE SAME USED BY FAIRCHILD STRATOS CORPORATION, REF. R490-006, P. 12.



SIDE VIEW



PLAN VIEW



VIEW LOOKING AFT

NOTE: C.G. IS AT T.S. 72- REF. R490-006, P. 13.

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CRITICAL LOADING

DESIGN LOAD FACTORS (LIMIT)

COND.	n_x	n_y	n_z	θ	ψ
6	± 2	± 6.5	-6	± 6	0

REF. R490-006, P. 16.

~ LIMIT INERTIA LOADS ~

STA.	WT. (#)	C.G. STA.	$P_{\theta=1}$ (#)	P_x (#)	P_y (#)	P_z (#)	M_y ("·#)	M_z ("·#)
10	13.73	3.83	2.42	± 27	± 89	-97	± 640	-509
22	19.17	6.92	3.23	± 38	± 124	-134	± 2172	-1735

SAMPLE CALCULATIONS—STA. 10 —

$$P_{\theta=1} = Wd/g = 13.73 (72-3.83)/396.4 = 2.42\#$$

$$P_x = n_x W = \pm 2(13.73) = \pm 27\#$$

$$P_y = n_y W = \pm 6.5(13.73) = \pm 89\#$$

$$P_z = n_z W + \theta \cdot P_{\theta=1} = -6(13.73) \pm 6(2.42) = -97\#$$

$$M_y = n_y Wd + \theta \cdot P_{\theta=1} \cdot d = \pm 6.5(13.73)(10-3.83) \pm 6(2.42)(10-3.83)$$

$$M_y = \pm 640\text{"·#}$$

$$M_z = n_z Wd = -6(13.73)(10-3.83) = -509\text{"·#}$$

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DESIGN AIRLOADS (LIMIT)

REF. R490-003, P. 72.

$\alpha = 0^\circ$

$B = 2.811^\circ$

STA	P_x (#)	P_y (#)	P_z (#)	M_y ("·#)	M_z ("·#)
10	1682	-542	-353	-2523	-4867
22	1682	-832	-765	-9251	-13,545

SAMPLE CALCULATIONS - STA. 10 —

$$P_x = A.F._{STORE} = 1682^\# \text{ REF. R490-003, P. 72.}$$

$$P_y = S.F._{SO} V_{ySO}^{(1)} + S.F._{SB} V_{ySB}^{(2)} = -168(1.92) + 1418(-.155) = -542^\#$$

$$P_z = N.F._{SO} V_{zSO}^{(2)} + N.F._{SB} V_{zSB}^{(4)} = 841(-.42) - 266(0) = -353^\#$$

$$M_y = N.F._{SO} M_{ySO}^{(5)} + N.F._{SB} M_{ySB}^{(6)} = 841(-3) - 266(0) = -2523 \text{ "·#}$$

$$M_z = S.F._{SO} M_{zSO}^{(7)} + S.F._{SB} M_{zSB}^{(8)} = -168(18) + 1418(-1.3) = -4867 \text{ "·#}$$

TO ACCOUNT FOR GENERATOR EFFECT, VALUES OF $V_y, V_z, M_y,$ AND M_z WERE READ AT STATIONS 18 INSTEAD OF 10, AND 30 RATHER THAN 22.

*REF. R490-003, P. 72.

REF. R490-006: (1) P. 46. (5) P. 39.

(2) P. 50. (6) P. 43.

(3) P. 38. (7) P. 47.

(4) P. 42. (8) P. 51.

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SPRAY TANK NOSE CONE ANALYSIS

NET DESIGN LOADS (LIMIT)

STA.	P_x (#)	P_y (#)	P_z (#)	M_y (in-#)	M_z (in-#)
10	1709	-631	-450	-3163	-5976
22	1720	-956	-899	-11,423	-15,280

STA.	P_x (#)	$P_R = P_y + P_z$ (#)	$M_R = M_y + M_z$ (in-#)
10	1709	776	6900
22	1720	1314	19,070

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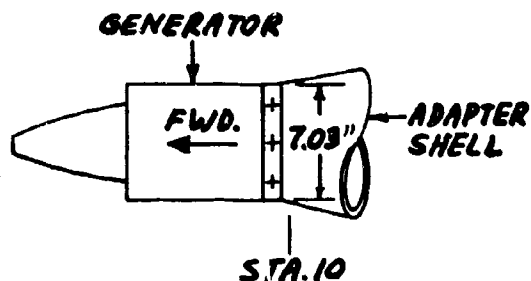
SHELL STRESSES PRIMARY

STA. 10

6061-T6 AL. ALLOY
 $t = 0.07"$

$$A = 2\pi R t = 2\pi(3.02)(.07) = 1.33 \text{ IN.}^2$$

$$I = \pi R^3 t = \pi(3.02)^3(.07) = 6.08 \text{ IN.}^4$$



$$f_c = \frac{P}{A} = \frac{1709}{1.33} = 1285 \text{ PSI (LIMIT)}$$

$$f_b = \frac{M_c}{I} = \frac{6300(3.02 + .035)}{6.08} = 3160 \text{ PSI (LIMIT)}$$

$$f_s = \frac{VQ}{It} = \frac{V \left(\frac{2\pi R t}{\pi} \right) \left(\frac{R}{2} \right)}{\pi R^3 t (2t)} = \frac{V}{\pi R t} = 2 \frac{V}{A} = 2 \left(\frac{776}{1.33} \right) = 1165 \text{ PSI (LIMIT)}$$

FROM MIL-HDBK-5, P. 3.2.6.0(b); $F_{tu} = 42,000 \text{ PSI.}$
 $F_{su} = 27,000 \text{ PSI.}$

FROM LAC SM 70a, P. 8, CASE 33; $R_s^m + (R_b + R_c)^m = 1$

FROM LAC SM 70a, FIG. 9: FOR $B = 90^\circ$, $\frac{D}{t} = 100$; $m = 2$.

$$R_s = \frac{1.5(1165)}{27,000} = 0.065 \quad R_b + R_c = \frac{1.5(3160 + 1285)}{42,000} = 0.159$$

FROM LAC SM 70a, FIG. 8: $\overline{OA} = 0.71$, $\overline{OB} = 4.02$.

M.S. = +4.67

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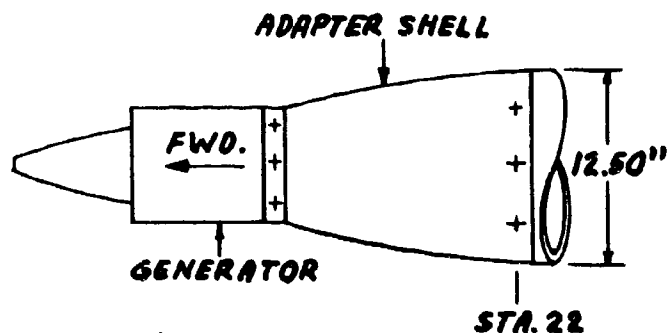
SPRAY TANK NOSE CONE ANALYSIS

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STA. 22

6061-T6 AL. ALLOY
 $t = 0.07"$

$A = 2.75 \text{ IN.}^2$
 $I = 53.8 \text{ IN.}^4$



$$f_c = \frac{P}{A} = \frac{1720}{2.75} = 626 \text{ PSI (LIMIT)}$$

$$f_b = \frac{Mc}{I} = \frac{19,070 (6.25 + .035)}{53.8} = 2230 \text{ PSI (LIMIT)}$$

$$f_s = 2 \frac{V}{A} = 2 \left(\frac{1314}{2.75} \right) = 953 \text{ PSI (LIMIT)}$$

$$R_s = \frac{1.5(953)}{27,000} = 0.053 \quad R_b + R_c = \frac{1.5(2230 + 626)}{42,000} = 0.102$$

FROM LAC SM 70a, FIG. 8; $FOR_m = 2$; $\overline{OA} = 0.47$, $\overline{OB} = 4.02$.

M.S. = + 7.57

* REF. P. 6.

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BIRMINGHAM, ALABAMA

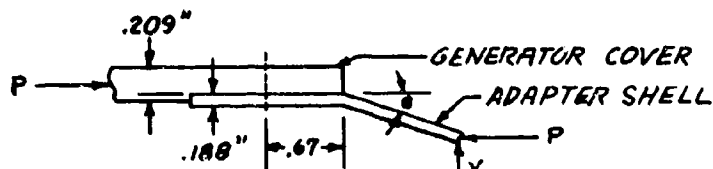
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SPRAY TANK NOSE CONE ANALYSIS

SHELL STRESSES
SECONDARY

STA. 9

$$\theta = 22^\circ$$



$$P_{MAX} = \frac{P_x}{2\pi R} + \frac{M_x}{\pi R^2} \quad \text{DETAIL OF ADAPTER SHELL ATTACHMENT TO GENERATOR COVER}$$

$$P_{MAX} = \frac{1709}{2\pi(3.02)} + \frac{6300}{\pi(3.02)^2}$$

$$P_{MAX} = 311 \text{ #/IN. (LIMIT)} = 467 \text{ #/IN. (ULT.)}$$

$$V = P \tan \theta = 311 \tan 22^\circ = 311 (.405) = 126 \text{ #/IN. (LIMIT)} = 189 \text{ #/IN. (ULT.)}$$

ADAPTER SHELL —

ASSUME MOMENT (.67V) IS TAKEN ENTIRELY BY ADAPTER SHELL AT ATTACHMENT IF P IS TENSILE.

$$M_s = .67(126) = 84.3 \text{ #/IN. (LIMIT)} = 127 \text{ #/IN. (ULT.)}$$

$$f_{bs} = \frac{6M_s}{t^2} = \frac{6(84.3)}{(.188)^2} = 14,350 \text{ PSI (LIMIT)} = 21,500 \text{ PSI (ULT.)}$$

$$f_{c, PRIMARY} = P_{MAX} / t = 311 / .188 = 1660 \text{ PSI (LIMIT)}$$

$$f_{c, P} = 1.5(1660) = 2490 \text{ PSI (ULT.)}$$

$$f_{c, MAX} = f_{cs} + f_{c, P} = 14,350 + 1660 = 16,010 \text{ PSI (LIMIT)} = 25,990 \text{ PSI (ULT.)}$$

$$F_{tu} = 48,000 \text{ PSI REF. P. 6.}$$

$$M.S. = +0.61$$

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SPRAY TANK NOSE CONE ANALYSIS

GENERATOR COVER —

ASSUME MOMENT FROM Y IS REACTED ENTIRELY BY GENERATOR COVER IF P IS COMPRESSIVE.

MAT'L: E233A-T5 MAG. ALLOY

$$\nu = \frac{E}{2G} - 1 = \frac{6.5*}{2(2.4)*} - 1 = 0.35 * \text{REF. MIL-HDBK-5, P. 4.2.8.0(b).}$$

FROM ROARK, P. 271, CASE 10:

$$\lambda = \sqrt{\frac{3(1-\nu^2)}{R^2 t^2}} = \sqrt{\frac{3[1-(.35)^2]}{(3.02-.10)^2 (.209)^2}} = 1.61$$

$$\text{MAX. } S'_1 = \frac{1.932 V_0}{\lambda t^2} = \frac{1.932(126)}{1.61(.209)^2} = 3460 \text{ PSI (LIMIT)}$$

$$\text{MAX. } S'_1 = 1.5(3460) = 5200 \text{ PSI (ULT.)}$$

$$f_{c \text{ PRIMARY}} = P_{\text{MAX.}}/t = 311/.209 = 1490 \text{ PSI (LIMIT) } 2240 \text{ PSI (ULT.)}$$

$$f_{c \text{ MAX.}} = S'_1 + f_{c p} = 3460 + 1490 = 4950 \text{ PSI (LIMIT) } = 7440 \text{ PSI (ULT.)}$$

$$F_{tu} = 20,000 \text{ PSI, } F_{cy} = 14,000 \text{ PSI REF. MIL-HDBK-5, P. 4.2.8.0(b).}$$

$$\underline{\underline{M.S. = +1.69}}$$

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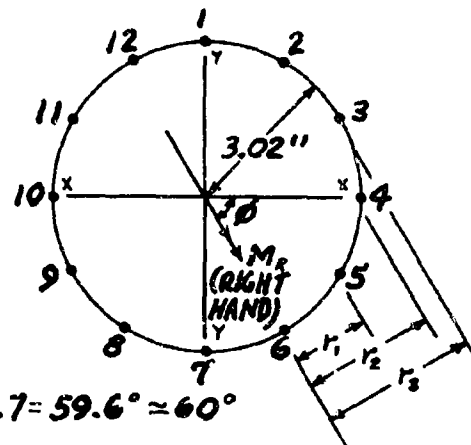
SPRAY TANK NOSE CONE ANALYSIS

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ATTACHMENT LOADS

STA. 9

THE ADAPTER SHELL IS ATTACHED TO THE GENERATOR COVER WITH 12 AN509 3/16" SCREWS AS SHOWN. THE LOCAL THICKNESS OF THE ADAPTER SHELL IS 0.188" IN THIS REGION.



$$\phi = \tan^{-1} \frac{M_z}{M_y} = \tan^{-1} \frac{5376}{3163} = \tan^{-1} 1.7 = 59.6^\circ \approx 60^\circ$$

$$r_1 = 3.02 \sin 30^\circ = 3.02 (.5) = 1.51''$$

$$r_2 = 3.02 \sin 60^\circ = 3.02 (.867) = 2.61''$$

$$r_3 = 3.02$$

$$E_s = 4(1.51)^2 + 4(2.61)^2 + 2(3.02)^2 = 54.62 \text{ IN.}^2$$

$$P_s = \frac{M_z r}{E_s} + \frac{P_x}{N} = \frac{6300(3.02)}{54.62} + \frac{1709}{12} = 491^* (\text{LIMIT}) = 798^* (\text{ULT.})$$

ALLOWABLE SINGLE SHEAR = 990* REF. HAYES SDM, SECT. 702.211.

$$f_{br} = \frac{491}{(.188)(.188)} = 14,000 \text{ PSI}$$

$F_{br} = 58,000 \text{ PSI } (e/d = 2.0) \text{ REF. MIL-HDBK-5, P.3.2.6.0(b).}$

SHEAR ON SCREW IS CRITICAL.

$$M.S. = +0.34'$$

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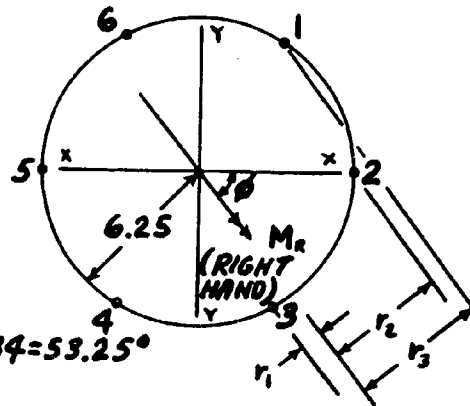
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STA.22

THE ADAPTER SHELL IS ATTACHED TO THE CENTER SECTION BY 6 AN509 5/16" SCREWS AS SHOWN. THE LOCAL THICKNESS OF THE ADAPTER SHELL IS 0.140" IN THIS REGION.



$$\phi = \tan^{-1} \frac{M_x}{M_y} = \tan^{-1} \frac{-115,280}{11,423} = \tan^{-1} 1.34 = 53.25^\circ$$

$$r_1 = 6.25 \sin 6.75^\circ = 6.25 (.118) = 0.74$$

$$r_2 = 6.25 \sin 53.25^\circ = 6.25 (.802) = 5.01$$

$$r_3 = 6.25 \sin 66.75^\circ = 6.25 (.919) = 5.73$$

$$E_r^2 = 2[(0.74)^2 + (5.01)^2 + (5.73)^2] = 117.1 \text{ in.}^2$$

$$P_4 = \frac{M_x r}{E_r^2} + \frac{P_x}{N} = \frac{19,070(5.73)}{117.1} + \frac{1720}{6} = 1222 \# (\text{LIMIT}) = 1833 \# (\text{ULT.})$$

ALLOW. ULT. SINGLE SHEAR = 2685# REF. HAYES SDM, SECT. 702.211

$$f_{br} = \frac{1222}{(.912)(.14)} = 28,000 \text{ PSI}$$

$F_{br} = 58,000 \text{ PSI}$ REF. P.10.

BEARING ON SHELL IS CRITICAL.

$$M.S. = \underline{\underline{+1.06}}$$

APPENDIX III

**WEIGHT AND BALANCE ANALYSIS
MODIFIED A/B45Y-1 BIOLOGICAL SPRAY TANK
EQUIPPED WITH WIND DRIVEN GENERATOR**

Summary

Specification MIL-C-8591C requires that the center of gravity of airborne stores be located equidistance between the suspension lugs with a tolerance of $\pm$ three (3) inches. The modified A/B45Y-1 Spray Tank configuration meets this requirement. For the original tank with midpoint suspension at Station 72.0, the tank empty CG location (Station 75.3) fell outside this requirement. The modified tank empty CG location (Station 73.01) is located 1.01 inches aft of the mid suspension point (Station 72.0) which will be the normal condition for jettison during operational usage of the spray tank. The modified tank full CG location (Station 71.13) is located 0.87 inches forward of the mid suspension point (Station 72.0). The modification weight penalty is 34.35 pounds.

Basic Data - Original A/B45Y-1 Tank

	<u>Weight</u>	<u>CG Location</u>
Tank empty	230.5 lbs.	Sta 75.3
Agent	529.0 lbs.	Sta 70.2
Tank Full	759.5 lbs.	Sta 71.7

Location of Suspension Lugs

	<u>FWD</u>	<u>AFT</u>
14 inch lugs	Sta 65.0	Sta 79.0
30 inch lugs	Sta 57.0	Sta 87.0

Mid suspension point location Sta 72.0

(Reference: Original Handbook of Instructions)

Basic Data - Modified A/B45Y-1 Tank

Tank Empty Weight Build Up Actual Values:

	<u>Weight Lbs.</u>	<u>Arm Inches</u>	<u>Moment Inch/Lbs.</u>
Original tank empty	230.5	73.3	17,356.65
Added components			
Wind driven generator	15.0	3.0	45.0
Nose cone additional weight	3.5	15.0	52.5
Ring splice P/N 100-06545	1.0	17.25	17.25
Umbilical connector assembly	1.0	93.00	93.00
Clip lower P/N 100-06534	0.5	128.0	64.0
Clip upper P/N 100-06535	0.5	128.0	64.0
Relay and mounting hardware	0.75	128.0	96.0
Ballast P/N 100-06563	2.0	128.0	256.0
Ballast P/N 100-06564	3.1	128.0	396.8
Ballast P/N 100-06573	7.0	128.0	896.0
	264.85	73.01	19,337.2

Tank Full Weight Build Up:

	264.85	73.01	19,337.2
Tank empty	<u>529.0</u>	<u>70.2</u>	<u>37,135.8</u>
Agent	793.85	71.13	56,473.0
Tank full			

Summation:	<u>Original Tank</u>		<u>Modified Tank</u>	
	<u>Weight</u>	<u>CG Location</u>	<u>Weight</u>	<u>CG Location</u>
Tank empty	230.5	75.3	264.85	73.01
Agent	529.0	70.2	529.0	70.2
Tank full	759.5	71.7	793.85	71.13

Tank weight increase: 34.35 lbs.
 CG empty moved forward: 2.29 inches
 CG full moved forward: 0.57 inches

APPENDIX IV

LIST OF CLASS II DRAWINGS
A/B45Y-1 SPRAY TANK MODIFICATION
TTU-251/E TEST SFT

List of Class II Drawings Detailing the A/B45Y-1 Spray Tank Modification

<u>Drawing Number</u>	<u>Title</u>
100-06525	Modification Spray Tank, Complete
100-06526	Family Tree
100-06527	Cable Assembly, External Power
100-06528	Modification Spray Tank
100-06529	Adapter Cable Assembly, F105
100-06531	Adapter Cable Assembly, F100
100-06532	Nose Cone
100-06534	Clip, Lower
100-06535	Clip, Upper
100-06538	Cable Assembly, J1
100-06539	Schematic
100-06540	Wiring Diagram
100-06541	Cable Assembly, W1
100-06542	Cable Assembly, J3
100-06543	Cable Assembly, External Power Relay
100-06544	Cable Assembly, Miscellaneous Wires
100-06545	Ring Splice
100-06555	Adapter Cable, F4C
100-06558	Sleeving
100-06559	Marking Drawing
100-06561	Shear Plate
100-06562	Angle Bracket
100-06563	Ballast
100-06564	Ballast
100-06565	Adapter Plate Assembly, F105
100-06567	Adapter Plate Assembly, F4C
100-06568	Adapter Plate Assembly, F100
100-06569	Cover Plate
100-06570	Adapter Plate, F100
100-06571	Adapter Plate, F4C
100-06572	Adapter Plate, F105
100-06573	Ballast
100-06578	Boss
100-06579	Cap
100-11293	Wiring Diagram
100-11294	Schematic
100-11295	Relay Mounting Bracket Assembly
100-11296	Relay Mounting Bracket

List of Class II Drawings Detailing the TTU-251/E Test Set Design

<u>Drawing Number</u>	<u>Title</u>
100-06530	Test Set Assembly
100-06548	Wiring Diagram
100-06549	Schematic
100-06550	Cable Assembly, P1
100-06551	Cable Assembly, P13
100-06552	Cable Assembly, N/S

<u>Drawing Number</u>	<u>Title</u>
100-06553	Cable Assembly, T/S
100-06554	Cable Assembly, Miscellaneous Wire
100-06556	Cable Assembly, P14
100-06557	Rotary Switch
100-06560	Decal Practical Wiring Diagram
100-06574	Cable Assembly, W1
100-06575	Cable Assembly, W2
100-06576	Cable Assembly, W3
100-06577	Cable Assembly, W4

APPENDIX V

REVIEW AND ANALYSIS OF THE ENVIRONMENTAL TESTING
CARRIED OUT ON
THE A/B45Y-1 BIOLOGICAL SPRAY TANK

Review and Analysis of the Environmental Testing Carried out on the A/B 45Y-1 Biological Spray Tank

Introduction

An analysis of the environmental testing carried out on the A/B 45Y-1 Biological Spray Tank during its development history was prompted by a letter from Col. N.H. Cox, dated 20 September 1965 forwarded to Hayes International Corporation from the Directorate of Armament Development, Eglin Air Force Base, Florida (Ref. ATCB/Mr. Solomon/882-2457). This letter was supplemented with a copy of a memo written by Mr. W.J. McCoy, APGC, Eglin Air Force Base, which indicated the possibility of a 9000# increase in lug limit load for 14" ejector racks when carrying this store.

Summary

A review and analysis was made of all the test reports pertaining to testing of the A/B 45Y-1 Biological Spray Tank. It was concluded that the tank has been over-driven in most tests as test input vibratory acceleration levels were not attenuated in accordance with the appropriate test specifications MIL-E-5272 and MIL-STD-810A to which the tanks were tested for test specimens weighing in excess of 50 lbs. Large magnification factors were evident in the bomb rack to store suspension system and through the plastic center body structure of the tank. It is felt that these two factors significantly contributed to the failure of the test specimen tank during testing. The effect of these factors was further amplified by the failure of attachment hardware locking mechanisms.

It is recommended that the tank be retested in accordance with MIL-STD-810A with full attenuation values applied to input levels and that additional locking devices be incorporated in the test specimen to prevent the loosening of attachment hardware.

Referenced Documents

MIL-E-5272C	MIL-A-8591C
MIL-STD-810A	MIL-N-25027C

Development History of the A/B 45Y-1 Biological Spray Tank

The A/B 45Y-1 Biological Spray Tank was originally developed by Fairchild Stratos under Contract DA-18-064-AMC-7(A).

The tank was later modified by the Hayes International Corporation under Contract AF 08(635)-4600 to incorporate a wind driven generator located at the nose of the tank to provide electrical power for the tank heater system.

The original tank was designed in accordance with MIL-A-8591C to meet the requirement of Figure 7, page 12 for stores weighing between 501# to 1250#. No additional magnification factors were added to these design limit load factors as Paragraph 5.3 states this is not necessary. As built the original tank weighed 230# empty and 760# full. The estimated weight penalty resulting from the modification was 40 lbs. giving the modified tank weight of 270# empty and 800# full.

Environmental Test History of the A/B 45Y-1 Biological Spray Tank

Three separate tanks were subjected to environmental testing, all tests being carried out at Picatinny Arsenal.

These tests for which reports are available were vibration testing in the longitudinal, vertical and lateral axes.

1. Test #1

Test Speciman	Original Tank
Test Number	4-63
Date	26 March 1963

2. Test #2

Test Speciman	1st Modified Tank
Test Number	87-64
Date	4 January 1965 15 February 1965

 } 2 Documents

3. Test #3

Test Speciman	2nd Modified Tank
Test Number	43-65
Date	22 June 1965

Flight Test History of the A/B 45Y-1 Biological Spray Tank

Approximately 200 hours of flight time have been accumulated on various specimens of the original spray tank.

Review of Previous Test Programs

From a review of the reports for the three test programs it was readily apparent that all test specimens experienced problems and failures during testing. In almost all instances they seemed to be products of low frequency resonance testing. Analysis of the recorded instrumentation data for these runs indicated large magnification of the input accelerations at resonance in all axes due to the flexibility of the tank center body structure.

This was complemented with additional magnification through the suspension system in the longitudinal axis. In some instances the accelerometer pickups indicated substantial deflections in axes other than that of the input with the vector resultant for these values also indicating a large magnification factor through the tank center body structure and suspension system.

In comparing the magnification factors for the three tests the similarity of those for test #1 and test #3 were readily apparent. However, test #2 indicated a degree of damping at low frequency resonance. It was felt that this variation in behavior phenomena was due to the dissimilar properties of individual tank structures. The tank center body is a hand laid up plastic structure and at best it would be difficult to maintain identical characteristics which would result in identical physical properties.

Test #1 and 2 were conducted in accordance with MIL-E-5272 procedure XII and test #3 in accordance with MIL-STD-810A, Method 514.1.

The method for conducting the tests is identical in both instances, initially a resonance search is conducted by sweeping the input spectrum from 5 thru 500 CPS. This is followed by resonance running at the resonant frequencies. The runs are conducted in all three axes.

Both test procedures state that for resonance running of test specimens weighing more than 50 lbs. the vibratory acceleration input applied to the test specimen may be reduced by 1 g for each 10 lbs. increment of weight above 50 lbs. to a value no lower than 50% of the original test curve. (MIL-E-5272, Para. 4, 7, 12, 1; and MIL-STD-810A, Method 514.1, Para. 8 under Resonance Dwell, Part II). As the spray tank in its original form weighed 760 lbs. and 800 lbs. after modification it certainly qualified for the 50% reduction in input acceleration for resonance running. This concession was only made available in Test #1 carried out on the original tank. It is felt that this feature alone of driving the tank in resonance at twice the required input contributed to some of the problems and failures in Tests #2 and 3.

The three to one magnification factor across the bomb rack tank suspension system in the longitudinal axis which certainly confirms the observations of Mr. W. J. McCoy in his memo (these observations probably being confirmed by the actual failure of the bomb rack in Test #2 in this axis) is outside the scope of either contractor (Fairchild or Kayes) as the tank suspension system certainly meets the requirements of MIL-A-8951C. The lug load computed by Mr. McCoy is derived from the test data and this value is hardly affected by the modification penalty weight of 40 lbs. Rather it is the product of store weight and acceleration and the only way to reduce this value is to reduce either the store weight or acceleration significantly. Obviously the store weight cannot be reduced but the acceleration level can, as previously pointed out, with the 50% reduction in input acceleration value. It is also felt that the suspension system probably contributes to the movement of the store in axes other than the input axis.

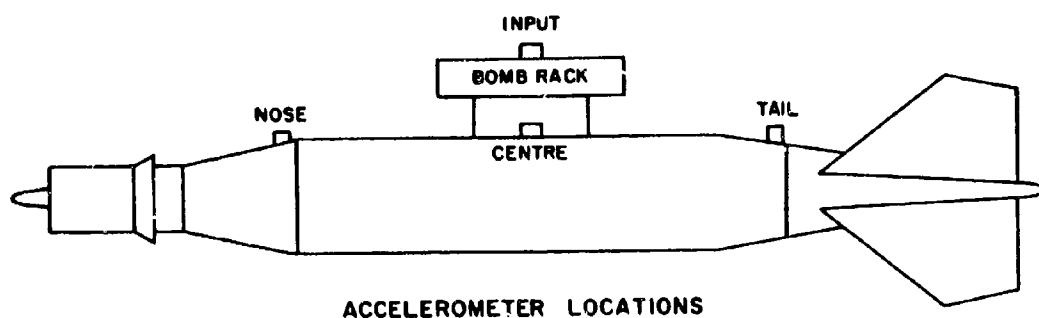
From a comparison of the accelerometer readings contained in the test data included with the reports of the three tests, it was possible to determine the magnification factors present during the tests between the data pickup locations. These values are shown in Figures #1 and #2, for the three axes, longitudinal, lateral and vertical. Using these values, it should then be possible to predict acceleration levels at the various pickup locations for a known input.

Review of Problem Areas and Damage Incurred During Test

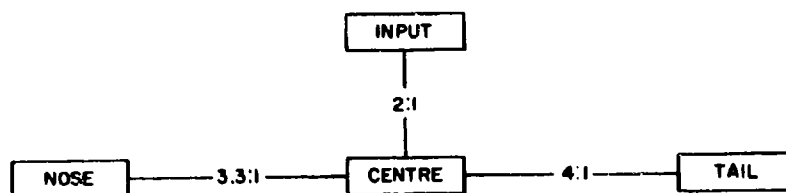
From a review of the reports for the three test programs, it was possible to compile a chart, Figure 5, summarizing all the problem areas and damage incurred during testing, similar types of problems grouped together by common location.

Group 1

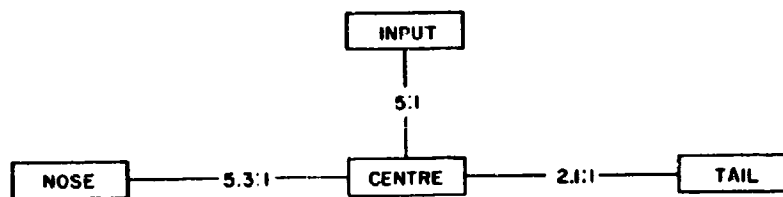
In all tests trouble was experienced with loosening up of the sway braces on the bomb rack. During Test #1 local hardpads were taped to the tank structure. This was probably done to eliminate friction burning of the sway braces into the plastic tank structure as was the case in Test #3 where the burn depth extended through two layers of fabric, the cause being excessive relative motion in the longitudinal axis. In test #2 the rear lug on the bomb rack fractured probably due to excessive loading, a possible condition pointed out by Mr. McCoy in his memo, which can result from the three to one magnification through the suspension system of the input acceleration level.



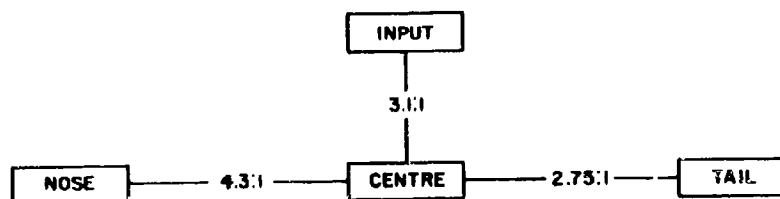
ACCELEROMETER LOCATIONS



VERTICAL AXIS

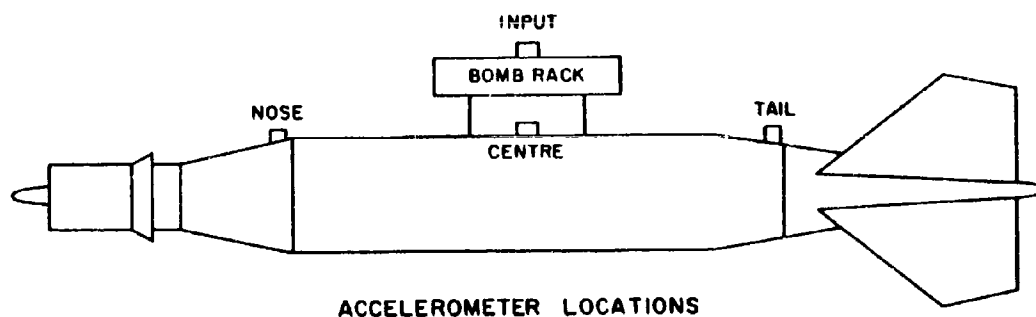


LATERAL AXIS

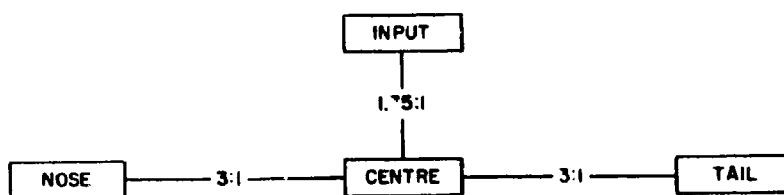


LONGITUDINAL AXIS

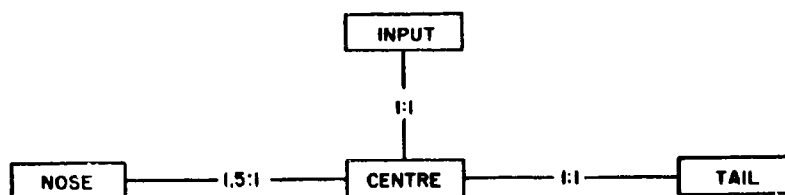
Figure 1 PEAK MAGNIFICATION FACTORS



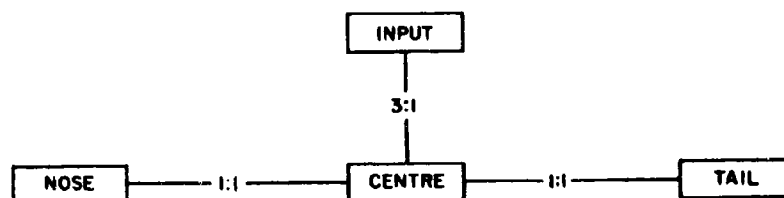
ACCELEROMETER LOCATIONS



VERTICAL AXIS



LATERAL AXIS



LONGITUDINAL AXIS

Figure 2 AVERAGE MAGNIFICATION FACTORS

SUMMARY OF PROBLEM AREAS AND DAMAGE

GROUP NUMBER	SUBJECT	TEST #1 Original Tank			TEST #2 1st Mod Tank			TEST #3 2nd Mod Tank		
		Vertical	Lateral	Longitudinal	Vertical	Lateral	Longitudinal	Vertical	Lateral	Longitudinal
1	Bomb Rack to Tank Attachment Loosened Rear Lug on Bomb Rack Fractured Photographs Show Taped on Hard Pads for Sway Braces Evidence of Burning on Tank Hardback Under the Sway Braces	X					X X	X	X	X
		X	X	X						
2	Air Bottle Movement Clamps Rubbing Against Skin Bottle Clamp Broken, Bottle, Loose, Plumbing Damaged	X					X	X		
3	Attachment Hardware Loosened at Nose Cone Center Body Interface Attachment Hardware Sheared at Nose Cone Center Body Interface Attachment Hardware Sheared at Nose Cone Generator Interface	X						X	X	
							X	X	X	
4	Attachment Hardware Loosened at Tail Cone Center Body Interface Attachment Hardware Worked into Tail Cone Skin		X					X		
			X							
5	Fractured Liquid Line in Tail Tail Cap Broke Loose						X	X	X	
6	Ballast Mounting Brackets Fractured						X			
7	Tank Fractured Aft of Nose Cone Attachment			X						
8	Transformer Brackets Broken in Generator Generator Shroud Loosened Generator Shroud Attachment Hardware Failed									
								X	X	X

FIGURE 3

Group 2

Air bottle movement resulting in some instances with broken clamps and attendant plumbing was probably due to excessive loading recorded as high as 44g at the nose pickup. With a weight of 23 lbs. at 44g at 53 CPS the air bottle becomes quite an impacting force. Some restraining of the air bottle is also lost when loosening of the nose cone attachment hardware allows the nose assembly to whip.

Group 3

Attachment hardware at the nose cone to center body interface loosened due to failure of the locking devices under high loading allowing the cantilevered nose cone assembly to whip, this condition eventually leading to the shearing of some of this hardware.

Group 4

Attachment hardware at the tail cone to center body interface loosened due to failure of the locking devices under high loading here again allowing the cantilevered tail cone to whip resulting in the hardware working into the soft plastic skin of the tail cone.

Group 5

The liquid line in the tail was fractured due to whipping of the tail cone which fatigued the welded joint at the pipe flange forward of the flow indicator. Visual inspection of this flange assembly indicates its relative fragility when compared to the other flange located only three inches away on the same assembly. The tail cap broke loose due to excessive loading resulting from whipping of the tail cone when the attachment hardware loosened up.

Group 6

Failure of the ballast mounting brackets was probably due to excessive loading (20g +).

Group 7

Failure of the tank just aft of the nose cone attachment is attributed to improper testing techniques in this instance by the test facility.

Group 8

Failure of the transformer mounting brackets and shroud hardware and locking devices resulted from excessive loading caused by inherent magnification factors in the tank structure and whipping of the nose cone after loosening of the nose cone attachment hardware.

Further study of the test reports indicated that for each test the testing in the various axes was not carried out in the same sequence.

Test #1 was vertical, lateral, longitudinal

Test #2 was lateral, vertical, longitudinal

Test #3 was lateral, longitudinal, vertical

In test #1 the tank successfully completed vertical and lateral and failed in longitudinal. In test #2 the tank successfully completed lateral and vertical and failed in longitudinal. In test #3 the tank successfully completed lateral, longitudinal then experienced trouble in vertical.

In tests #1 & 2 the major damage occurred in the longitudinal axis though prior damage may have occurred in the other axes. In test #3, failure occurred in the vertical axis after completion of the longitudinal axis where the major damage could quite conceivably have been caused. Based on these observations it would seem that the longitudinal axis might well be the most destructive due to the excessive slippage in the suspension system in this axis.

Conclusions

The following conclusions were drawn from the review of the test data available for the three environmental test programs carried out on the A/B 45Y-1 Biological Spray Tank.

1. The vibratory acceleration (g loading) input for the resonance dwell testing was twice as large as that required by MIL-E-5272C and MIL-STD-810A for tests #2 and 3.

2. The magnification factor between the bomb rack and the spray tank in the longitudinal axis was an unknown factor during the design phase. This magnification is not called for in MIL-A-8591C and cannot be calculated as it is a function of bomb rack to store lug fit.

NOTE: It is a combination of 1 and 2 which prompted Mr. W. J. McCoy's memo restricting flight testing. The correct vibratory acceleration (g loading) input should lower the lug limit load for the 14-inch ejector rack below the design limit loads for arrested landing and catapulting.

3. The plastic center body structure of the spray tank is quite flexible resulting in large amplification factors at both extremities, (nose and tail) during resonance with variations from unit to unit giving differing behavior patterns due to varying material properties resulting from the method of construction.

4. Failure of the locking mechanism for the hardware attaching the nose cone and tail cone assemblies

a. The locking torque for the existing blind nut plates located on the tank center body and deteriorated with each screw removal and replacement.

b. The initial screw preload torque was probably lost with minor wear in the fiberglass structure at the tail.

5. Items 1, 2, 3, & 4 all contributed to failure of the tank during test. Item 1, twice the required vibratory acceleration input level at the bomb rack, plus item 2 the three to one magnification across the rack to store mechanical interface subjected the tank to input loads six times greater than that required for resonance testing. This load was further amplified by item 3 the inherent flexibility of the plastic center body structure. The resultant excessive loads at the nose and tail attachment points was applied to all components located at and beyond these extremities and these loads were further increased by the whipping action of the nose cone and tail cone assemblies after the loosening up of their attachment hardware due to item 4.

6. The original tank configuration at a weight of 760 lbs. successfully completed 200 hours of flight test even though a complete environmental test program was never successfully completed. Had the test specimen used in test #1 completed longitudinal testing the method of coupling the input vibratory acceleration by-passed the bomb rack to store mechanical interface and its attendant problems detailed in item 2. This test specimen also benefitted from the 50% input attenuation for resonance testing not applied in later tests.

7. The first modified tank used in test #2 came within 2 minutes of completing the test program using a resonance dwell input of 10g per MIL-E-5272, without the 50% allowable attenuation. Consequently it is reasonable to assume that the tank could successfully complete testing with this reduced to a 2-1/2g input level as required by MIL-STD-810A with 50% attenuation.

Recommendations

1. It is recommended that the A/B 45Y-1 Biological Spray Tank be re-submitted for environmental testing in accordance with MIL-STD-810A. Vibration testing should be in accordance with Curve B of Figure 514-1, per time table 514-11. For resonance dwell running all input values should be reduced to 50% of the values of Curve B of Figure 514-1 reference Procedure I, Part II of Paragraph 8 on page 514-13. Predicted g level readings for the tank while running in resonance are shown in Figures 4 and 5.

2. In order to increase the remaining locking torque of the captive nut plates used for the nose cone and tail cone attachment hardware it is proposed to use self-locking screws with H1-torque heads with torque requirements of 30 - 40 inch pounds. The captive nut plates, part number NAS 1068A4 should have a minimum breakaway torque of 3.5 inch pounds per MIL-N-25027C, Table III on page 6, but it is anticipated that this value has deteriorated due to re-use. The replacement screws, part number NAS 1164 will give an additional 3.5 inch pounds of breakaway torque which should help obviate the locking problem in conjunction with the reduced input loads. Re-evaluation of the stress requirements for the attachment hardware for this test level indicates that the screw size and quantity are adequate and it is the low minimum breakaway torque which is the prime problem. Consequently as a back up to the substitution of locking screws it is proposed, in case this does not solve the locking problem, to prepare a kit to install 5/16-24 attachment screws using a blind nut installation similar to H1-shear part number BN359 which can be readily installed at the test facility during the test. This installation will give a screw attachment with a minimum breakaway torque of 6.5 inch lbs.

3. Further it is suggested that some local hard pad plates be provided which can be affixed to the tank at the sway brace contact locations. This will provide a harder contact surface thereby eliminating the wear down through the plastic which is one of the causes for the mechanical interface to loosen and may even provide a degree of damping to this interface which will attenuate the relative displacement and reduce the magnification factor.

4. It is suggested that some ruling be made about time history usage of the test facility bomb rack. A typical three axis test run is considered to be equivalent to an aircraft life cycle of 10-15 years. Continual re-use of the same bomb rack will obviously age the bomb rack to the degree where it is either fatigued and fails (as might have been the case in Test #2) or it becomes worn and allows large relative movement resulting in high magnification factors.

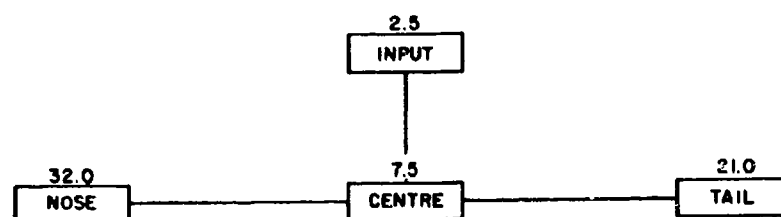
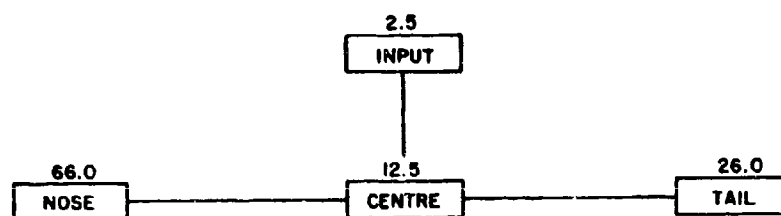
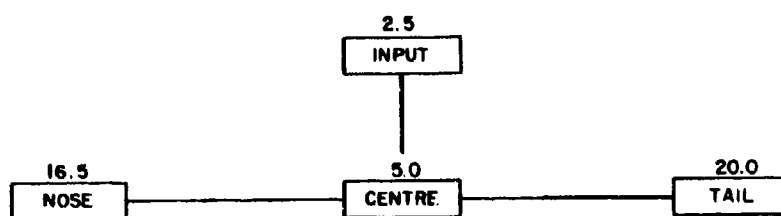
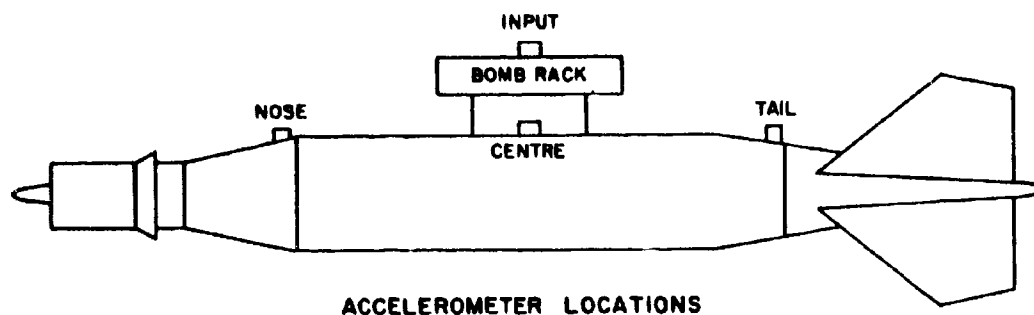
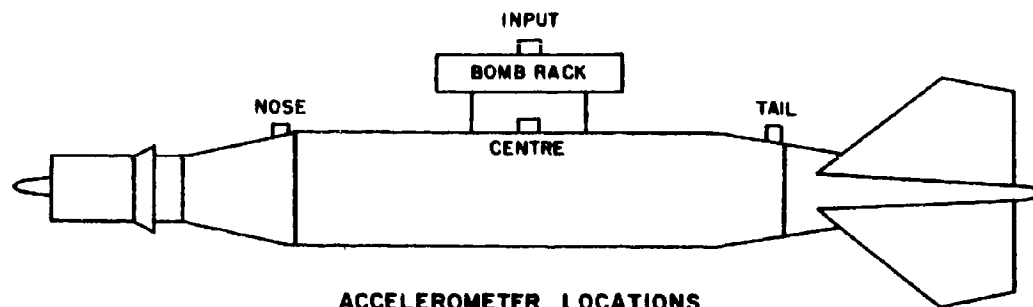
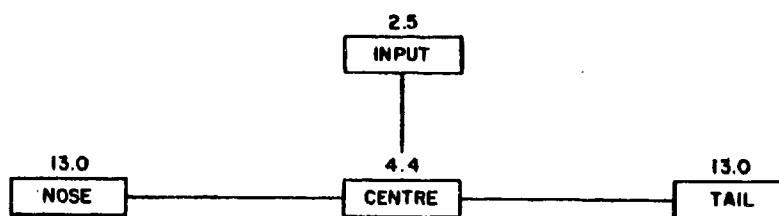


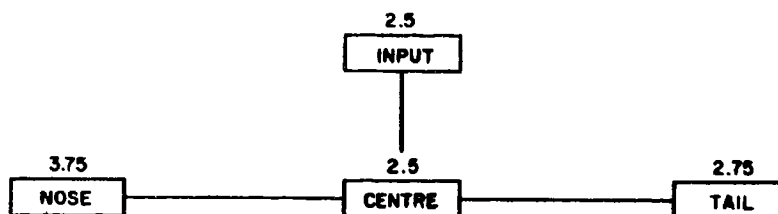
Figure 4 PEAK PREDICTED "G" LOADS



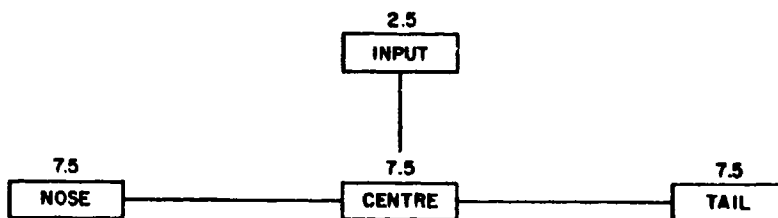
ACCELEROMETER LOCATIONS



VERTICAL AXIS



LATERAL AXIS



LONGITUDINAL AXIS

Figure 5 AVERAGE PREDICTED "G" LOADINGS

5. It is recommended that all available previous test data be made available to a contractor at the onset of the contract where the work task involves modification of existing hardware.

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4 DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report - July 1964 through March 1966		
5 AUTHOR(S) (Last name, first name, initial) Kemp, James A		
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13 ABSTRACT The existing A/B45Y-1 Biological Spray Tank was modified to incorporate a wind-driven electrical generator to power the tank heater system, thereby making the tank independent of the carrying aircraft for this service. The generator was mounted to the nose of the tank using a new aluminum nose cone which interfaced with the existing nose cone attachment points located on the forward bulkhead. Weight and balance was adjusted by the addition of ballast weights attached to the aft bulkhead. In addition, the tank electrical control circuitry was redesigned to ensure complete operational compatibility of the tank with the existing aircraft control wiring and the variety of umbilical connector types and locations at the numerous pylon stations on the various designated aircraft (F-4C, F-105, F-100). As modified, the tank was subjected to environmental testing and incurred damage. An analysis of the test data indicated that the generator and its attachments were being subjected to excessive loads due to the flexing of the tank plastic centerbody. It was concluded that the existing tank structure, which could not be readily modified, did not lend itself to the mounting of additional weight at its extremities.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Spray tank, biological, airborne						

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13. ABSTRACT - Continued

Consequently, it was decided to limit the modification of the remaining existing tanks, to control circuit and aircraft mating changes only. The Class I drawings were revised to reflect all the changes made during the development of the tank modification, and show the tank structure strengthened to allow for the mounting of a wind-driven generator on future tanks. Wiring was included to give a choice of supplying heater power from either the wind-driven generator or the carrying aircraft.

These modifications were supplemented with the design of a test set to aid in checking out the electrical systems of the tank and the control circuits of the various carrying aircraft at the numerous pylon stations.

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